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Changes of Impact Force During Performance of Straight Punch With Two Boxing Techniques – Case Study

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ABSTRACT

PURPOSE: Performance in boxing is a combination of strength, speed, and stability to create maximum impact. One of the types of punches commonly used in boxing is the straight punch. The magnitude of force exerted at the point of impact is influenced by a number of factors. Therefore, some biomechanical parameters can have greater effect than others during punch performance. Likewise, different technique modalities influence punch force. This study aims to determine differences between kinetic and kinematic parameters of punches performed with two different techniques (with and without weight shifting). METHODS: Overall, 20 straight punches were performed (10 for each observed technique) by a top-level female boxer (26.1 years old, height 170.3 cm, weight 63.2 kg). Afterwards, four kinematic variables (shoulder, upper arm, forearm, and hand velocities) were analyzed together with the position of center of mass (Xsens, Awinda). Also, overall foot pressure force of both feet (Novel pressure insoles) was analyzed for each technique, as well as the impact force of each punch (Punchsensor). Differences between the techniques were determined by MANOVA. RESULTS: Significant differences were found in foot pressure force and impact force, with higher values of punch force determined in the straight punch performance that includes weight shifting ($p=0.00$). Regarding kinematic parameters, there were significant differences in shoulder velocity, forearm velocity, and center of mass position ($p=0.00$). Upper arm and hand velocity variables did not differ significantly. This result indicates that different punch preparation can exhibit greater force and better performance. CONCLUSION: The understanding of movement pattern in punching could provide insightful instruction to coaches and boxers on how to generate powerful straight punches. The presented data objectively determined differences between two approaches in performing a straight punch which could help in correcting technical performance.

INTRODUCTION

Boxing is a combat sport that has high physical and mental demands with the primary objective to perform as many punches as possible and to avoid getting hit back (Šiška, Brodani, Štefanovsky & Todorov, 2016). There are four main types of punches in boxing, and those are the jab – a sudden punch, the cross – a straight punch, the hook - a short side power punch and the uppercut – a short swinging upward power punch (Khasanshin, 2021). A straight right punch is thrown often by the dominant hand and its technique is very precise and could potentially alter the competition result. The magnitude of force exerted at the point of impact is governed by a number of factors, such as the kinematic parameters of upper limbs, trunk movements, leg movements, and weight shifting (Cheraghi, Alinejad, Arshi & Shirzad, 2014). Performance in boxing would then be a combination of strength, speed, and stability to create maximum impact (Loturco et al., 2016). In terms of kinematic analysis, researchers used the accelerometer and motion analysis to analyze punching velocity, as well as linear velocities of the fist, elbow, and shoulder. The upper extremity was preferred to the lower extremity because the lower extremity was relatively static compared to the upper extremity (Tong-Iam, Rachanavy & Lawsirirat, 2017). The efficiency of a punch in boxing largely depends on the dynamics of velocity of body segments carrying out movements in multi-link systems of the human body (Gu, Popik & Dobrovolskiy, 2018). Based on the above mentioned, it is also required to engage a muscle chain as much as possible in order to have a strong punch. One such example would be twisting the torso in the direction of the punch, so not only the mass of the hand and arm are involved (Deliu, Stoica & Dreve, 2021). Although lower body segments do not engage directly in the punch, they are of great importance for a quick reaction and a stable position. Leg drive has been observed to build-up momentum in the kinematic chain helping towards a greater fist velocity and the effective mass shifting. Also, stability and shifting weight on both legs with pressure distributed optimally on different parts of the foot in crucial moments could help in performing a punch of great impact (El-Oujaji, Provot, Bourgain & Dinu, 2019). Force impact is mainly produced by body segment mass and velocity. Velocity depends on the rational mechanical structure of a punching movement and is ensured by consistent work of the body segments, which are displayed in a strict sequence (Gamaliy & Vasilyev, 2004). The biomechanical analysis of straight punches performed with two different preparatory techniques in the first phase of landing a punch will enable us to identify the kinematical features of punch effectiveness and to compare differences between these two approaches in performing a straight punch in boxing. The understanding of movement pattern in punching could provide insightful instruction for coaches and boxers on how to generate powerful straight punches.

METHODS

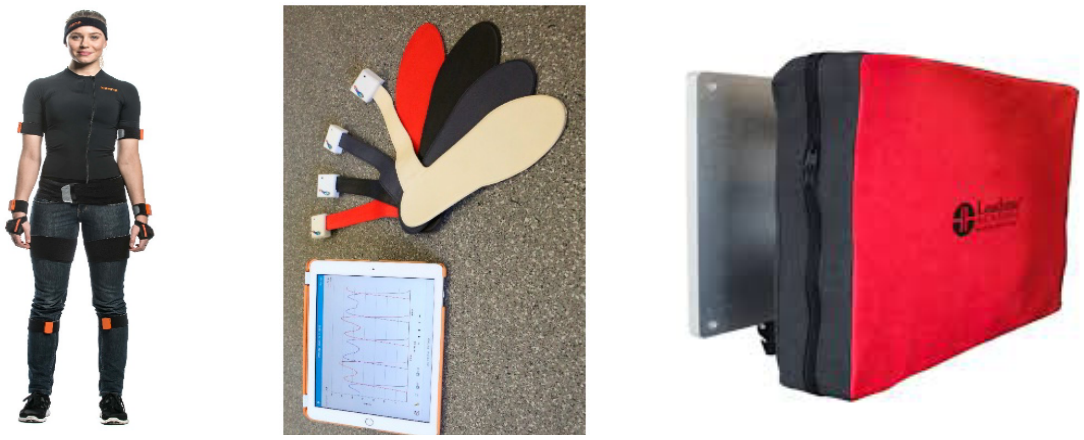
Participant

The respondent was a top-level Croatian female boxer in the category up to 64 kg (26.1 yr; 170.3 cm; 63.2 kg). During the testing, the respondent was in the preparatory period, without health

problems or any locomotor difficulties. Only punches with the dominant (right) hand were observed and analyzed.

Variables

For the purpose of testing, the following measuring devices were used: Punchsensor (Loadstar sensors, USA) for measuring impact force; Loadsol (Novel, Germany) kinetic insoles for measuring pressure force or force transfer; Xsens (Awinda, The Netherlands) kinematic system for measuring space-time parameters of the upper extremities.



a) **b)** **c)**

Figure 1. Kinetic and kinematic systems used in the measurements: **(a)** – Xsens Awinda kinematic suit; **(b)** – Novel Loadsol insoles; **(c)** - Punchsensor force sensor.

The following variables were observed by using the kinematic suit: maximum velocity of the right shoulder when performing a punch (Shoulder_V); maximum velocity of the upper arm when performing a punch (Upper_arm_V); maximum velocity of the forearm when performing a punch (Forearm_V); maximum velocity of the hand when performing a punch (Hand_V); the lowest position of the body's center of mass (COM). Precise measurement with the kinematic suit has been observed in studies (Dinu et al., 2016; Khurelbaatar, Kim, Lee & Kim, 2015) and it represents an ideal instrument for observing boxing performance technique. The maximum pressure forces of the left (Foot_L_F) and right (Foot_R_F) foot when performing a punch were observed with pressure force measuring insoles. Studies (Burns, Zendler & Zernicke, 2019; Renner, Williams & Queen, 2019; Seiberl, Jensen, Merker, Leitel & Schwirtz, 2018) previously established good metric characteristics of this device. The Punchsensor measured the maximum force of a single punch (Punch_F). The measuring systems were used synchronously, i.e., the kinematic parameters of performance technique and the kinetic parameters of foot pressure force and punch force were recorded at the same time. The device synchronization was conducted similarly as in previous studies (Bon, Očić, Cigrovski, Rupčić & Knjaz, 2021; Čubrić, Rupčić, Cigrovski, Matković & Šagat, 2021).

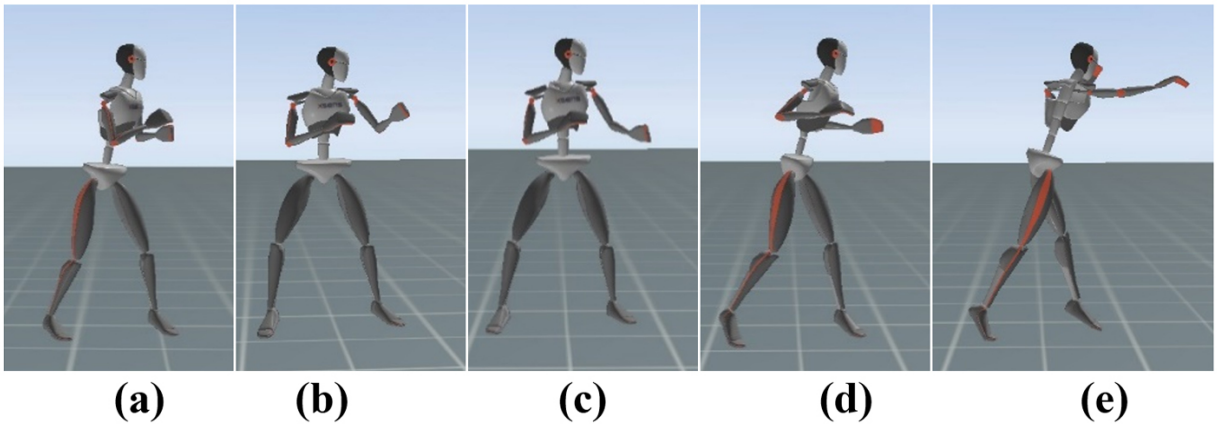


Figure 2. Performance of the straight punch without weight shifting: **(a)** – starting position; **(b)** – initial swing phase; **(c)** – initial punch phase; **(d)** – middle punch phase; **(e)** – end of the straight punch.

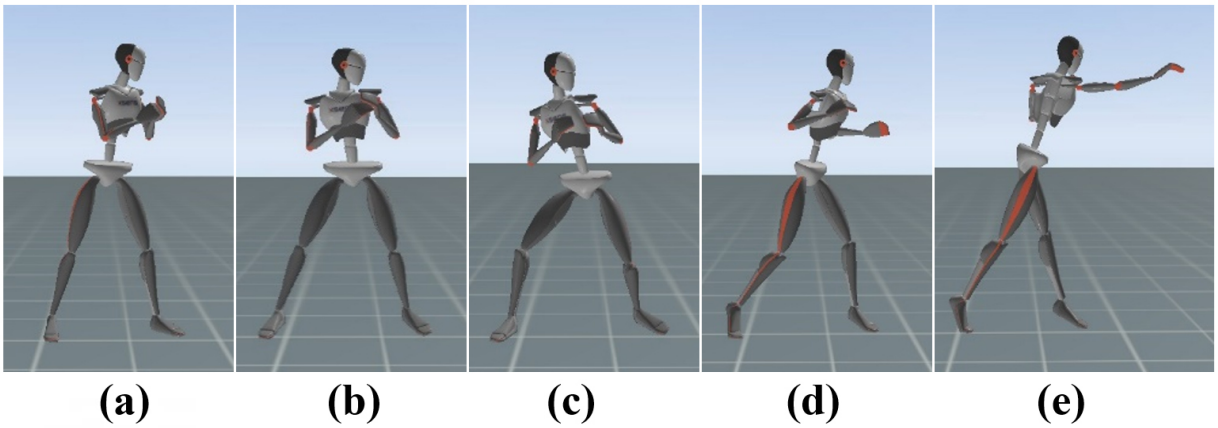


Figure 3. Performance of the straight punch with weight shifting: **(a)** – starting position; **(b)** – initial swing phase; **(c)** – initial punch phase; **(d)** – middle punch phase; **(e)** – end of the straight punch.

Statistical analysis

Statistical package Statistica version 13.5.0.17 (TIBCO Software Inc, Palo Alto, CA) was used for data analysis. Basic descriptive parameters for all measured variables were calculated. MANOVA was used for the detection of differences between straight punch performance when using two different preparatory techniques for the punch (with and without weight shifting). Differences between observed parameters were determined by using ANOVA analysis. The results were considered significant when $p < 0.05$.

RESULTS AND DISCUSSION

Table 1. Basic descriptive statistical parameters of the observed variables for both preparatory techniques of performing the straight punch.

		N	Mean	Minimum	Maximum	St.Dev.
Foot_L_F (N)	Non-shift	10	1087,35	794,88	1415,10	220,20
	Shift	10	790,82	657,80	933,16	84,91
Foot_R_F (N)	Non-shift	10	1275,71	956,12	1844,70	277,82
	Shift	10	1490,23	1426,04	1574,80	50,13
Shoulder_V (m/s)	Non-shift	10	1,81	1,69	1,98	0,10
	Shift	10	2,06	1,92	2,25	0,13
Upper_arm_V (m/s)	Non-shift	10	3,27	2,45	3,91	0,41
	Shift	10	3,51	2,71	4,07	0,43
Forearm_V (m/s)	Non-shift	10	8,63	8,30	9,12	0,27
	Shift	10	9,34	8,57	9,93	0,45
Hand_V (m/s)	Non-shift	10	8,71	7,24	9,70	0,96
	Shift	10	9,29	7,43	10,46	0,99
COM (cm)	Non-shift	10	88,74	87,58	91,09	1,11
	Shift	10	82,41	81,31	85,14	1,08
Punch_F (N)	Non-shift	10	1396,40	1198,00	1500,00	96,51
	Shift	10	2091,20	1973,00	2253,00	80,55

Legend: Foot_L_F – pressure force of the left foot; Foot_R_F – pressure force of the right foot; Shoulder_V – velocity of the shoulder joint; Upper_arm_V – velocity of the upper arm segment; Forearm_V – velocity of the forearm segment; Hand_V – velocity of the hand segment; COM – center of mass position in centimeters; Punch_F – value of force exerted during straight punch.

The basic descriptive indicators of the results indicate higher values of foot pressure forces on the ground in conditions when the punch was preceded by the transfer of body mass to the back leg. The highest achieved pressure force was in the right foot (1844.70 N). Also, when observing the velocities of individual segments of the hand used to perform the punch, higher maximum velocities were achieved when the mass was transferred. The more distal the segment, the higher was the velocity achieved. The wrist velocity was the highest (10.46 m/s). COM values were higher in conditions when no additional preparation for the punch was carried out. Punch force (Punch_F) was higher with previous preparation (2091.20 vs. 1396.40 N).

Table 2. Results of MANOVA for the straight punch executed with two different preparatory techniques.

Test	Value	F	P
Wilks	0,02	66,37	0,00*

*marked values were significant when $p < 0.05$

Results presented in Table 2 show statistically significant difference between two observed preparatory techniques (with and without weight shifting) of straight punch performance (F=66,37; p=0,00).

Table 3. Results of ANOVA analysis of differences between observed parameters.

Dependent Variable	F	p
Foot_L_F	15,79*	0,00*
Foot_R_F	5,77*	0,03*
Shoulder_V	22,88*	0,00*
Upper_arm_V	1,60	0,22
Forearm_V	18,20*	0,00*
Hand_V	1,72	0,21
COM	165,76*	0,00*
Punch_F	305,50*	0,00*

Legend: *marked values were significant when $p < 0.05$; Foot_L_F – pressure force of the left foot; Foot_R_F – pressure force of the right foot; Shoulder_V – velocity of the shoulder joint; Upper_arm_V – velocity of the upper arm segment; Forearm_V – velocity of the forearm segment; Hand_V – velocity of the hand segment; COM – center of mass position in centimeters; Punch_F – value of force exerted during straight punch.

Table 3 shows differences in the observed kinetic variable of the left foot pressure force between two preparatory techniques for straight punch performance ($p < 0.00$). Also, the difference was confirmed when observing pressure force of the right foot ($p = 0.03$). When analyzing kinematic parameters, there were differences in shoulder velocity when performing the straight punch ($p < 0.00$). Also, forearm velocity differed significantly between the performed preparatory techniques ($p < 0.00$). The mentioned velocity values were significantly higher when shifting the weight before the straight punch performance. Significant difference was also found in the values of center of mass ($p < 0.00$), i.e., based on the results of descriptive statistics, the boxer was in lower position when shifting her weight on her back foot before the straight punch performance. When observing overall values of impact force of the straight punch, it can be concluded that there was significant difference between two preparatory techniques ($p < 0.00$). When performing weight shifting before the punch, a greater force of impact was exerted. Based on the gained results, it can be concluded that the boxer was more successful when performing weight shifting on her back foot in the first phase of performing the straight punch. In that case, higher velocity values were achieved in the shoulder and forearm. Also, the boxer starts the punch in lower position, which, in combination with the above mentioned, consequently helps in producing greater impact force of straight punches. The exerted force was much higher when compared to the technique that does not include weight shifting (2091.20 N vs. 1396.40 N). Šiška et al. (2016) determined average values of senior boxers (3585.9 ± 1366.2 N) for both genders. As this was almost double than in the presented research, Šiška et al. did not separate male from female boxers so it cannot be completely compared to the results of this study. Comparing different force strikes in combat sports, authors Beranek, Votapek & Stastny (2020) emphasized that the straight punch exerted

the greatest values of 3427 N. These forces are under great influence of body weight and length of body segments. Further investigation and detailed analysis of kinematic parameters are needed to fully understand the significance of the straight punch and the factors influencing its ideal performance. Also, it has to be mentioned that the pressure force of the back foot was higher when shifting the weight (1490,23 N vs. 1275,71 N), which can also help in greater energy creation and in energy transfer necessary for a greater impact. It should be noticed that, when discussing factors that influence the punch outcome, some authors conclude that optimal values of kinematic parameters are important for the performance of the punch. However, even more important are inter- and intra-muscular coordination which directly influence the force developed in a strike (Băiţel & Deliu, 2014). The above mentioned is the greatest limitation of this study because detailed information about muscle activity could help in fully understanding the movement pattern of the executed straight punches.

CONCLUSION

Based on the conducted analysis for the purpose of this case study, it can be concluded that greater impact forces are achieved when using preparatory technique which includes weight shifting on the back foot in the first phase of executing a straight punch. Higher values of shoulder and forearm velocities were determined, along with lower position of center of mass and higher values of foot pressure force of the back foot. These are the factors that help in transferring more energy to the straight punch. However, to make valid conclusions, the overall biomechanical analysis should be conducted to get a clearer insight in various integrated parts of kinematics, kinetics and muscular involvement when executing different boxing techniques and punches. Also, it is important to conduct the same testing protocol with a larger sample size and to compare the observed parameters for various categories, and for both males and females. Nevertheless, the data presented in this research can serve to coaches in the overall analysis of the boxing technique. Even though the observed variables represent a small detail in the straight punch performance, it is the little details that often make the difference between winning and losing.

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Determinants of Reactive Agility Performance in Table Tennis Players

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ABSTRACT

BACKGROUND: Table tennis is considered as a reaction sport, in which reaction speed is the key factor of sports performance. However, in addition to the quality of sensory (or cognitive) functions, it also requires a rapid motor response. Reactive agility is one of the most important qualities of table tennis performance. It comprises both sensory and motor components. Therefore, the aim of this study was to find the relationship between reactive agility performance and reaction speed (sensory part), sprint and change of direction speed, and muscle strength parameters (motor part) and thus to identify determinants of reactive agility in table tennis players. METHODS: Fifteen male competitive table tennis players (26.3 ± 4.0 years, 179.4 ± 6.0 cm, 77.2 ± 6.4 kg) performed the Reactive Agility Test (RAT), three reaction time tests (simple and choice reaction, reaction to four visual stimuli), sprint for 5 m, 505 Agility test, countermovement and drop jumps. RESULTS: Pearson correlation coefficient revealed a significant relationship between RAT performance and reaction time to four visual stimuli ($r = 0.801$, $p < 0.001$). Nonsignificant, but the medium correlation was found between RAT performance and choice reaction time ($r = 0.404$) and decision-making time, which was calculated as a difference between choice and simple reaction time ($r = 0.410$). These results showed that reactive agility is determined by the cognitive component (reflected by the reaction time) in table tennis players. CONCLUSION: It seems that fast reactions associated with hand movements are more important than explosive strength and speed abilities in table tennis performance. Therefore, the trainers should focus primarily on the development of reaction-speed abilities in their training program. Secondary, they should focus on more specific movements (e.g., lateral change of direction or speed of first steps) rather than linear sprint speed or changing of direction under angles higher than 90°. Additionally, it seems that explosive strength training has only supportive character in relationship to the sports performance.

Keywords: motor component, racquet sports, reaction time, sensory component

INTRODUCTION

Table tennis is one of the fastest sports games in the world and performance in this sport is the result of multiple factors. It requires precise and fast movements with the high level of coordination (Kondrić et al., 2013). The players often have to move to an appropriate position using various footwork according to the opponent´s strike (forward or backward step, side-step, cross step) (Fuchs et al., 2018; Malagoli-Lanzoni et al., 2014; Zhang et al., 2018). Therefore, the level of reactive agility is one of the limiting factors of table tennis sports performance, which includes sensory and motor components (Young et al., 2002), and currently also technical aspects (Young et al., 2015). Due to the small playing area and high velocity of ball, the higher demands on sensory component are needed in this sports game (Vacenovský, 2014). Sports with direct opponents challenge the brain and these activities require a higher-level of cognitive function to be successful (Walsh, 2014). Therefore, playing table tennis brings more benefits associated with improving visual reaction time (Vidja et al., 2012) and is considered as one of alternatives to keep a good level of agility performance at any age especially in late middle-aged subjects when it tends to decrease more markedly (Horníková et al., 2018). Player needs to anticipate the opponent´s intentions in severe time constraints, recognize meaningful cues in the context of the game, and to decide and initiate which action to take as a response (Abernethy, 1991). It means that only rapid processing of the stimulus in the brain is not sufficient, because it is usually associated with subsequent high-speed movements of the lower body with fast but short accelerations and breaking phases (Padulo et al., 2016). Vacenovský (2014) reported the importance of the motor component, too, and that mainly explosive strength, because the movement behind the table consists of many multidirectional short starts as a response to visual stimuli – the ball. In addition to explosive strength, the motor component also includes sprint speed (linear and with directional changes) leg muscle strength (muscle power, reactive strength) and core strength (Young et al., 2002; Young et al., 2015). Nevertheless, many studies investigated only hand reaction time in table tennis players (Bhabhor et al., 2013; Cam et al., 2014; Deepa & Sirdesai, N. 2016). The motor response was thus minimized mostly only to the movement of finger. In these types of tests, table tennis players dominated compared to the healthy controls, but they achieved also shorter reaction times than players of other sports. Some authors were aware of the importance of both sensory and motor components, and they used specific reactive agility tests (Utama et al., 2021; Vacenovský et al., 2015). It seems that stop´n´go running tests are more suitable for table tennis players compared to non-stop running agility tests because they can better reflect the structure of effort in this sport.

This study is based on the model of Young et al. (2002) and its latest modification (Young et al., 2015), in which reactive agility comprises of two main components – cognitive (as a sensory) and physical (as a motor). Several studies investigated the relationship between reactive agility and parameters of motor abilities (Horička et al., 2014; Lockie et al., 2014; Sattler et al., 2015). However, there is a lack of information about the sensory part of this ability and their contribution to reactive agility in different types of sports. Therefore, the aim of this study is to investigate the relationship between reactive agility performance and parameters of reaction speed, sprint and change of direction speed, and leg muscle strength in table tennis players.

The modified version of the reactive agility test was used in this study. It consists of 20 movement reactions in the four directions arranged in a semicircle according to the visual stimulus appearing on the light semaphore. The movement type and distance (stop´n´go test with including speed of first one or two steps) was adapted as closely as possible to the specific conditions of table tennis. Therefore, the contribution of both sensory and motor components to reactive agility test performance may be expected.

METHODS

Participants

Total of 15 male table tennis players participated in this study (26.3 ± 4.0 years, 179.4 ± 6.0 cm, 77.2 ± 6.4 kg). The mean duration of sport specialization was 13 ± 4.0 years and they have trained in average 4.7 times per week with one match. Inclusion criteria were as follows: to be an active player (regularly play matches), to have at least 3 trainings per week (+ match), required level of performance (1st – 3rd league in Slovakia). Players who were injured in the last three months were excluded from this study. All participants were informed of the procedures, the main purpose of this study and signed an informed consent. The procedures were in accordance with the ethical standards for human experimentation as stated in Helsinki Declaration.

Data Collection

All participants performed a standard warm-up routine (light jogging, dynamic stretching exercises and then attended a familiarization session where testing conditions were explained, and one trial set was shown. At first, reaction time tests were performed using FiTRO Reaction Check (FiTRONIC, Bratislava, Slovakia) and Witty SEM (Microgate, Bolzano, Italy). Then countermovement and drop jumps were performed using OptoGait (Microgate, Bolzano, Italy) and reactive agility test, sprint for 5 m and 505 Agility test were measured by Witty SEM system from Microgate again. All tests were performed in a table tennis hall with a Taraflex vinyl sports floor.

Simple and Choice Reaction Time Test

Fitro Reaction Check consists of one or two switches connected by means of an interface to a computer. The software measures the time between appearing the stimulus and the response of participant by pushing the switch. The participants must respond to a visual stimulus (green circle) as fast as possible in a simple reaction test. In the choice reaction time test, they had to respond as fast as possible in accordance to a visual stimulus appearing on a computer screen – push the right switch when the green circle appeared and the left switch when the red cross appeared. Two trials of 20 responses were performed in each test with one-minute break between them. The better mean reaction time of two trials was selected for the analysis. Decision-making time was calculated as a difference between choice and simple reaction time.

Reaction Test to Four Visual Stimuli

The Witty SEM consisting of four light photocells which were placed in-line on the table with a distance 10 cm between them. They include a motor sensor, so it was not necessary to touch them directly. The task was to response as fast as possible with dominant hand (starting in the

middle of semaphores) to photocell which lit up green. The others remained unenlightened. The participants were required to move back with their hand to the middle of these semaphores, so they had to complete the same movement distance. The test consisted of 20 reactions (four in each light photocell) which were generated immediately after each response. The result was the better total time of the test from two trials.

Countermovement jump (CMJ)

The participant starts from standing position with hands placed on the hips. They performed knee flexion (at a 90° angle) followed immediately by extension of legs as high as possible. They were asked to land in a fully extension without hip, knee, or ankle flexion. The higher of two jumps were selected for further analysis.

Drop Jump (DJ)

Drop jump was used to measure the reactive strength. The participants started from a 30 cm height box with hands on their hips, and their task was to step with their preferred leg and rebound as high as possible with both legs with a minimum contact time. They were required to avoid more pronounced knee bending and kicking during the jump. The result of this test was the reactive strength index (RSI) calculated as a ratio of the height of jump and ground contact time. The highest index from the two trials was taken for further analysis.

Reactive Agility Test (RAT)

It was used the modified version of stop´n´go reactive agility test from Sekulic et al. (2014). Four light photocells were placed in a semi-circular arrangement at a distance of 2 m from the starting point. The task was to respond to a visual stimulus (green light) as fast as possible, wave at this photocell and run back to the starting point. The test consisted of one trial with 20 reactions (5 reactions in each direction). Before this trial, they had one test trial of five stimuli. The result was the total time of the test.

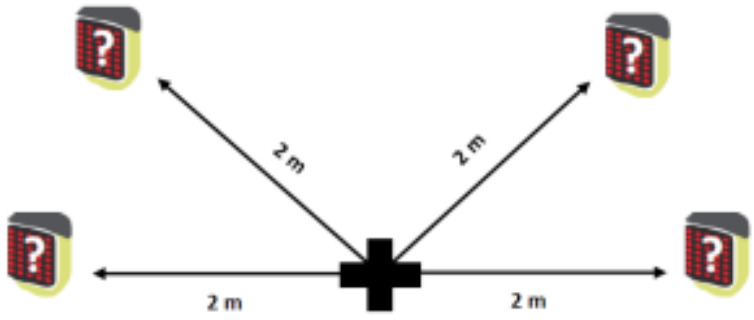

Figure 1. Modified Reactive agility test for table tennis players.

5 m Sprint Test

This test assessed the acceleration sprint for a short distance. The task was run as fast as possible 5 m from starting gate to the second gate positioned at a distance of 5 m. Participants started 30 cm behind the starting line to prevent early triggering of the starting gate. Gates were set at a width of 1.5 m and a height of 1.20 m. Two trials were carried out with one-minute rest, the result was a shorter time of them.

505 Agility Test

This test measured the change of direction speed. It includes a 15 m linear sprint, one-directional change at a 180° angle and another sprint for 5 m to the finish gate. The test result included a time only of 5 m sprint before and after changing of direction. They were asked to place their left or right foot on the line of this turn, depending on the trial (one to the left and one to the right side). They had two trials with 2-minutes of rest between them, the better one was taken for further analysis.

Statistical Analysis

The data were computed in the statistical program SPSS for Windows (version 22.0, SPSS, Inc., Chicago, IL, USA). Descriptive statistics (mean ± SD) were calculated for all results. The Shapiro-Wilk test was used to determine whether the data were normally distributed. The standardized measure of the dispersion of probability distribution was check via coefficient of variation (CV). The higher values in coefficient of variation in decision-making time and drop jump arose as result of the calculation from two different measured parameters. Pearson correlation coefficient was used to find the relationship between the reactive agility performance and parameters of other variables (reaction speed, sprint speed and explosive strength). The size of correlation coefficient (r) was interpreted by Hendl (2004): 0.10 – 0.30 – small effect; 0.31 – 0.70 – medium effect; 0.71 – 1 – large effect. Additionally, the coefficient of determination (R2) was used to estimate the contribution of measured variables to reactive agility. The level for statistical significance was set at $p < 0.05$.

RESULTS

Results of the tests achieved by table tennis players and coefficient of variation are shown in Table 1.

Table 1. Descriptive statistics of table tennis players performance

Test	Mean ± SD	CV
Simple Reaction Time [ms]	295.6 ± 9.0	3 %
Choice Reaction Time [ms]	407.5 ± 30.1	7.4 %
Decision-making Time (CRT-SRT) [ms]	111.9 ± 25.4	22.7 %
Reaction Time to Four Visual Stimuli [s]	9.5 ± 0.8	8.4 %
Reactive Agility Test [s]	39.6 ± 2.1	5.3 %
5 m Sprint Test [s]	1.1 ± 0.1	9.1 %
505 Agility Test [s]	2.4 ± 0.1	4.2 %
Countermovement Jump [cm]	36.9 ± 4.8	13 %
Drop Jump (RSI)	1.2 ± 0.3	25 %

Note. SD = standard deviation, CV = coefficient of variation.

The RAT performance significantly correlated with the reaction time to four visual stimuli ($r = 0.801$, $p < 0.001$). Nonsignificant, but medium effect size was detected with choice reaction time ($r = 0.404$) and decision-making time ($r = 0.410$). The coefficient of determination was $R2 = 0.642$, which means that reaction speed explained the reactive agility performance by 64.2 % in table tennis players. Reaction test to four visual stimuli included choice reaction, which confirmed significant relationship with choice reaction time test and decision-making time ($r = 0.612$, $p = 0.015$ and $r = 0.588$, $p = 0.021$, respectively). The relationship between RAT performance and speed and muscle strength parameters was not significant with only a small effect size (Table 2).

Table 2. Pearson´s correlation matrix of relationships among all variables measured

TEST	SRT	CRT	DM	RFS	CMJ	DJ (RSI)	RAT	5 m sprint	505 Agility
SRT	–								
CRT	0.637*	–							
DM	0.402	0.962**	–						
RFS	0.392	0.612*	0.588*	–					
CMJ	-0.348	-0.657**	-0.657**	-0.286	–				
DJ (RSI)	0.422	-0.309	-0.517*	-0.022	0.268	–			
RAT	0.196	0.404	0.410	0.801**	-0.160	-0.335	–		
5 m sprint	0.102	0.146	0.137	0.010	-0.035	-0.04	-0.035	–	
505 Agility	-0.026	0.327	0.398	0.089	-0.290	-0.510	-0.058	0.380	–

Note. SRT = simple reaction time; CRT = choice reaction time; DM = decision-making time; RFS = reaction time to four visual stimuli; CMJ = countermovement jump; DJ = drop jump * = $p < 0.05$; ** = $p < 0.01$.

DISCUSSION

Reactive agility test performance significantly correlated with the reaction time to four visual stimuli. It may be ascribed to the structure of these tests, in which reaction to four visual stimuli was needed. It means that the sensory component was the same and they differed only in motor component. Reaction time test required shorthand movement, while RAT included the whole-body movement. On the other side, less similarity of conditions could affect nonsignificant, but medium effect size between time in RAT and choice reaction and decision-making time. These parameters were measured by another diagnostic system than RAT and they have differed for example in the type or size of stimuli and recording of participant´s response. Nevertheless, it can be concluded that perceptual and decision-making factors contribute to reactive agility performance of table tennis players by 64.2 %. These results are difficult to compare with the others because we did not find the similar studies focused on table tennis players. Many authors investigated reactive agility in relationship to speed and strength parameters mostly in team sports, but only a few of them were focused on sensory component (Henry et al., 2016; Scanlan et al., 2014; Spiteri et al., 2015; Šimonek et al., 2017).

Surprisingly, there were not found significant correlations between the time in the reactive agility test and any parameters of sprint speed and muscle strength in table tennis players. Based

on the study of Young et al. (2015) and Young et al. (2002) we assumed, that RAT performance will be determined by both, sensory (perceptual and decision-making factors) and motor components (mainly by reactive strength). In an older deterministic model of reactive agility from the year 2002, the change of direction speed represented the motor component. In the newer one (Young et al., 2015), it was replaced by the physical factors which include leg muscle qualities (strength, power, reactive strength), core strength, and straight speed. This knowledge was confirmed by several authors in their studies. For example, it was revealed significant relationships between the time in the Y-shaped agility test under reactive conditions and 10 m sprint time in active males and basketball players (Lockie et al., 2014; Oliver & Meyers, 2009). Furthermore, the time in RAT (Five-Time Shuttle Run to Gates test) highly correlated with the change of direction speed test in a study of Popowczak et al. (2021). In our study, no significant relationship between the time in RAT and sprint time for 5 m was found. One possible reason could be that our RAT required only the speed of the first one or two steps. Probably, the distance of 5 m is less specific for table tennis players. A similar explanation may be also attributed to the nonsignificant relationship between RAT performance and time in the 505 Agility test. Their structure differed, especially in the running distance and angle of directional change. Whereas our RAT was force-oriented (type of stop´n´go test) rather than velocity-oriented, we assumed the significant relationship mainly with the parameter of reactive strength – RSI, which is important especially in explosive starts and change of directions (Bourgeois et al., 2017; Jeffries et al., 2015). This assumption was not confirmed, probably due to lower values of RSI in our group of table tennis and/or their inability to transfer this power to more specific conditions.

These findings indicate that the sensory component is the main determinant of reactive agility in table tennis players. However, this ability undeniably consists of the motor component as well, its relationship showed to be nonsignificant to reactive agility. It may be attributed to the low similarity in structure between sprint and change of direction speed tests and the main reactive agility test. Likely, the shorter running distance and changes in direction under lower angles could be more specific for these players in testing and training. Another possible reason should be the small transfer of speed and strength abilities to reactive agility itself or more specific conditions of table tennis.

The relatively high variations in players´ level of sports performance can be considered as the main limitation of this study. For future research, it would be interesting to investigate the difference in determinants of reactive agility between recreational, semi-professional and professional table tennis players and to compare their demands on both sensory and motor component.

CONCLUSION

In this study, there was a significant relationship between the time in reactive agility testing and reaction time to four visual stimuli. The performance in RAT was determined by the reaction speed by 64.2 % in table tennis players. Although a significant relationship with other parameters of reaction speed was not observed, medium effect size indicates that also choice reaction time and decision-making time may determine the reactive agility performance, but probably in the second-order factors.

These findings indicate that the sensory component contributes to reactive agility performance rather than the motor component in table tennis players. Although the importance of sprint speed and explosiveness in this sports game is undeniable, they are not directly responsible for the level of sports performance in table tennis. Nevertheless, it is important to focus also on the motor component in the training because reaction to ball is mostly if not always connected with the fast movement of lower extremities. It can be assumed that table tennis players who achieved great values of reaction time should focus just on the development of movement speed through explosive strength and sprint speed training.

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Match Outcome and Running Performance Among UEFA Champions League Soccer Players

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ABSTRACT

This study aimed to examine position-specific differences in running performance (RP) according to the match outcome in UEFA Champions League (UCL). The players' RPs (n=244) were collected during UCL group stage matches (n=20) in the 2020/21 season using semi-automatic optical system InStat Fitness, and classified according to their playing positions as: central defenders (CD; n=79), fullbacks (FB; n=65), central midfielders (CM; n=55), wide midfielders (WM; n=28) and forward (FW; n=17). The RP variables included: total distance covered, low-intensity (LIR) (<14.3km/h), running (14.4–19.7 km/h), high-speed running (HSR) (19.8–25.1 km/h), and sprinting (>25.2 km/h). Match outcome was observed as win, draw and loss. One-way analysis of variance (ANOVA) was used to examine differences in RP according to the match outcome. Significant differences in TD (F-test=4.16, p=0.02) and LIR (F-test=4.51, p=0.01) among match outcomes were observed for FBs. Specifically, FBs covered significantly greater TD when their team won than when lost (p=0.03, d=0.79). In addition, FBs' LIR was significantly greater in won matches than in drew (p=0.04, d=0.92) and lost matches (p=0.03, d=0.77). The RP of players on all other playing position were similar irrespective to the match outcome (F-test=0.08 to 2.84, all p>0.05). These results indicated that winning UCL matches is not strongly influenced by players' physical performance, except for FBs who tended to covered greater total- and low- distance when their teams won. This study indicated limited overall influence of RP on success in matches at elite-level soccer. The findings from this study may help soccer coaches to ensure optimal physical preparation of players in elite soccer.

Keywords: physical performance, winning, elite players, playing positions, football

INTRODUCTION

Soccer is a complex team sport characterized by high physical demands (Teixeira et al., 2021). Aiming to understand such demands, analyses of match running performance (RP) are commonly undertaken using semi-automatic multiple camera systems or global and local positioning system technologies (Buchheit et al., 2014; Modric, Versic, & Sekulic, 2021; De Albuquerque Freire et al., 2022). The high validity and reliability of these systems allow quantification of the total distance covered, distances covered in various speed zones (i.e., jogging, running, high-intensity running, sprinting) and acceleration rates (Chmura et al., 2021). At present, elite soccer players travel 9 to 14 km in total during a game with high-intensity running accounting for 5–15% of this distance (Modric, Versic, & Sekulic, 2020). To ensure that players are optimally prepared for such high physical demands imposed during competitive match play, it is imperative that players are exposed to comparable demands under controlled training conditions (Harper, Carling, & Kiely, 2019).

For this reason, several investigations have analysed the RP that were best associated with winning a match. Briefly, older studies demonstrated that soccer players performed significantly less high-intensity activities when winning than when losing (Castellano, Blanco-Villaseñor, & Alvarez, 2011; Lago-Peñas, 2012), while more recent studies reported no differences in distance covered at higher speeds regardless of the match outcome (García-Unanue et al., 2018; Barrera, Sarmento, Clemente, Field, & Figueiredo, 2021). In addition, Chmura et al. (2018) and Andrzejewski et al. (2016) in their studies reported that differences in RP according to the match outcome are position-dependent. Specifically, authors reported that wide midfielders and forwards ran significantly longer, while central defenders and fullbacks ran significantly shorter distances at higher speeds in won matches than in lost matches.

Considering that authors of these studies drawn their conclusions observing teams which belongs to the only one country, it is possible that these inconsistencies might be characterized by geographical, cultural, historical and social aspects of observed competition (Sarmento et al., 2013; Sapp, Spangenburg, & Hagberg, 2018; Tuo, Wang, Huang, Zhang, & Liu, 2019). On the other hand, it possible that evolving nature of soccer had a large effect on results (Barnes, Archer, Bush, Hogg, & Bradley, 2014). Irrespective of causality, association between physical performance and winning outcomes is still unclear. To help clarifying this issue, analysis of recent RP data from soccer competition at elite level which includes teams from different countries seems reasonable. One of the most elite competition that includes teams from different countries is UEFA Champions League (UCL) (Lago-Peñas, Lago-Ballesteros, & Rey, 2011).

In general, studies rarely investigated RP in UCL. To date, only few studies analysed RP of soccer players that competed in UCL. Briefly, Di Salvo et al. (2010) and Minano-Espin et al. (2017) analysed only RP at higher speeds, Bradley et al. (2014) focus was on gender differences in RP, while Modric et al. (2021) analyesed only RP in context of ball possession. Evidently, there is no study to evaluate position-specific RP of players that competed in UCL according to the match outcome. The findings from such study may help soccer coaches to identify physical performance required for winning the matches, and tailor players' training programs accordingly. Therefore, this study aimed to examine position-specific differences in running performance (RP) according to the match outcome in UEFA Champions League (UCL).

METHODS

Participants and design

The participants (n=179) in this study were top elite soccer players from teams that competed in the group stage of the UCL in the 2020/21 season. Players' RPs were obtained from 20 matches from groups A (n = 3), B (n = 3), C (n = 4), E (n = 4), F (n = 3) and G (n = 3). From all included matches, six of them were finished without winner. Only the results of players who participated in entire matches were analysed, and goalkeepers were excluded from the analysis due to the specificity of the position. As result, 244 match RPs were retrieved and used as cases for this study. In the line with previous studies (Di Salvo et al., 2010), players' RP was divided according to soccer-specific playing positions as follows: central defenders (CD; n = 79), fullbacks (FB; n = 65), central midfielders (CM; n = 55), wide midfielders (WM; n = 28) and forwards (FW; n = 17). Playing position classification was done based on players' activity on the pitch and the primary area where this activity was performed. All data were anonymized in accordance with the principles of the Declaration of Helsinki to ensure player and team confidentiality. The investigation was approved by the ethical board *** hidden for reviewing ***. Written permission for data used was obtained from Instat Limited (Limerick, Republic of Ireland, 5 June 2021).

Measurements

RP data were collected using a semiautomatic camera tracking system (InStat Fitness, Instat Limited, Limerick, Republic of Ireland). This tracking system includes static cameras installed on the roof of the soccer stadium. Utilizing trigonometry, the camera continuously captures the location of the players. This procedure allowed to quantify the total distance and distance covered in different speed zones. The use of this tracking system has appeared in previous research (Modric, Versic, Drid, et al., 2021). The reliability of this tracking system has been demonstrated, as the tracking system has passed the official Fédération Internationale de Football Association (FIFA) test protocol for Electronic & Performance Tracking Systems (EPTS) (a report is available on the official FIFA webpage) (Modric et al., 2022). RP variables included total distance covered (TD), low-intensity running (LIR) (<14.3 km/h), running (14.4–19.7 km/h), high-speed running (HSR) (19.8–25.1 km/h), and sprinting (>25.2 km/h). The match outcome was observed as loss, draw, win.

Statistical analysis

All data were log-transformed to reduce the nonuniformity of error, and normality was tested using the Kolmogorov–Smirnov test procedure. Homoscedasticity was checked by the Levene test. The statistical analyses were performed on log-transformed data, but the results in table are presented as true-value means and standard deviations. Differences in RP among the match outcomes (win, draw, loss) were analysed by one-way analysis of variance. Scheffe post-hoc test was applied to examine specific differences. The effect size (ES) was evidenced throughout the calculation of Cohen's d, and interpreted as follows: trivial (<0.2), small (>0.2–0.5), moderate (>0.5–0.8) and large (>0.8) (Cohen, 2013). The level of statistical significance was set at $p<0.05$. All statistical analyses were performed using the Statistica software package (Version 13; TIBCO Software, Palo Alto, CA, USA).

RESULTS

Significant differences in TD (F-test=4.16, p=0.02) and LIR (F-test=4.51, p=0.01) were observed among various match outcomes for FBs. Specifically, FBs covered significantly greater TD when their team won than when lost (p=0.03, ES=0.79, moderate). In addition, FBs' LIR was significantly greater in won matches than in drew (p=0.04, ES=0.92, large) and lost matches (p=0.03, ES=0.77, moderate). The RP of players on all other playing position were similar irrespective to the match outcome (F-test=0.08 to 2.84, all p>0.05).

Table 1. Descriptive statistics and differences in running performance according to the match outcome (data are given as mean±SD)

	Match outcome	TD (m)	LIR (m)	Running (m)	High-speed running (m)	Sprinting (m)
CD	Loss	10152±643	8048±508	1482±226	524±139	98±87
	Draw	10284±760	7983±444	1639±317	562±192	102±72
	Win	10153±720	7967±578	1563±321	543±138	81±65
	F (p)	0.31 (0.73)	0.18 (0.83)	2.04 (0.14)	0.39 (0.67)	0.52 (0.59)
FB	Loss	10671±852 W	7900±584 W	1797±385	810±185	165±79
	Draw	10825±526	7949±330 W	1827±257	832±174	220±121
	Win	11287±687 L	8309±468 L, D	1967±280	830±148	185±102
	F (p)	4.16 (0.02)	4.51 (0.01)	1.64 (0.20)	0.11 (0.89)	1.64 (0.20)
CM	Loss	11861±492	8432±411	2532±379	820±186	79±65
	Draw	11824±785	8358±297	2532±494	841±246	95±67
	Win	11975±477	8570±348	2509±308	805±218	96±80
	F (p)	0.28 (0.75)	1.71 (0.19)	0.02 (0.98)	0.13 (0.88)	0.30 (0.74)
WM	Loss	11267±850	8235±579	2003±337	901±163	129±45
	Draw	11134±671	8035±426	1910±363	989±105	206±74
	Win	10911±655	8064±287	1860±328	817±211	175±122
	F (p)	0.43 (0.65)	0.53 (0.59)	0.34 (0.	2.84 (0.08)	2.47 (0.10)
FW	Loss	10400±782	7880±474	1616±375	736±54	168±75
	Draw	10393±895	7784±525	1724±366	783±271	104±79
	Win	10678±825	8000±322	1767±407	768±247	144±56
	F (p)	0.20 (0.82)	0.30 (0.74)	0.24 (0.79)	0.08 (0.92)	1.20 (0.33)

CD – central defenders, FB – full backs, CM – central midfielders, WM – wide midfielders, FW – forwards; TD – total distance; LIR – low-intensity running; R – running, HIR – high-intensity running; LSignificantly different ($p < 0.05$) from loss, DSignificantly different ($p < 0.05$) from draw, WSignificantly different ($p < 0.05$) from win.

DISCUSSION

This study was the first to examine position-specific differences in RP according to the match outcome in UCL. Significant differences in RP among various match outcomes were observed only for FBs, while RPs of other players were similar irrespective to outcome of the match. Such finding indicated limited overall influence of RP on winning at elite-level soccer.

High intensity efforts are critical to the outcome of matches as they relate to activities that are key to the final match result such as movements to win the ball and actions with agility to go past defending players (Castagna, Chamari, Stolen, & Wisloff, 2005; Valter Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009). Considering that some previous research evidenced greater RPs in more successful teams from various elite soccer competitions (Valter Di Salvo et al., 2009; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009; Andrzejewski et al., 2016; Chmura et al., 2018), it is not surprising that in scientific community is often postulated that a high level of RP is important aspect of winning (Hoppe, Slomka, Baumgart, Weber, & Freiwald, 2015). However, this postulation contrasts our main findings showing that RPs, especially at higher speeds, were poorly related to the match outcome.

Specifically, we found that winning outcome were characterized by increased RP only for FBs. In detail, FBs' TD and LIR were ~ 5% longer when team won than when lost (both medium ES), possibly indicating their greater activeness in attacking activities when team winning. On the other hand, RPs (e.g., TD, LIR, running, HSR and sprinting) of all other players were similar irrespective to outcome of the match. These findings clearly suggest that players' physical performance is poorly related to the winning, demonstrating trivial influence of RP on success in elite-level soccer. Although these results may look controversial when taking into account previous considerations that high level of RP is important aspect of winning, results from current study are actually in the line with more recent studies which also demonstrated trivial influence of RP on success (Hoppe et al., 2015; Asian Clemente et al., 2019).

In brief, authors which investigated Spanish La Liga reported similar players' RP at higher speeds irrespective to the final position on the table (Asian Clemente et al., 2019). Similarly, authors which investigated German Bundesliga revealed that players' total distance and high-intensity running were similar irrespective to the total points earned (Hoppe et al., 2015). Therefore, it seems that players' RP is poorly related to the achievement of their teams in the elite soccer. It is most likely the overall technical and tactical effectiveness has a greater impact on results and a team's final league ranking than RP, as previously suggested (Zhou, Zhang, Lorenzo Calvo, & Cui, 2018; Asian Clemente et al., 2019). However, as we herein did not analyse technical and tactical performance, such considerations should be confirmed in future studies by analysing RP integrated with technical and tactical performance.

The present investigation has some limitations that should be considered. This study included only 20 randomly selected matches from the group stage of the UCL; however, this is a very common obstacle in studies involving players who compete in elite soccer (Paul S Bradley et al., 2011; Modric, Versic, Drid, et al., 2021). In addition, contextual factors such as team and opposition quality or match location, which have been shown to influence physical performance in national

soccer competitions (Castellano et al., 2011; Aquino et al., 2020), were not considered in the current study. However, differences in teams' and opponents' quality in UCL are most likely lower than in national competitions, and consequently influence on MRP may be negligible. Also, all observed matches were played without audience or with limited capacity in the stands due to the COVID-19 pandemic (Link & Anzer, 2021); therefore, influence of match location (i.e., home advantage) may be insignificant.

CONCLUSION

This study demonstrated that winning UCL matches is not strongly influenced by players' physical performance, indicating limited overall influence of RP on success in matches at elite-level soccer. However, any conclusion regarding the eventual non-importance of the physical performance in soccer would be (at least) irresponsible. Considering previous studies which demonstrated that UCL is one of the most physically demanding soccer competitions (V. Di Salvo et al., 2010; P. S. Bradley et al., 2014; Miñano-Espin et al., 2017), players still must be able to handle high RP to participate in UCL regardless the fact that it will not assure success in the match. Therefore, it is clear that competing in the UCL require the conditioning of the players to be at highest possible level. Soccer coaches should ensure an adequate conditioning stimulus during the training process aiming to maximise and maintain players' physical capacities while playing in UCL or seeking UCL qualification.

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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Walking Speed: A Factor in the Physical Fitness of the Elderly

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ABSTRACT

The main purpose of the study was to explore whether gait velocity predicts the level of separate and overall physical fitness. In this study, we asked one hundred and twenty older adults over the age of 60 (mean ± SD age 71 ± 7 38 years, height 159 ± 21 cm, weight 70 ± 13 kg) to complete a Senior Fitness Test battery to assess the level of physical fitness and walked across the Zebris pressure platform (Munich, Germany) to measure gait velocity. To calculate overall physical fitness, we summed z-score values of each physical fitness test. Pearson's coefficient (r) was used to determine the level of correlation and coefficient of determination (r2) for variance explained between gait velocity and physical fitness. Respondents conducted a battery of six tests: "chair stand in 30 s", "arm curl in 30 s", "2–minute step test", "chair sit-and-reach test", "back scratch test" and "8-feet up-and-go test". Gait velocity was significantly correlated with chair stand in 30 sec ($r = 0.45$, $r^2 = 20\,\%$, $p < 0.001$), arm curl in 30 sec ($r = 0.56$, $r^2 = 31\,\%$, $p < 0.001$), 2-minute step test ($r = 0.44$, $r^2 = 19\,\%$, $p < 0.001$), chair sit-and-reach test ($r = 0.46$, $r^2 = 21\,\%$, $p < 0.001$), back scratch test ($r = 0.30$, $r^2 = 9\,\%$, $p < 0.001$) and 8-feet up-and-go test ($r = -0.23$, $r^2 = 5\,\%$, $p = 0.011$). Gait velocity was not significantly correlated with waist circumference ($r = 0.12$, $r^2 = 1\%$, $p = 0.189$). Overall physical fitness was strongly correlated with gait velocity ($r = 0.75$, $r^2 = 56\,\%$, $p < 0.001$). In conclusion this study shows that gait velocity may be an easy and quick screening tool to predict the level of separate and overall physical fitness in a sample of older adults.

Keywords: elderly, speed, performance, correlation, tool

INTRODUCTION

Population of older adults aged ≥60 years has increased by 2% in the last 50 years, and it has been estimated that the percentage will increase up to 20% by 2050[1]. Studies have shown that older adults suffer from twice as many disabilities and four times as many physical limitations as people aged < 60 years[2]. It has been-well documented, that aging is associated with many health-related consequences, including cardiovascular[3], metabolic[4] and musculoskeletal[5] diseases and overall mortality[6]. The key of successful aging represents functional independence and maintaining high quality of life[7]. Physical performance deteriorates by age, which is a strong predictor of the aforementioned aging goals[8]. In older adults, the most common way to engage in regular physical activity is walking[9]. Biomechanical parameters of walking in elderly significantly change through reduced speed gait, often accompanied by a reduction in step length and an increment in the time spent in double limb support[10]. As like physical performance, preferred gait speed has been associated with health effects, including lower risk of falls and reduced risk of all-cause mortality[11]. In population-based studies, objective measurement of physical fitness is often time-consuming and cost much. Since gait speed is a quick and valid predictor of the health of the older adults[6,7], it is speculated that such measure may also be a significant predictor of physical fitness. According to the literature, only a handful of studies have examined the associations between gait velocity and physical fitness in older adults[7, 12–14]. Specifically, Ferrucci et al.[12] showed that walking speed was linearly associated with knee extensor strength over the entire range of strength. Another two studies showed similar results, where the gait time decreased linearly with increasing knee extensor strength[13] and strength measure (composed of sum of knee extension, knee flexion and ankle dorsiflexion muscle strength scores) was the strongest predictor of six-meter walking speed[14]. Finally, a study by Ciprandi et al.[7] showed that only hand grip strength was significantly associated with gait stability. In clinical practice, gait speed is often assessed through a few functional mobility and balance scales, including Self Paced Walking Test[15], The Timed Up and Go Test[16] and The Physical Performance and Mobility Examination Test[17]. Although easy to perform, more objective measures, like pressure platform, may be a more reliable and valid instrument to assess gait velocity. Available evidence suggests that no study has explored the association between gait velocity using pressure platform and physical fitness in older adults. Therefore, the main objective of the study was to explore whether gait velocity predicts the level of separate and overall physical fitness in a sample of older adults.

MATERIALS AND METHODS

Study participants:

In this cross-sectional study, we recruited older adults ≥ 60 years from five neighborhoods in the city of Zagreb. At the first stage, we spread the information about the main aims and benefits of the study via posters. At the second stage, 210 participants agreed to join the study. Of these, 73 did not provide full data and 17 could not be longer in the study, due to personal issues. Finally, we based

our study on 120 older women (100%). Based on previous studies18, the inclusion criteria were: (1) being ≥ 60 years old, (2) living independently in the community, (3) passed the Short Portable Mental Status Questionnaire[19], (4) be able to ambulate for at least 10 m with or without an aid, (5) being free from neurological diseases, and (6) could arrange their own transport to a testing venue in their community. All participants had given a written informed consent before entered the study. All procedures performed in this study were anonymous and according to Declaration of Helsinki, also approved by the Faculty of Kinesiology, University of Zagreb, Croatia.

Dynamic plantar pressure:

To assess the level of plantar pressure under each participant's feet while walking, we used Zebris plantar pressure platform (FDM; GmbH Munich, Germany; number of sensors: 11.264; sampling rate: 100 Hz; sensor area: 149 × 54.2 cm). According to previous studies, the calibrated platform was placed on a firm, level surface, with a custom-designed dense walkway surrounding the plate to provide a level walking surface18. Each participant was instructed to walk at a comfortable speed across the platform without shoes and socks. Also, all participants were required to look straight forward, not targeting the pressure platform. When they reached the end of a walkway, they needed to turn around for 180º and continue to walk again over the platform. Finally, when they reached the end of a second walkway (trial), they again turned around for 180º and walked final time across the platform till the end of a walkway. Previous evidence has suggested that collecting 3–5 trials across the pressure platform is more reliable in populations affected with diseases, such as arthritis[20]. If we noticed that the participant had targeted the pressure platform or had obvious gait deviations, trials were discarded and we repeated the measurement. Zebris software generated the data regarding the gait velocity in km/h.

Physical fitness:

Senior Fitness Test was used to assess the level of physical fitness[21]. It is composed of 6 tests as follows: (1) chair stand in 30 sec, (2) arm curl in 30 sec, (3) 2 – minute step test, (4) chair sit – and – reach test, (5) back scratch test and (6) 8 - feet up – and – go test. In addition, we measured waist circumference between the last rib and umbilicus and entered it in the model. Chair stand in 30 sec was used to assess lower body strength and participants needed to come to a full stand from a seated position with arms folded across the chest. Arm curl in 30 sec was the second test representing a general measure of upper – body strength and involved counting the number of times a person could curl a hand weight (5 pounds or 2.3 kg for women and 8 pounds or 3.6 kg for men) through a full range of motion. The third test included a person stepping in place and raising the knees to a height halfway between the patella (knee cap) and iliac crest (front hip bone). This test was a measure of aerobic endurance. Next, chair sit – and – reach test aimed to assess lower – body flexibility. The test involved sitting at the front edge of a stable chair with one leg extended and the other foot flat on the floor. With hands on top of each other and arms outstretched, the participant reached as far forward as possible toward the toes. The score was expressed in cm (higher score was better) and was measured 3 times, where the best score was taken in the model. The purpose of the back scratch test was to assess upper-body flexibility, particularly shoulder flexibility. The test involved reaching one hand over the shoulder and down the back as far as

possible and the other hand around the waist and up the middle of the back as far as possible, trying to bring the fingers of both hands together. The score was expressed in cm (higher score was better) and was measured 3 times, where the best score was taken in the model. Finally, 8- feet up–and-go test had the purpose to assess agility and dynamic balance. The test involved getting up from a seated position and walking as quickly as possible around the cone that is 8 feet (2.4 m) away and returning to the seated position. The test was performed 2 times and the result was expressed in sec. In addition, we objectively measured height and weight (using Seca portable stadiometer and scale) and asked the participants about their chronological age.

Foot pain:

Presence of foot pain was determined according to previously used question: "On most days do you have pain, aching, or stiffness in either of your feet?"22. Responses were: (1) 'No'; (2) 'Yes, left foot only'; (3) 'Yes, right foot only'; (4) 'Yes, both feet'; (5) 'Yes, not sure what side' and (6) 'Unknown'. For this analysis, responses 'Yes, left foot only', 'Yes,right foot only', 'Yes, both feet and 'Yes, not sure what side' were collapsed into 'Yes' vs. 'No' category. Of note, none of the participants responded with 'Unknown' response.

Data analysis:

Basic descriptive statistics are presented as mean ± SD or median (25th–75th percentile range) for normally and not normally distributed variables. We calculated z–score for each physical fitness test. To get overall physical fitness score, we summed all z–scores. The correlations between all physical fitness components and overall physical fitness with gait velocity were examined by using Pearson's and Spearman's coefficient of correlation (r). To get the shared variance explained between the two variables, we calculated coefficient of determination (r^2). All analyses were performed in Statistical Packages for Social Sciences (SPSS Inc., Chicago, Illinois, USA) with statistical significance of $p < 0.05$.

RESULTS

Basic descriptive statistics of the study participants are presented in Table 1. The correlations between gait velocity, separate components of physical fitness and overall physical fitness score are presented in Figure 1 and Figure 2. Gait velocity was significantly correlated with chair stand in 30 sec ($r = 0.45$, $r^2 = 20$ %, $p < 0.001$), arm curl in 30 sec ($r = 0.56$, $r^2 = 31$ %, $p < 0.001$), 2-minute step test ($r = 0.44$, $r^2 = 19$ %, $p < 0.001$), chair sit-and-reach test ($r = 0.46$, $r^2 = 21$ %, $p < 0.001$), back scratch test ($r = 0.30$, $r^2 = 9$ %, $p < 0.001$) and 8-feet up-and-go test ($r = -0.23$, $r^2 = 5$ %, $p = 0.011$). Gait velocity was not significantly correlated with waist circumference ($r = 0.12$, $r^2 = 1$ %, $p = 0.189$). Overall physical fitness was strongly correlated with gait velocity ($r = 0.75$, $r^2 = 56$ %, $p < 0.001$). When we adjusted for foot pain, similar significant correlations between gait velocity, separate components of physical fitness and overall physical fitness score remained significant.

Table 1. Basic descriptive statistics of the study participants (N=120)

Study variables	mean ± SD
Age (years)	71 ± 7
Height (cm)	159 ± 21
Weight (kg)	70 ± 13
Waist circumference (cm)	91 ± 12
Chair stand in 30 sec (#)	17 ± 4
Arm curl in 30 sec (#)	19 ± 5
2-minute step test (#)	170 ± 44
Chair sit–and-reach test (cm)*	7 (1 - 11)
Back scratch test (cm)*	0.8 (-8 - 4)
8-feet up–and-go test (sec)	5 ± 1
Overall physical fitness (z-score)*	-1 (-2 – 1)
Gait velocity (km/h)	3 ± 1
Foot pain (Yes/No, %)**	53/47

*denotes using median (25th-75th percentile range)

**denotes using percentage (%)

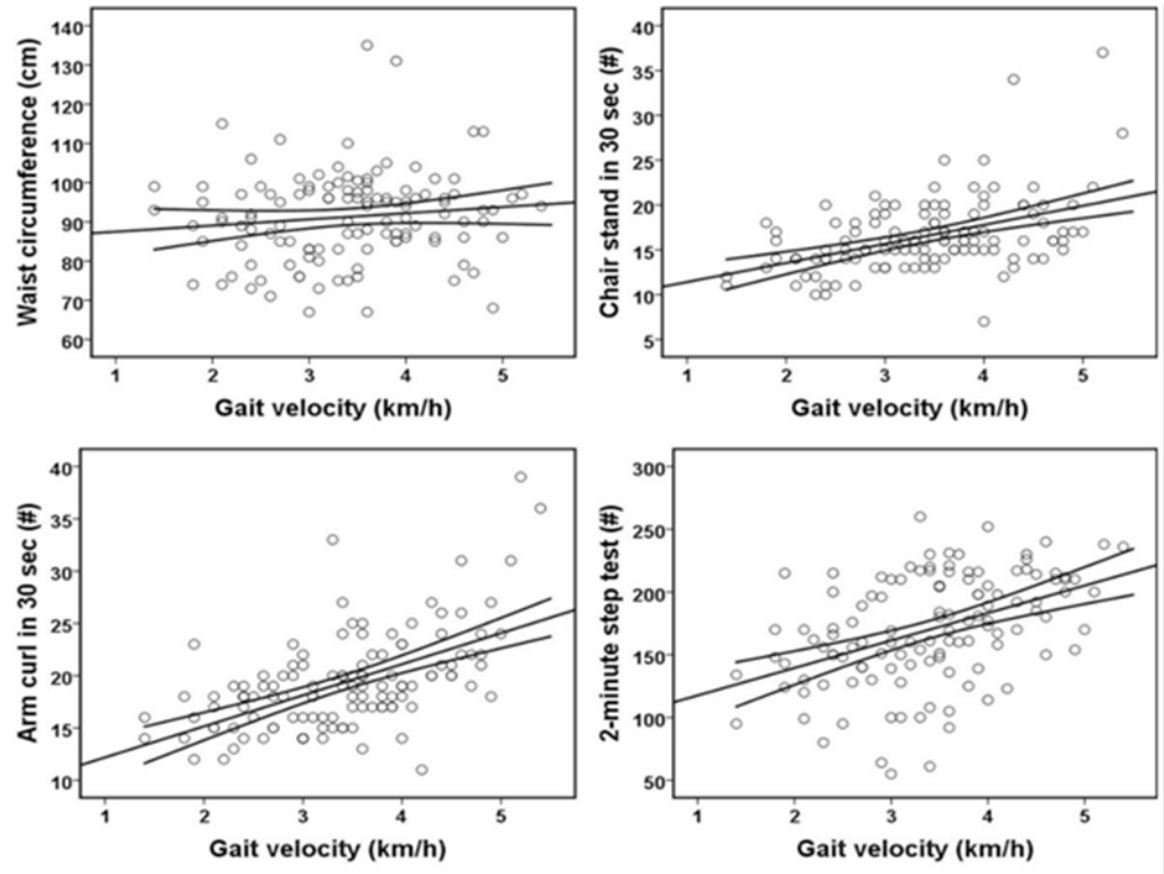

Figure 1. The correlations between gait velocity and waist circumference, chair stand in 30 sec, arm curl in 30 sec and 2-minute step test (N=120).

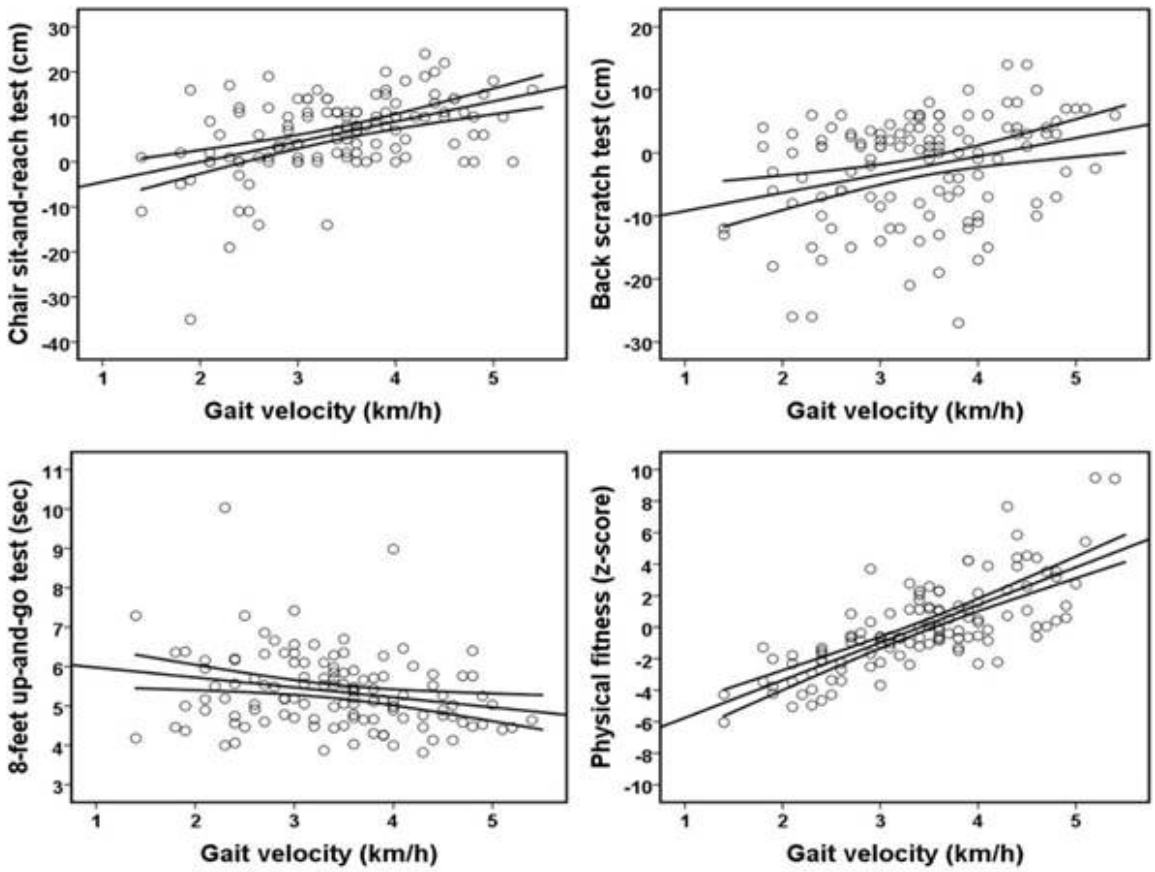

Figure 2. The correlations between gait velocity and chair sit-and-reach test, back scratch test, 8-feet up-and-go test and overall physical fitness (N=120).

DISCUSSION

The main objective of the study was to explore whether gait velocity predicts the level of separate and overall physical fitness in a sample of older adults. Our main findings were: (1) gait velocity was significantly correlated with all physical fitness components ($p < 0.001$), except with waist circumference and (2) gait velocity was strongly correlated with overall physical fitness. Our results are in line with previous cross-sectional studies conducted among older adults[7],12–14. In brief, evidence showed that walking speed was associated with knee extensor strength over the entire range of strength. Moreover, gait time decreased linearly with increasing knee extensor strength[13] and strength measure (composed of sum of knee extension, knee flexion and ankle dorsiflexion muscle strength scores) was the strongest predictor of six- meter walking speed[14]. Different to previous evidence, a study by Ciprandi et al.[7] showed that only hand grip strength was significantly associated with gait stability. The same group of authors also showed, that gait variability was significantly and negatively correlated with the level of physical activity, where participants with moderate gait variability and high preferred walking speed seemed to meet the recommended levels of physical activity[23]. Recently, two longitudinal studies have examined the association between gait velocity and physical performance[24,25]. A prospective cohort study with a follow-up period of 10.5 years showed that gait speed and physical performance independently predicted the risk of all-cause mortality[24], therefore both gait velocity and physical fitness served as

significant factors to determine the level of successful aging. Another longitudinal study showed that slow gait was associated with poor physical function, concluding that gait velocity should be a summary index of lifelong aging and potential screening tool for physical and functional decline[25]. Both gait velocity and physical fitness play an important role for maintaining healthy aging process and preserve high quality of life. Previous studies have shown that walking is a most frequent type of exercise among older adults, which requires a significant amount of metabolic energy[23]. This study shows that gait velocity objectively assessed by a pressure platform is a valid instrument to predict the level of physical fitness, especially overall physical fitness. Thus, gait velocity should be implemented in clinical settings as a screening tool to assess physical fitness in older adults. This study has a few limitations. First, by using a cross- sectional design, we cannot conclude the causality of the correlation that is higher levels of physical fitness led to faster gait velocity. Second, we based our findings on a relatively small sample of participants (N = 120), and larger sample size may provide with somewhat different strength of the association. Third, we based our study on a sample living in the urban part of the country, speaking Croatian and only White race. Therefore, future studies should explore longitudinal associations between gait velocity and physical fitness in population-based studies and in different World regions to generate relevant and comparable data. In conclusion, our study shows that gait velocity is moderately correlated with separate components of physical fitness, yet strongly correlated with overall physical index. If gait velocity is used in clinical settings or population-based studies among older adults, results in objectively measured overall physical fitness may be explained by 56% variance of gait velocity.

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Differences in the Situational Parameters of Tennis Matches Between Winners and Losers in The Women's Main Draw Competition At Roland Garros 2022

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ABSTRACT

Tennis is a world class competitive sport played under the rules of the International Tennis Federation. Also, tennis is characterized by repetitive actions of different types of strokes in match. The aim of this study was to determine if there are differences in the situational efficiency parameters between two groups of players (winners and losers) in the women's main draw competition at Roland Garros 2022. This study included 125 main draw matches. Differences in performance were analysed across 7 situational efficiency variables: aces, double faults, 1st serve average speed, 2nd serve average speed, winners, unforced errors and forced errors. The results showed significant differences between winners and losers group of players with the following parameters on the winners' side: winners (25.03/19.83; $p < 0.0071$) and unforced errors (22.80/29.06; $p < 0.0071$). The results demonstrated that there were no significant differences in double faults, 1st serve average speed, 2nd serve average speed, forced errors and aces. In addition to all the above, it is notable that more successful tennis players, as well as having more winners, record less unforced errors. The information obtained should be used by tennis coaches in planning trainings and preparing matches in order for their tennis players to achieve maximum results.

Keywords: match analysis, match statistics, player efficiency

INTRODUCTION

Performance in tennis consists of several interrelated parameters that include technical, tactical, psychological, and functional abilities (Kovacs, 2007). In order to achieve successful performance in tennis, female tennis players must develop many interrelated tennis skills to reach high level of success in a tennis match. Success or failure of any type of stroke in tennis can be a matter of

precision in terms of only several centimetres (Bower & Cross, 2005). To win a match, the number of errors must be reduced to a minimum, thus players with a higher percentage of accuracy of strokes are usually more successful. In top-level tennis, the precision of performing strokes is manifested through good ball placement into specific zones of the tennis field, depending on the situational conditions of a point (Kovacs, 2006). Playing the ball quickly into the planned part of the field is an important efficiency factor for winning a match among female tennis players. Quality ball placement and speed of the stroke are essential for attaining the best performance, and therefore their assessment is really important for the overall quality of the stroke (Terraza-Rebollo & Baiget, 2021). In addition to performing a stroke quickly and with precision, maintaining a high percentage of placing strokes into the field, during intensive periods in a match, presents a key component for winning in modern-day fast-paced tennis (Kovacs, 2007). Studies have shown that in terms of successful performance, speed and accuracy while performing strokes are closely linked (Maquirriain et al., 2016; Antúnez et al., 2012).

Quality among female tennis players is manifested in the ability of prolonging loss of strength, speed and consistency of strokes, which is essential for success during a tennis match. The effects of fatigue in tennis can be demonstrated as unforced errors, reduced speed and accuracy, poorer ball placement (reduction in footwork and poorer preparation for the stroke), as well as incorrect tactical choices (Davey et al., 2002; Girard & Millet, 2008). Upon analysis of competitive performances at Grand Slam tournaments, tennis players can be given insight into the characteristics of the observed parameters, which can thus be used to indicate relevant efficiency segments at the biggest competitions (Vorel, 2016). Research like this is providing results and guidelines about the differences among the analysed parameters in competitive performances that can determine the winner of a match on a clay tennis court. The parameters of situational efficiency that were analysed refer to the initial, middle, and final part of a tennis point.

METHODS

The sample of examinees consisted of 128 female tennis players who participated in matches of the main draw at Roland Garros 2022. Statistical data from 125 played matches was analysed. Two matches were not included in the analysis as they were not completed. Situational efficiency parameters were compared between two groups (winners and losers) in all matches of the main draw of the Roland Garros 2022 tournament. Situational efficiency of players was analysed by using seven dependent variables; aces, double faults, 1st serve average speed, 2nd serve average speed, winners, unforced errors, forced errors. Independent variables are two groups (winners and losers). The mentioned parameters of situational efficiency are officially tracked and collected on official website of Roland Garros 2022 (rolandgarros.com) and analyzed by Infosys system – official partner for data & match analytics of Roland Garros 2022.

Descriptive statistics parameters were calculated for all the variables: arithmetic mean ($\overline{x}$) and standard deviation (SD). Normality of distribution was tested by using the Kolmogorov Smirnov test. Using the Statistical Program v14.0.0 the median test showed that differences between the indicators of the competitive performance of the two groups of players (winners and losers) at the

RG 2022 were determined. The level of statistical significance was set at $p < 0.05$. After adjusting for multiple comparisons α was 0.0071. The obtained results are considered to be statistically significant if the level of significance is $p < 0.0071$.

RESULTS

Results of the analysis of the collected data determined differences between two groups (winners and losers) of female tennis players in matches, as is presented in Table 1. Using the Kolmogorov Smirnov test to determine the normality of the distribution it was found that 2 variables in the group of losers (2nd serve average speed and unforced errors) are normally distributed, while the other observed variables are not normally distributed.

The results presented in Table 1. indicate a statistically significant difference between two groups (winners and losers) of tennis players ($p < 0.0071$). Descriptive indicators of competitive performance and the results of the determined differences obtained with the median test between two groups of players who won and lost are presented in Table 1.

The obtained results show there is a statistically significant difference between two groups (winners and losers) in the following variables: winners and unforced errors. It should be noted that the mentioned variables mostly refer to the middle and final part of the tennis point during a match. The variables related to the quality of service performance (aces, double faults, 1st serve average speed and 2nd serve average speed) show that there is no statistically significant difference.

Table 1. Descriptive indicators of competitive performances and median test results of two groups of players (winners and losers)

Variable	Status	n	Mean	Minimum	Maximum	SD	Median	K–S	Median p
Aces	Winners	100	2.29	0.00	8.00	1.96	2.00	0.20	0.29
	Losers	100	1.73	0.00	10.00	1.83	1.00	0.17	
Double faults	Winners	100	3.08	0.00	10.00	2.27	3.00	0.17	0.15
	Losers	100	3.52	0.00	10.00	2.28	3.00	0.15	
1st serve average speed	Winners	100	155.44	112.00	175.00	11.52	157.00	0.12	0.12
	Losers	100	152.54	115.00	171.00	11.20	154.00	0.10	
2nd serve average speed	Winners	100	130.03	56.00	167.00	14.29	132.00	0.16	0.05
	Losers	100	127.79	97.00	157.00	10.33	128.00	0.07	
Winners	Winners	100	25.03	9.00	54.00	10.01	23.00	0.10	0.00*
	Losers	100	19.83	3.00	48.00	10.16	17.00	0.13	
Unforced errors	Winners	100	22.80	4.00	58.00	10.27	21.50	0.09	0.00*
	Losers	100	29.06	4.00	54.00	11.11	29.00	0.07	
Forced errors	Winners	100	19.50	4.00	45.00	9.13	18.00	0.13	0.01
	Losers	100	23.26	8.00	60.00	8.11	22.00	0.10	

* – level of significance $p < 0.0071$ (after Bonferronni correction)

DISCUSSION

The results of this research indicate that two group of players (winners and losers) do not differ in all the analysed situational parameters. Match winners group demonstrated results that indicate more consistent and precise performance of strokes throughout the entire match. This can be noticed on the basis of a lower number of forced and unforced errors, as well as a higher number of winners, which demonstrates that group winners of matches have a more active game, i.e., more domination in the middle part of the point. If one analyses previous research that addressed statistical parameters in matches on clay surfaces, the conclusion can be made that such matches demonstrate longer duration of points when compared to other playing surfaces, which precisely underlines the relevance of the middle part of the point (Fernandez et el., 2006; O'Donoghue & Ingram, 2001). The results obtained in this research indicate that more active, however, at the same time safer play, leads to a positive outcome in tennis matches. The afore mentioned is also confirmed by another earlier research (Vorel, 2016) where the differences between two groups (match winners and losers) originated precisely in efficiency parameters for the middle and final part of the point. The mentioned research also determined that group of players who won have more winners, with a significantly lower incidence of unforced errors. In addition, it should be mentioned that pervious research also found that the number of winner strokes is in correlation with the playing characteristics of group of players who won (Filipčić et al., 2008). A lower number of forced and unforced errors can be interpreted as a result of better training, where group of winners in matches, as a result of their physical conditioning preparation and quality of technical performance, succeed in preserving the playing initiative and waiting for a mistake by their opponent or creating an opportunity for performing a winner in high-tempo points. Winners matches group do not allow for an opportunity to their opponents to take over the playing initiative in a point by playing quick and precise strokes in a high tempo. The mentioned ultimately makes the difference between two groups (match winners and losers).

The results obtained in variables that refer to the initial part of the point, and which relate to serve characteristics (aces, double faults, 1st serve average speed and 2nd serve average speed), indicate that in female competition a fast serve does not create a significant initial advantage at the beginning of the point. The reason for the afore mentioned is very likely in the type of playing surface on which Roland Garros tournaments are played. Clay surfaces decrease the speed of the ball in a higher degree (after the bounce) due to the larger coefficient of friction, so that its bounce off is somewhat higher in comparison to other playing surfaces (Barbaros Tudor et al., 2008; Kaučić, 2015). As a result of the mentioned characteristics of the playing surface, it is possible that serve speed in women's tennis does not represent a significant advantage, as well as that it is not as much of a key factor for winning points. Along with it, no significant difference was found in the aces variable, which can indicate that other serve characteristics, instead of serve ace, could relate to quality of serve (such as good serve placement – ball placement, ball rotation, precision and variability of performing different types of serves) can contribute to winning a point. This can indicate that serve trainings should primarily be directed in the sense of creating a quality stroke that can potentially create an advantage for a better performance quality of the following second stroke, and for gaining advantage and domination in the

middle part of the point. On the other hand, if trainings are used to actively target players' abilities, which shall as a product result in increasing serve speed, this can potentially create a significant advantage between players in terms of serve performance. Previous research in male competition supports the mentioned fact (Benjak et al., 2014; Bertović, 2019), as a significant difference can be noticed in the speed of serve performance between two groups of players (winners and losers). During this research, group of winners performed faster 1st and 2nd serve, however, this difference did not show a statistical significance, and it can be noticed that the opportunity for taking over a more concrete initiative in the point was claimed during its middle part. Likewise, group of winners also demonstrated a lower number of double faults, and even though differences in this variable are not significant, the afore mentioned fact contributes to the statement that players who won perform the serve stroke in a more quality manner and with more self-confidence.

CONCLUSION

This research determined the differences in situational efficiency parameters between two groups of female tennis players who won and lost matches at the Roland Garros 2022 main draw. In this research, efficiency parameters for the middle part of the point demonstrated as most relevant for efficiency in a tennis match. The obtained insight is also confirmed in previous research, according to which group of players who won matches play a more precise game, have a lower number of errors during the match, and at the same time, due to a higher quality of stroke performance, succeed in achieving dominance in a point and in winning more direct points by playing more aggressively. Upon analysis of situational parameters, it can be noticed that differences are found in the number of winners and unforced errors, precisely in parameters that refer to the middle part of the point. The obtained results, according to which group of players who won are more successful in maintaining precision, while at the same time playing more aggressively during the entire match, can be interpreted by using several factors on which efficiency depends, as follows: physical conditioning of players, tactical selection of strokes and psychological readiness throughout the entire match. The mentioned results of this research are a demonstration of statistical parameters that are relevant for competitive efficiency, and that should certainly be analysed in terms of other mentioned factors as well. Overall analysis of results for top-level female tennis players in the world conducted in such a manner can be of assistance for training personnel teams in preparing players for the competitive period on clay surfaces. Tennis trainings before competitions on clay surfaces should be based on a high percentage of drills in which precisely the situational conditions for the middle and final part of the point are initiated. In future research it would be interesting to analyse the differences in parameters of situational efficiency between two groups of female tennis players who won and lost matches played on different surfaces.

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Despite the Covid-19 Pandemic, People With Chronic Neurological Disease (Multiple Sclerosis) are Trying to Maintain Physical Activity

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ABSTRACT

Multiple sclerosis (MS) is a chronic autoimmune neurodegenerative disease. This disease can manifest itself in many different neurological symptoms such as (gait and balance impairment, sensory deficits, muscle weakness, spasticity, bladder impairment, fatigue, cognitive impairment etc.). For successful disease management not only pharmacological treatment is important, but also a healthy lifestyle including regular physical activity. However, pandemic restrictions limited access to sport facilities and together with home-office regimen, increased the sedentary behaviour in all population. The pandemic level of physical activity in people with MS in the Czech Republic remains unclear. Therefore, using an online cross-sectional survey we aimed to evaluate physical activity (PA) level in people with MS during Covid-19 pandemic. Two hundred ninety-seven persons with MS filled out online survey, 83 % women, with a mean age 43.7 years (SD 11.3). Most respondents had mild to moderate disability (74 %). During pandemic year 2020, 23 % persons with MS ceased their PA, 18 % reduced their PA, 25 % continued their PA as before, 11 % increased their PA, and 20 % did not perform any PA in the past and did not do so during the pandemic. Aerobic activity was the main type of performed PA, followed by health exercise and yoga. Total of 37 % people reported that their fitness level had decreased during the pandemic.

Keywords: Covid-19, physical activity, exercise, multiple sclerosis

INTRODUCTION

Multiple sclerosis (MS) is a chronic autoimmune neurodegenerative disease affecting especially young adults. This disease can manifest itself in many different neurological symptoms (gait and balance impairment, sensory deficits, muscle weakness, spasticity, bladder impairment, fatigue, cognitive impairment etc.). For successful disease management, not only pharmacological treatment is important but also a healthy lifestyle including regular physical activity (Giovannoni et al.2016). Exercise in people with MS is acknowledged as safe symptomatic treatment (Tallner et al.2012). Some exercise experts consider regular training as primary prevention for MS (Dalgas et al.2019, Riemenschneider et al.2018). However, during the year 2020, pandemic restrictions limited access to sport facilities and together with work place restrictions (home-office regimen, lockdown) increased the sedentary behaviour in all population.

The new coronavirus was first described in December 2019 in China and in March 2020 the first case of Covid-19 appeared in the Czech Republic. Pandemic restrictions applied from March to May 2020 and then in autumn during next pandemic wave from October to December 2020 (unfortunately followed by next pandemic waves in 2021) limited physical activity for general population as well as people with chronic diseases (such as MS). Social distancing and the closure of sport venues together with a reduction of rehabilitation services limited opportunities for physical activity (PA). In Czech Republic sport venues were closed during spring months 2020 and from autumn 2020 to spring 2021. Regular physical activity (PA) is an integral part of disease management, but nevertheless the pandemic level of physical activity in people with MS in the Czech Republic remains unclear. Therefore, using an online cross-sectional survey we aimed to evaluate physical activity level in people with multiple sclerosis during Covid-19 pandemic.

MATERIALS AND METHODS

An online survey questionnaire for people with MS was distributed via e-mail and common local social websites of patient organizations dedicated to MS. The survey was anonymous and depends on the patient will to respond with total number of 16 closed questions. Specifically, participants were asked to report on whether and to what extent the pandemic conditions had altered their physical activity level. Then type, common duration and frequency of PA were reported. Data collection took place for 2 months (during summer 2021). Descriptive information to characterize the population was collected. The questionnaire was the same as Israeli researchers used to evaluate pandemic physical activity in their MS population (Kalron et al.2021).

The Ethical Committee of Sport College Palestra approved the survey (date 3.2.2021, VŠP/0382/2021). Statistical analysis was performed using MS Excel. Data are expressed as absolute scores and percentage distribution.

Total number of two hundred ninety-seven people with MS filled out the online survey with a mean age 43.7 years, 83 % of respondents were women. Most respondents had mild disability (74 %), 22 % walk with support (moderate disability) and 4 % use a wheelchair (severe limitation). For more details about the patient´s characteristics see Table 1.

RESULTS

Table 1 Demographic characteristics

Parameter N=279	Number (percent)
Mean age	43.7 years (SD 11.3)
Gender - Female	249 (83 %)
Disease duration	
up to 1 year	17 (5.7 %)
1–5 years	61 (20.5 %)
6–10 years	68 (22.8 %)
over 10 years	151 (50.8 %)
Covid disease	
No	203 (68.3 %)
Yes with mild symptoms only	46 (15.5 %)
Yes with moderate symptoms	46 (15.5 %)
Yes with severe symptoms (hospitalization needed)	2 (0.7 %)
After Covid-19, I still feel some difficulties (respiratory, pain, fatigue etc.) – mild only	40 (13.4 %)
After Covid-19, I still feel some difficulties (respiratory, pain, fatigue etc.) – moderate to severe	14 (4.7 %)

During pandemic year, in spring 2020 the 23 % people with MS ceased their PA, 18 % reduced their PA, 25 % continued their PA as before, 11 % increased their PA during the pandemic, and 20 % did not perform any PA in the past and did not so during the pandemic. Very similar situation occured during autumn 2020 when a new pandemic wave came and restrictions again limited public life (Table 2).

Table 2 Physical activity behaviour during the pandemic

Physical activity behaviour during spring 2020	Number (percent)
I have not performed any physical activity in the past and did not so during the pandemic	61 (20.5 %)
I stopped performing physical activity during spring 2020, although I had done so before pandemic	69 (23.2 %)
I performed less physical activity	56 (18.8 %)
I continued performing my physical activity	77 (25.9 %)
I performed more physical activity than usual	34 (11.4 %)
Physical activity behaviour during autumn 2020	**Number (percent)**
I have not performed any physical activity in the past and did not so during the pandemic	55 (18.5 %)
I stopped performing physical activity during autumn 2020, although I had done so before pandemic	66 (22.2 %)
I performed less physical activity	59 (19.8 %)
I continued performing my physical activity	80 (26.9 %)
I continued performing my physical activity	37 (12.4 %)

Subjectively perceived fitness level.	Number (percent)
My fitness level has improved.	35 (11.7 %)
I feel no change in my fitness level.	151 (50.8 %)
My fitness level has decreased.	111 (37.4 %)

As for the patient´s self-reported fitness level, 37.3 % reported their fitness level decreased during the pandemic, 50.8 % felt no change, and 11.7 % reported an improvement. The main type of performed PA was aerobic activity (53.5 %), followed by health exercise (35.6 %) and yoga (17.5 %). All results of the survey are presented in Table 3.

Table 3 Physical activity characteristic

Parameter	Number (percent) All N=297	Mild disability N=220 (74,1 %)	Moderate disability (walking with support) N=64 (21,5 %)	Severe disability (wheelchair user) N=13 (4,4 %)
Main performed physical activity?				
Aerobic physical activity	159 (53.5 %)	133 (60.5 %)	23 (35.9 %)	3 (23 %)
Muscle strength exercise	29 (9.7 %)	22 (10 %)	4 (6.2 %)	3 (23 %)
Combined aerobic and muscle strength	26 (8.7 %)	18 (8,2 %)	5 (7.8 %)	3 (23 %)
Yoga	52 (17.5 %)	41 (18.6 %)	11 (17.2 %)	0 (0 %)
Health exercise	106 (35.6 %)	65 (29.5 %)	33 (51.5 %)	8 (61.5 %)
I do not perform exercise at all	40 (13.4 %)	32 (14.5 %)	7 (10.9 %)	1 (7.7 %)
How long was your typical physical activity session?				
15 min	32 (10.7 %)	19 (8.6 %)	13 (20.3 %)	0 (0 %)
15-45 min	119 (40 %)	83 (37.7 %)	29 (45.3 %)	7 (53.8 %)
More than 45 minutes	71 (23.9 %)	60 (27.3 %)	6 (9.4 %)	5 (38.5 %)
No regular physical activity	74 (24.9 %)	57 (25.9 %)	16 (25 %)	1 (7.7 %)
How many PA sessions were performed on average within a week?				
1	26 (8.7 %)	17 (7.7 %)	7 (10.9 %)	2 (15.4 %)
2-3	99 (33.3 %)	77 (35 %)	19 (29.7 %)	3 (23 %)
4-5	52 (17.5 %)	39 (17.7 %)	9 (14 %)	4 (30,7 %)
daily	31 (10.4 %)	17 (7.7 %)	11 (17.2 %)	3 (23 %)
No regular activity	89 (29.9 %)	70 (23.5 %)	18 (28.1 %)	1 (7.7 %)
Meeting PA guidelines	105 (35.3 %)	81 (36.8 %)	16 (25 %)	9 (69 %)

DISCUSSION

According to the results of our online survey, 41 % of the Czech people with MS who responded, stopped or reduced their leisure time PA during the Covid-19 pandemic year 2020. However,

regular exercise or physical activity is for people with MS very important for managing their disease. Even without pandemic period, people with MS face many barriers to engaging to physical activity, such as fatigue, physical disability, safety concerns and lack of accessibility (Vanner et al.2008, Learmonth et al.2016). During pandemic time, this was compounded by loss of in person group physical activity, and closure of spaces for physical activities for people with disabilities (Koopmans and Peletier, 2021). The most limited activity of people with MS during pandemic was aerobic training and technology-assisted rehabilitation interventions. On the other hand home exercise or walking has become more popular and widespread (Kahraman et al.2022).

Recent data on the impact of Covid-19 in the general European population show the reduction of physical activity ranged from 7 % to 38 %. Based on step counts from Fitbit devices, the reduction of PA in the Czech Republic during spring 2020 was 20 % (Staff, 2020). So the reduction of PA in the present cohort of Czech people with MS was more pronounced than in healthy peers. This finding might be influenced by fear from Covid-19 and increased anxiety and depression among people with MS during pandemic time (Stojanov et al.2020, Alnajashi and Jabbad 2020).

Our findings show that majority of our responders (75 %) reported performing regular physical activity. Although only 35.3 % participants meet the recommended amount of physical activity for people with MS, which is ≥ 150 min weekly (Kalb et al.2020). This finding is very positive considering the challenging pandemic situation.

Comparing our results with an Israeli study using the same questionnaire, the percentage of people with MS who stopped or reduced their PA was lower than in Israel (41 % vs. 50 %). The percentage of people who continued their PA as before was similar (25 % vs. 20 %). Fewer people in our sample increased PA during the pandemic (11 % vs. 18 %). This could be related to the longer disease duration in our sample. In the Israeli sample, 48.3 % of people have disease duration shorter than 5 years, whereas in our sample only 26 %. More than fifty percent have a disease duration longer than 10 years, so our sample of MS population is more representative. In both samples aerobic activities were the most common (53.5 % vs. 72.1%). These activities, including indoor (home exercise on aerobic exercises machines such as stationary bicycle, elliptical etc.) or outdoor activities like walking, cycling or jogging, could be performed even when there were restrictions on gyms and fitness centres. And pools and some other sport facilities were closed, and it was recommended to keep social distance. Health exercises were also popular in our sample (35.6 %), followed by yoga exercise (17.5 %) and muscle strength training (9.7 %). These physical activities could be more easily performed even in more disabled persons with MS. A positive finding from our study is the fact that in challenging time of the Covid-19 pandemic, even more disabled people using walking aid and wheelchair users, a significant proportion of participants did not stop their physical activity and were still active (50.6 % continued in some type of PA). A European multicentre study looking at participation in physical activity among people with MS also describes a decline in exercise participation (from an initial 83 % pre-pandemic to 75 % during the pandemic). Overall, the intensity of PA has also decreased. The most common activity performed by all European patients was walking (Moumdjian et al.2022).). In another international study looking at the impact of the pandemic on 131 patients with progressive MS, 71% engaged in some form of physical activity, with aerobic activities predominating (Chiaravalloti et al.2020). These findings are similar to those

in our sample of Czech patients, where aerobic activities, including walking, were also the most frequently performed.

A limitation of our study is that in the subgroup of severely disabled people with MS, only physically active persons completed our survey. Unfortunately, we know from clinical practice that this group of people often do not engage in exercise activities. However, the other groups seem to be more evenly represented by active and less active persons.

CONCLUSION

Our results show that despite the pandemic restrictions, one-third of people with MS who responded to the survey maintained regular physical activity (mainly aerobic activities).

On the other hand, 40 % of people with MS ceased or decreased their leisure-time physical activity. Even in the COVID-19 pandemic, people with chronic neurological disease (multiple sclerosis) are trying to maintain physical activity. Therefore, it seems appropriate to offer them suitable telerehabilitation and motivational programs to help maintain compliance with regular physical activity.

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Negative Training Responses During the Runners' Career Could Cooperate in an Early Career Termination: A Case Study in Top-Level Female Runners from the Slovakian National Team

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ABSTRACT

Purpose: The early career drop-out in professional youth athletes is a complex and multi factors process and seems to be more common in individual sports with higher physical demands, such as running disciplines. The present study, therefore, investigated the training responses during the career of top-level female runners who terminated it early. **Methods**: Data from four female runners (aged from 22 to 24 years) from the Slovakian national team in running disciplines who have ended their careers early were collected. A semi-structured interview was performed to explore multiple factors (e.g., athletic career, training routine, training camps, racing, performance, recovery, nutrition sleep, health, motivation, psychological responses, relationship with coach, parents and friends, financial support, present status, and future plans) and by questionnaires about wellness, motivation, mental exhaustion and low energy availability. **Results**: The interview shows that the most common factors reported by the former runners were: early specialization, inadequate training dose-response (e.g., high intensity and insufficient recovery), pathological nutritional behaviour, health problems, psychological factors, and loss of motivation. The factors reported during the interview were associated with negative results of the wellness questionnaire (score 10 ± 1.9) and low energy availability (score 12 ± 2.9). **Conclusion**: The study highlights the negative training responses during the runners' career and it could trigger an early career termination. Based on the athletes' reports, was possible to notice that the early sports specialization in running disciplines affected negatively their health, nutrition and psychological aspects, and could be due to higher training loads and insufficient recovery. Caution should be taken by coaches and professionals involved during the sports specialization, in order to minimize the negative impact of training routines on youth athletes and consequently avoid an early drop-out.

Keywords: early specialization, overtraining syndrome, female and male athletic triads, relative energy deficiency, disorders eating, athletes

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INTRODUCTION

The early drop-out in professional youth athletes is a complex and multi factors process and seems to be more common in early sport specialization periods and in individual sports with higher physical demands, such as the running disciplines. Sports such as running are usually characterized by an intense training routine in order to optimize the athlete's performance (Striano and Purcell, 2006), and when this training is performed by youth athletes, can generate maladaptive responses in case of inappropriate training doses and insufficient response. The literature has described that an early specialization increased the athletes' chance of overtraining and overuse injuries triggered by a combination of high intensity and insufficient recovery, and this combination can trigger an early dropout due to physical and emotional burnout (Di Fiori et al., 2014; Valovich-McLeod et al., 2011).

Youth female athletes have been considered a population more sensitive to present health issues related to training maladaptation, inadequate energy consumption and eating behavior (Sharps et al., 2022). To address these health issues, the International Olympic Committee attributes the concept of Relative Energy Deficiency (RED-S), what was known as the female athlete triad (Reardon et al., 2019), caused by chronically poor energy availability and nutrition (Stellingwerff et al., 2021). The presence of low energy availability in youth female athletes can result in a delay of puberty, menstrual irregularities, development of harmful eating behaviors, stress fractures, loss of muscle mass and impaired physical capacity (Desbrow et al., 2019; Areta et al., 2021).

The interrelationship among poor energy availability, overtraining syndrome, impairment of emotions, and mental exhaustion can altogether provoke an early career termination. Taken together, considering that youth female is a risk population of poor health and the running sport modality is a high-demand sport, understanding the outcomes generated during the process of the running specialization period can help to identify possible variables responsible for early career termination in this specific population. The present study, therefore, investigated the training responses and the possible association with low energy availability, emotional responses and mental health during the career of top-level runners from the Slovakian national team who terminated it early.

METHODS

Participants

Data from four elite athletes (22–24 years old), who started and finished early their careers in top-level athletics were collected. The athletes competed in short, medium and long distances races, and represented the Slovak Republic. The inclusion criteria were to be a member of a youth athletics team before retirement and participation in at least one top competition in the youth

category, such as the World Championship, European Championship, or competitions organized by the International Olympic Committee (YOG, EYOF). Before starting, the runners were informed about the aim of the study and consented to participation.

Experimental design

The athletes were selected intentionally, based on the inclusion criteria. The study utilized qualitative and quantitative approaches. Qualitative research based on expert interviews is widely used as a method across multiple disciplines including sports science. Quality interviewing is often aimed at obtaining information or studying a particular field activity. Some studies in the field of sports science need to measure behavioral perspectives, such as athletes' motivation, attitudes, beliefs, and perceptions. These factors are difficult to measure without using qualitative research methods such as interviews. Qualitative methods are also useful in the study of contextual factors that affect athletic performance (Draper, 2009), thus, in the present study, the runners are the key informants who have specific knowledge and skills, and they are used as a source of information. Interview questions have been designed to explore the female runners' training during their youthfulness with open-ended questions to understand the key factors perceived by athletes to finish early their careers at the top level. The interview script was separated into two parts: the first part the questions related to their experience during the training period obtained by semi-structured questions and in the second part the questions were based on questionnaires about wellness, motivation, mental exhaustion and low energy availability.

Interview procedure

The interviews were standardized by using a semi-structured script in order to minimize possible bias. The questions were developed by two researchers: one former female runner and one researcher with previous experience in training demands in professional athletes. All four interviews were conducted by one researcher, who has previous contact with the athletes, which allowed her to guide the interview using specific terminology associated with the topic and generate a relaxing environment with the interviewees.

The procedure of interview occurred via an online phone call lasting approximately 2 hours, with each respondent separately. In the first part of the interview, semi-structured questions were asked. It was 28 open questions with 53 additional sub-questions in the thematic areas: athletic career, training routine, training camps, racing, performance, recovery, nutrition sleep, health, motivation, psychological responses, relationship with coach, parents and friends, financial support, present status, and future plans. The interviewer guided the respondents in order to go back in time and answer all the questions. In the second part of the interview, it was asked established questions based on questionnaires, in which they point out their training dose and response liked to wellness, motivation, mental exhaustion and low energy availability.

Questionnaires

To obtain information about wellness, motivation, mental exhaustion and low energy availability, it was chosen questionnaires already used in sport science literature, with an easy approach but relevant outcomes. The questions were made based on the runners' past experience during their career as top-level athlete representing the Slovakian national team.

Wellness Questionnaire: the wellness questionnaire gathers ratings of perceived muscle soreness, general well-being, fatigue, stress and sleep on a scale from 1 (very poor response) to 5 (very good responses). This instrument has been used widely in sports settings in different sports disciplines to monitor athletes' responses to training demands and used recently for the authors (Silva et al., 2022; Bernaciková et al., 2022). For this study, the questionnaire was used retrospectively to find out the level of fatigue in the runners during the period in which they began to suffer from stagnation or even a decrease in performance and overtraining status. The results were interpreted as follows: a total answer score of 4–8 indicates severe fatigue; 9-15 indicates moderate fatigue and a score of 16 or more indicates that the athlete is doing well and can continue training without restrictions (McGuigan, 2017).

Motivation Questionnaire and mental exhaustion questionnaires. The questions about motivation and mental exhaustion were built by previous studies of a sport psychologist (Květon et al., 2020; Burešová et al., 2021) and used recently in a mobile application to prevent chronic fatigue (Bernaciková et al., 2022) (see Supplemental Material). For the perception of mental exhaustion, it was asked 'how mentally exhausted do you feel during the training period? Twenty-three questions comprise this domain, with Yes or No options given. The total scores from 0–5 affirmative answers indicate that the training process was completely fine; 5–15 affirmative answers reveal a certain degree of psychological exhaustion; 15 or more positive answers warn of a high risk of psychological exhaustion, which could result in a decrease in performance. For the motivation domain, the focus was to find out how the respondents were motivated when they were thinking about ending their careers. Twenty-two questions were asked with 6 questions considered a high risk of loss of motivation; 10 questions a medium risk and 6 questions as low risk. If the respondent answers YES 5 times out of 6 low-risk questions, it means that she was highly motivated to continue her training. If an outcome was YES to 5 high-risk questions, the result indicates a loss of motivation. In this situation, it is obvious that the athlete was not so motivated, probably frustrated and the sport no longer fulfilled her. For all other resulting combinations, we identified incipient motivation problems.

Low Energy Availability Questionnaire (LEAF-Q). The LEAF-Q is a 25-item questionnaire used to screen physiological symptoms associated with female athlete triad and relative energy deficiency (Melin et al., 2014). The questionnaire considers three domains: gastrointestinal function, injuries and menstrual function. For the purpose of determining the possible occurrence of these irregularities, the questionnaire was also used in our research. A score ≥ 8 indicates a risk of low energy availability and female Triad. The LEAF-Q is validated in female athletes (aged 18–39), involved in ≥ 5 times/week training, reporting an adequate sensitivity (78 %) and specificity (90 %) (Melin et al., 2014).

Data analysis

Data from interviews were analyzed following the process of data engagement, coding and theme development (Braun and Clarke, 2021) as follows: i) data familiarization (reading and rereading the transcriptions of interviews); ii) systematic data coding (coding the whole texts and identify the part of the texts which are answering the research questions); iii) generating initial themes from

coded and collated data (combined the data into the main themes); iv) developing and reviewing themes (detailed analysis of the themes); v) refining, defining and naming themes (name, split, combined, or discarded themes, confirming if research questions were answered); and vi) writing the report. The transcription was made by the same researcher who performed the interviews and revised by a second researcher. After analyzing the verbal reports, the researchers together determined the words and phrases for each category of questions. The data from the questionnaires were calculated and described according to the established classification.

RESULTS

The results are briefly categorized and summed up in tables. Table 1 presents the runner's training characteristics. It was possible to observe a higher training volume (up to 20 hours per week) and poor active recovery (1 – 3x/week).

Table 1 Characteristic about training and races in runners

	Athlete 1	**Athlete 2**	**Athlete 3**	**Athlete 4**
Discipline/ best record	800 m: 2:12.07 min	100 m: 12.0 s 200 m: 24.68 s	800 m: 2:16.36 min 1500 m: 4:40.45 min	100 m: 12.18 s 200 m: 24.83 s
Training duration (min)	90	90	90–120	90–120
Training frequency (week)	8–10	8–10	8–10	10
Training volume (h/week)	12–15	12–15	14–20	15–20
Training intensity RPE (6–20)	15–20	11–20	15–19	14–20
Training camps (per year)	6	3	3	4
Races (per year)	38	40	27	40
Active recovery (per week)	1	1	1	3

Note: RPE= rating of perceived effort.

Complementary, it was asked during the interview about the strategies used by the runners to recover after training. The most common answers were massage, sauna and whirlpool. Two runners mention swimming and one runner mentions banking

Table 2 was created based on the synthesis of the open questions and the questions from the questionnaires. The outcomes were displayed in the categorical description, in order to present factors that can help better understand the runners' performance and behavior during the career that could affect the early termination. The results indicate a high risk of pathological conditions such as overtraining syndrome (OTS) and female athletic triad (FAT). An interesting point was that the runners presented adequate sleep, not disturbance and the length was usually 8.5 hours. The close questions gave the information that, besides the athletes sleeping soundly, they did not feel rested in the morning.

Table 2. Performance and behavior during the runner's career

	Athlete 1	**Athlete 2**	**Athlete 3**	**Athlete 4**
Training volume	high	high	high	high
Performance testing	low	low	regularly	low
Recovery	insufficient	sufficient	insufficient	insufficient
Nutrition	insufficient	insufficient	insufficient	sufficient
Disorders eating	yes	no	yes	no
Energy for training	low	medium	low	low
Training diary (monitoring)	yes	yes	yes	no
Peak of performance (years)	16 yrs.	17 yrs.	15 yrs.	16 yrs.
Performance stagnation	no	yes	yes	yes
Performance drop	yes (16 yrs.)	yes (18 yrs.)	yes (16 yrs.)	yes (16 yrs.)
Overtraining	high risk	increased risk	increased risk	high risk
Injuries	often	minimal	often	often
Burnout syndrome	high risk	high risk	increased risk	low risk
FAT	high risk	high risk	high risk	high risk
Changes in training	no	yes	no	no

Note: FAT= Female Athletic Triad.

Table 3 describes the outcomes of the wellness and low energy availability (LEAF-Q) questionnaires. All female athletes showed high risk in the LEAF-Q.

Table 3. Classification of wellness and low energy availability questionnaire

	Athlete 1	**Athlete 2**	**Athlete 3**	**Athlete 4**
Sleep quality	good	very good	very good	good
Muscle soreness	high	average	very sore	high
Stress level	high	high	average	average
Fatigue level	very fatigued	low	very fatigued	very fatigued
Total Score	9	14	10	10
LEAF-Q (score)	high risk (14 points)	high risk (10 points)	high risk (17 points)	high risk (10 points)

Note: LEAF-Q = Low Energy Availability in Females Questionnaire.

The Table 4 summarize the finding of the questionnaires, asked in the second part of the interview. The main outcomes assumed an incidence of symptoms of pathological conditions, which are increased level of fatigue, decreased level of motivation, increased level of psychological exhaustion and low energy sufficiency in sports.

Table 4. Results of the questionnaire survey of female respondents

Questionnaire	Athlete 1	Athlete 2	Athlete 3	Athlete 4
Wellness	↑ fatigue	↑ fatigue	↑ fatigue	↑ fatigue
Motivation	↓ motivation	↓ motivation	↓ motivation	↑ motivation
Mental exhaustion	↑ exhausting	↑ exhausting	↓ exhausting	↑ exhausting
LEAF-Q	↑ triad risk	↑ triad risk	↑ triad risk	↑ triad risk

Note: LEAF-Q = Low Energy Availability in Females Questionnaire.

In Figure 1, based on the combination of data from the interview, summarized and conceptualized the most common factors that could affect the early career termination of top-level female runners.

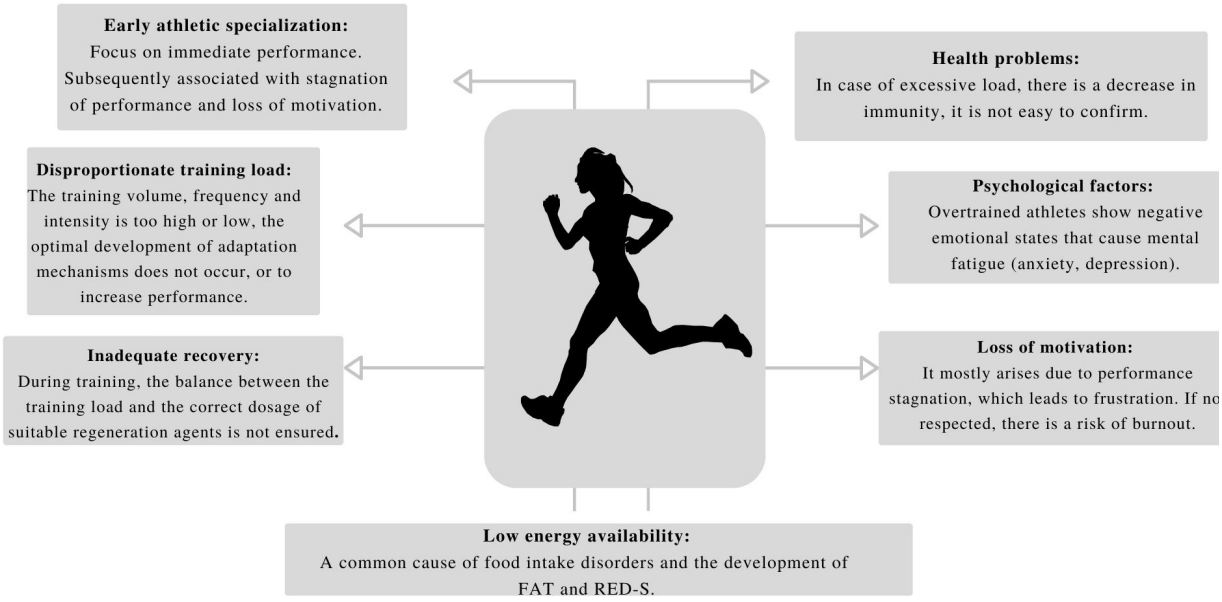

Figure 1. Sum up of factors observed during the career of top-level runners with early career termination

DISCUSSION

The main aim of the study was to investigate the training responses in top-level female runners who terminated their careers early. The main findings show that the most common career factors of the former runners were: early specialization, inadequate training dose-response (e.g., high intensity and insufficient recovery), pathological nutritional behavior, health problems, psychological factors and loss of motivation. The factors reported during the interview were associated with negative results of the wellness questionnaire (score 10±1.9) and low energy availability (score 12 ± 2.9).
Based on the runners' answers, it was possible to notice that they were overloaded. The training intensity was long-term high, as 3 out of 4 athletes reported an effort scale of 20 during the training period, which should not occur in a normal training process. This limit is referred to as

the maximum strain caused by maximally intensive interval training, which places high demands on the athlete's body leading to the development of pathological conditions. Therefore, in order to determine the optimal training intensity, regular monitoring of performance by physical tests and the monitoring of the wellness state is recommended (Bird, 2011). Only 1 out of 4 female athletes was enrolled in regular performance evaluation. In addition to excessive training intensity, the athletes also completed a high number of training units (or high training volume) – 10 TJ/week, which means 3-4x two-phase training per week.

Regarding the recovery process, it can be seen that the balance between training load and regeneration did not occur between them, which could lead to an emerging non-functional overreaching and overtraining syndrome (McFarland et al., 2014). The struggle with insufficient regeneration reported by 3 out of 4 runners was also indicated by the frequent occurrence of injuries with repetitive nature and a long recovery time from it, which often limited them in return to the training process. It was previously described that the exhaustion perceived by female athletes could also have been caused by low energy availability, which is one of the most frequent causes of fatigue in athletes (Melin et al., 2019, Loucks et al., 2011). In 3 out of 4 runners it was found a long-term low energy intake and 2 athletes previously suffered from disorders eating, which were most likely caused by pressure from the athletic environment. The LEAF-Q questionnaire gives the information that the runners were at high risk of the female athletic triad, scoring a total point higher than 8. Monitoring the sports performance and state of wellness (as part of the prevention of pathological conditions) was lacking or insufficient in the runners. Even though 3 ut of 4 athletes regularly kept a training diary, the monitoring process was never performed by the trainer /coach. Possibly, if the recorded data were shared, the coach could adjust the athlete's training load and recommend suitable regeneration in critical periods.

Maximum performance was reached at youth age, approximately around 16 years, and interestingly, at the same age, after achieved the peak, the runners reported experiencing a premature decline in their performance. Previous studies demonstrated that optimal peak performance in athletic disciplines is around 21–23 years for female sprinters and 24–26 years for middle and long-distance runners (Perič, Březina 2019), this information pointed out that the runners from the present study have reached their maximum peak earlier than recommended, which means an ending their promising athletic careers prematurely, even before the onset of the recommended peak age. As speculation, the early athletic specialization mainly contributed to this early career termination. It is possible that the athletes could not handle the pressure that was put on them when their surroundings assumed that their performances would grow further up.

For each runner, was recorded some symptoms of fatigue using the wellness questionnaire, together with mental exhaustion and motivation questionnaires. Compelling the results, it was possible to notice a high score of psychological exhaustion in 3 out of 4 female runners, probably arising from an unreasonable training load or the influence of the surrounding climate (e.g., environmental pressure, coach, relationships), which probably had a negative impact on their performance. In the same way, the motivation questionnaire supported that 3 out of 4 female athletes presented a loss of motivation to continue their sports career and frustration from failures and injuries. When a loss of motivation is detected, it is suggested to remove the causes of its occurrence and restore the athlete's motivation.

Unfortunately, in the case of the present runners, it is speculated that the loss of motivation was not sufficiently addressed and lasted too long, which probably led to the development of burnout syndrome. From this perspective, the impairment in the emotional state could increase the chance of a decision of ending their running career. Moreover, the interview responses showed that the coaches motivated and psychologically supported the runners throughout their careers, however, no changes were made in their training routines, failing to recommend changes in the area of nutrition and disorders eating, recovery and performance evaluation.

Practical recommendations

Overtraining, exhaustion, disorders eating, athletic triad, energy deficiency and burnout syndrome are generally recognized problems that commonly affect both performance and professionalism. It could be confirmed in the present study of female runners. As part of prevention, the authors recommend regular monitoring of training load and physical and psychological responses. At the first sign of an imbalance of training dose-response, an intervention should be performed in order to optimize the training load to avoid pathological conditions such as overtraining and female athlete triad syndromes. Special attention should be paid to performance stagnation and psychological changes which could be caused by the influence of the external environment and occurs before changes in physiological functions (Pernica et al., 2019).

Since psychological fluctuations are common in athletes from athletics modalities, the authors recommend also monitoring the psychological state in order to prevent the development of any pathological condition of the athlete. The questionnaires used in the present study (see Supplemental Material), could be used as a tool for long-term monitoring of the psychological components. Additionally, the LEAF-Q questionnaire could also guarantee early symptoms and help in the subsequent treatment of FAT and RED-S manifestations. A 24-hour recall or various measurements of body composition (e.g., InBody, bone densitometry, BOD POD) also have great validity in the prevention of these conditions (Łuszczki et al., 2021). The wellness questionnaire, which indicates the degree of fatigue, appears to be a very easy and informative tool to use in a practical context and can help in the prediction of the possible overtraining status in athletes. Another and perhaps the most important preventive measure for early retirement in athletics is the selection of a competent coach. The coach plays a key role in the development of athletes' performance and long-term careers, so an inability to plan an adequate training dose-response could lead to a harmful process triggering an early career termination. This topic was addressed by the respondents themselves, who state that they did not have enough competent and educated trainers in their area. In this matter, the authors emphasize the necessity of focusing on improving the education of athletics coaches, not only in the field of training load management but also in the field of sport psychology.

CONCLUSION.

The study highlights the harmful training responses during the runners' careers and it could trigger an early career termination. Based on the athletes' reports, was possible to notice that the early sports specialization in running disciplines affected negatively their health, nutrition and

psychological aspects, and could be due to higher training loads and insufficient recovery. Caution should be taken by coaches and professionals involved during the sports specialization, in order to minimize the negative impact of training routines on youth athletes and consequently avoid an early drop-out.

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High-Intensity Functional Training in Pregnancy: A Case Study

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ABSTRACT

High-intensity functional training (HIFT) is a popular activity that combines high effort and compound exercises. Many women aged 20 to 40 who are expected to become pregnant soon are also fond on it. HIFT is an activity in which the heart rate increases significantly, there is an increase in intra-abdominal pressure, free weights are also used. There is poor evidence of HIFT and its effect on pregnancy or childbirth. The subject of this case study was a healthy woman (31 years old) who has long-term experience with HIFT. The aim of the study was to analyze the training regime (length, intensity, heart rate) and the number of steps in the period from the 1st to the 38th week. The effect on the health of the mother and the fetus, the delivery, and the birth weight was monitored. The findings show that with an optimally set training program, HIFT can be a safe activity that has no adverse effect on pregnancy, fetal health, or childbirth. This is the first such study, so further research is needed.

INTRODUCTION

High-intensity functional training (HIFT) is a globally popular physical activity that mainly attracts the population aged 20 to 40 (Kercher et al., 2022). HIFT is an activity that involves a wide spectre of exercises and modalities (weightlifting, running, gymnastics, etc.). The training includes a combination of high-intensity exercises (at least a 7/10 rating of perceived exertion – RPE) and physiological parameters attained (Feito et al., 2018). Variability of exercises is typical as well - the same workouts repeat only rarely and they are a bit shorter, taking from about 5 to 40 minutes. Training sessions also consist of skills development, strength, and power.

High-intensity exercise or weight-bearing exercise during pregnancy has not been accepted in society yet and it is met with apprehension and prejudice. The general recommendation for

physical activity is 150 minutes of moderate-intensity exercise a week (Tinloy et al., 2014). The vigorous intensity with HRmax above 70 % (Beetham et al., 2019) is not regarded as optimal. Strength training is considered appropriate, but it should be very light, or exercises should be isolated (Schoenfeld, 2011).

HIFT is a high-impact activity that might be a potential health risk for the pregnant person or the unborn baby (Owe et al., 2016). Problems can be shocks or the risk of falling or being hit by a barbell. Another negative factor mentioned is exercise intensity associated with metabolic processes affecting fetal heart rate (HR) (bradycardia) or uterine artery volume blood flow (Salvesen et al., 2012). On the other hand, there is evidence that high exercise intensity (up to 90 % HRmax) or strengthening at the level of 1RM may not be associated with adverse effect (Gould et al., 2021; Sigurdardottir et al., 2019).

So far, there is little direct evidence for the suitability of HIFT for a pregnant woman. The author of this paper knows only about the study by Anderson et al. (2021), the subject of which was high-intensity training with functional movements. Other studies either include strength endurance training or work at a low-intensity (Barakat et al., 2008; Garnæs et al., 2017). Considering the number of young women doing HIFT and the fact that some of them might be unwilling to give up the sport while pregnant, it is necessary to know both risks and benefits. The aim of the research was to find out how a pregnant woman is affected if she does HIFT during the state of pregnancy in terms of cardiac activity and what the effect is on the course of pregnancy, parturition, and fetal health.

METHODS

Participant description

The selection criteria for inclusion in the research were as follows: healthy physically active woman, experience with HIFT for at least 1 year, first pregnancy, age 20–35 years. The subject of the case study was a physically active healthy woman (32-year-old, 170 cm, 62 kg) without any health restrictions. She was monitored for 38 weeks of pregnancy, the parturition was in the 39th week of monitoring. During the whole pregnancy, she was devoted to training without any limitations. The woman has been doing HIFT for a long time (7 years) and she also actively competes at the local level. The usual training regime before pregnancy included 5 training sessions per week. These training sessions included Olympic weightlifting, strength training (powerlifting, gymnastics), and conditioning using combinations of cardio, weightlifting, and bodyweight exercises. Selected strength performances: snatch with 50 kg, clean and jerk with 75 kg, back squat with 90 kg, strict press with 42.5 kg. The training plan was structured and focused on competition performance.

Nutrition before pregnancy was connected to the training regime – 100 grams of protein per day, 100–200 grams of carbohydrates a day, and 30–60 grams of fat a day. The diet was based on all-natural food, as for dietary supplements, she used complex mineral substances. Apart from covering the higher caloric expenditure, there was no special target for nutrition. The sleep schedule was consistent, aiming for 7 to 8 hours. During the state of pregnancy, caloric intake was increased, and vitamin and mineral supplement was taken.

The woman was monitored from the 1st to the 38th week pregnant via a smartwatch (iWatch). These days, smartwatches are a very accurate tool for monitoring HR, heart rate variability (HRV), calorie expenditure, or pedometer (Morresi et al., 2020; Phan et al., 2015). The training was not recorded four times due to low battery. More pauses in the training plan were caused by two cases of virus infection (5–7 days) and holidays (7 days).

Training

If a woman is pregnant, her workout routine is based on her actual medical condition and how she feels. The goal of the training plan was to maintain HIFT principles, regardless of absolute performance and strict adherence to the number and the prescribed content of training sessions. In the third trimester of pregnancy, 12 training sessions were left out and replaced by light physical activities (walking, gardening, etc.). The negative test result showed that she did not have gestational diabetes. Based on the medical examination, the training regime was not limited in any way.

The training plan was to have 4 to 5 training sessions a week. Each training session took from 45 to 70 minutes, starting with a warm-up exercise and with a cool-down exercise at the end of the session. Power/strength training or parts focusing on technique were involved in the training plan as well, the load ranged up to 90 % of the current (or estimated) 1 RM. The main part focused on conditioning, comprised of combinations from 2 to 6 exercises of various modalities. The form was both continuous and intermittent.

The woman did not undergo any cardiac stress exercise. Therefore, her absolute HR was calculated according to the formula HRmax = 226 - age. However, this is an approximate indicator, therefore the RPE was used as a part of the intensity setting and HR served just as an auxiliary indicator. The woman was instructed about RPE, the requirement was to exercise between 6–8/10. However, adapting to the current feeling was possible as well.

At a later stage of pregnancy, especially in the third trimester, some exercises were modified or eliminated. The reason was perceived discomfort and/or impossibility of performance and/or increased risk of injury (e.g., box jump, jump rope, burpee, SkiErg, squat snatch, toes to bar).

Table 1. Examples of the main part of training sessions

30th week	12 minutes AMRAP 2 minutes rest 12 minutes AMRAP	12 calories on air bike, 5 handstand push-ups 12 calories on bikeErg, 4 burpee pull-ups
36th week	16 minutes AMRAP	12 calories bikeErg, 12 ring rows, 20 squats, 10 strict dumbbell presses 2 x 12.5 kg
37th week	4 rounds of 1 minute work / 1 minute rest (16 minutes)	A. 14 wall balls (6 kg medicine balls), maximum calories on bikeErg, B. 14 dumbbell snatch (15 kg), maximum box step ups (50 cm)

AMRAP- as many repetitions as possible

Data collection and analysis

The woman wore the smartwatch 24 hours a day (except for charging time), and data was collected continuously. The watch includes a wrist sensor that monitors heart activity. The watch was also a pedometer that counts each step a person takes by detecting the motion of the person's hand. Data analysis was performed using Microsoft Excel. The data was downloaded from the smartwatch via firmware. The data is presented as an average ± SD (standard deviation). Figures were also created in Microsoft Excel.

RESULTS

Heart activity, step count, and active energy burned were monitored for 266 days. The number of training sessions was 129 with an average length of 30 ± 13,3 minutes. The duration of the training, the recorded heart rate (HRmax, HRavg) included, refers only to the main (conditioning) part (Figure 1, 2). The strength and technical part, warm-up and cool down were not included, but they were reflected in the active energy burned and step count.

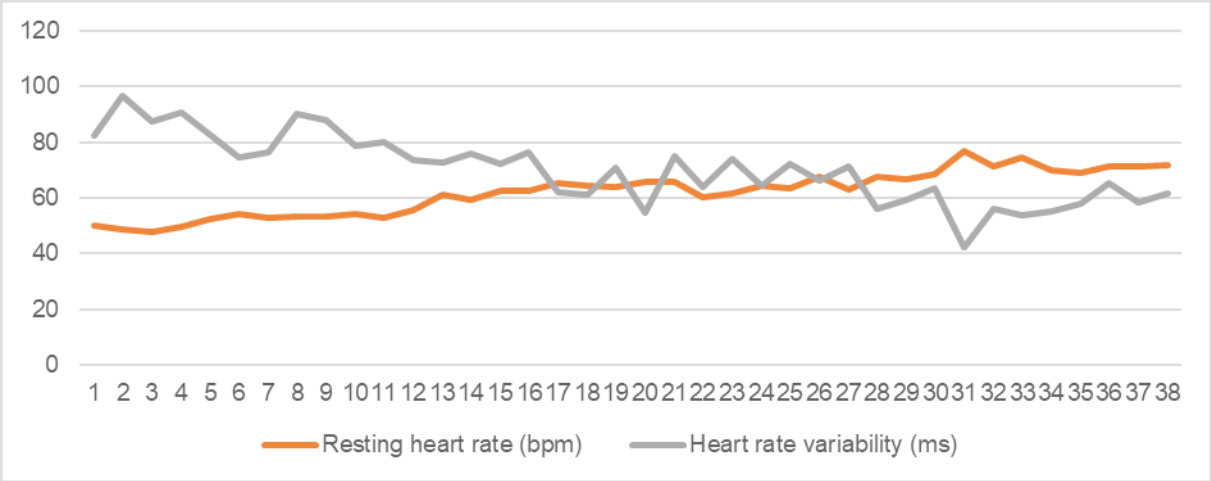

Figure 1. Average heart rate measurement records (resting HR, SDNN)

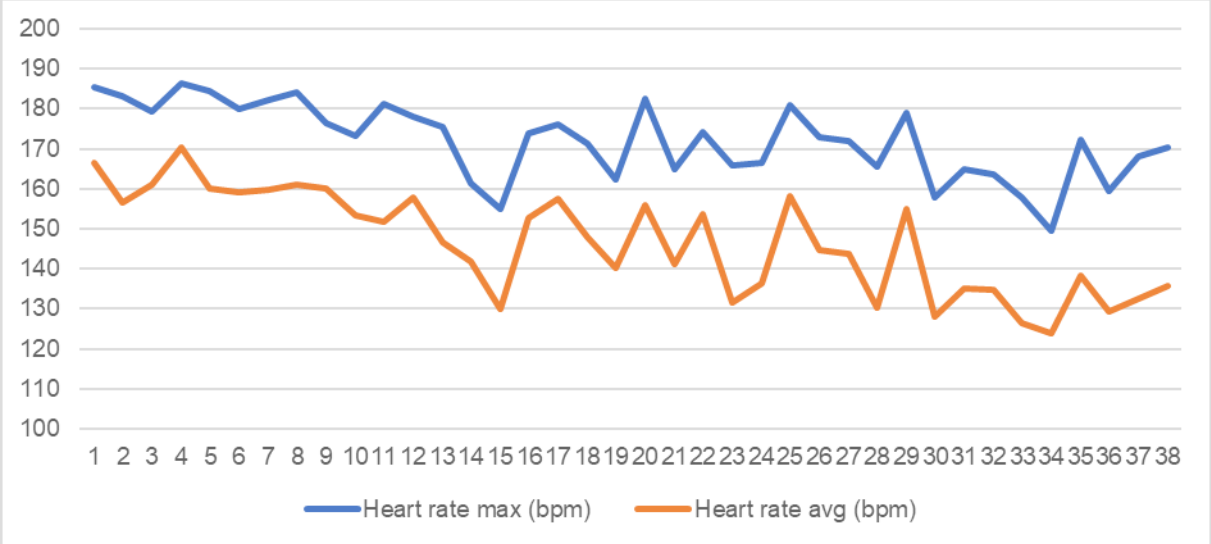

Figure 2. Average HRmax and HRavg in training sessions

Table 2. Overview of the monitored parameters (average and standard deviation)

	1. trimester	2. trimester	3. trimester	overall
Number of training sessions	48	46	35	129
Length of training sessions (minutes)	27,5 ± 8,6	31 ± 16	32 ± 14	30 ± 13,3
Number of steps (daily)	5467 ± 1664	5461 ± 2045	8700 ± 1955	6400 ± 2394
HRmax (bpm)	180,3 ± 8	170,5 ± 16,8	165 ± 16,5	172,7 ± 15,3
HRavg (bpm)	158,3 ± 10,2	145,7 ± 18	133,8 ± 19	147,2 ± 19
SDNN (ms)	81,7 ± 28,8	68,4 ± 28,8	57,2 ± 25,7	68,3 ± 29,3
Active energy burned (kcal)	404,5 ± 124,7	392,2 ± 127,8	468 ± 117,7	418,4 ± 127,5

Bpm – beats per minute; ms – millisecond; kcal – kilocalories

In the first and the second trimester, the number of training sessions was steady as well as the number of steps. In the third trimester, as has been already mentioned, the number of training sessions was reduced, and, on the contrary, the number of steps increased (Table 2). Thanks to this, the amount of active energy burned increased - however, this parameter depends not only on the number of steps and training sessions but also on the gradual weight gain (from 62 kg to 74 kg). Since it was possible to main the training time, the curves of steps and active burned energy show a similar course (Figure 3).

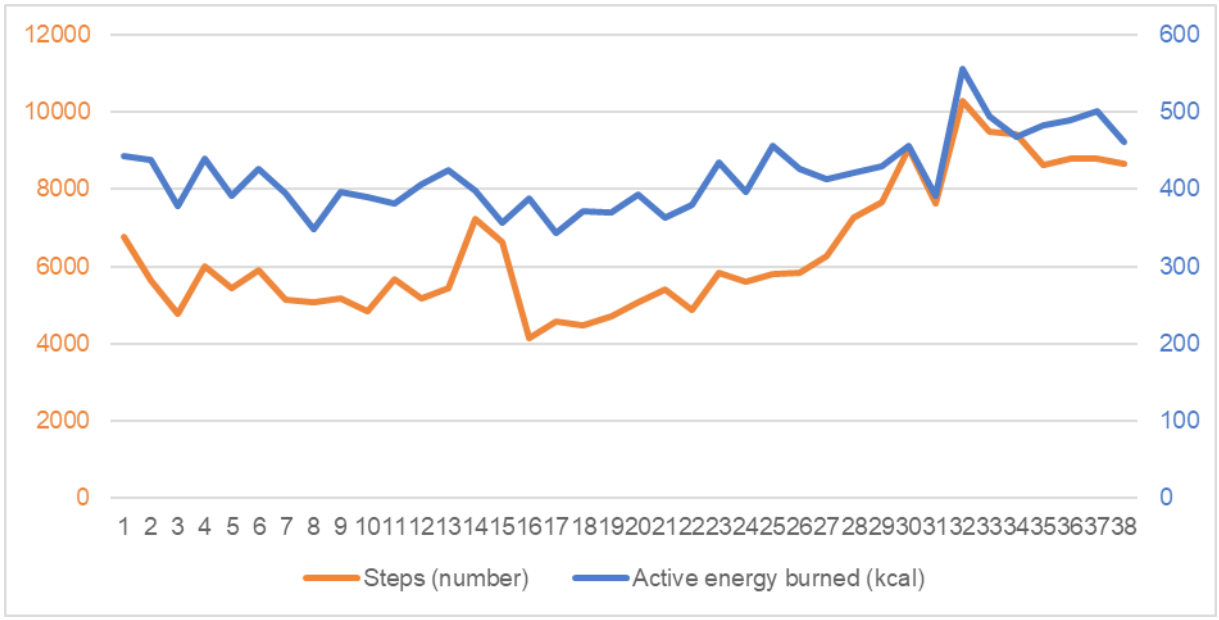

Figure 3. Step counts and active energy burned records

DISCUSSION

The subject of this case study was a pregnant woman who did HIFT. It was possible to monitor 38 weeks during which heart activity and physical activity parameters were monitored. The woman completed 3-4 training sessions per week in which she achieved high HR values above 80 % of

absolute HRmax. This regime did not affect fatigue monitored by HRV SDNN. Higher physical activity than recommended should not have any detrimental effects on childbirth or the fetus.
The typical features of HIFT are high intensity which was confirmed by the attained HRmax values. During some workouts, the woman's HR attained more than 185 bpm which is about 95 % absolute HRmax. During pregnancy, the average HR was 172,7 ± 15,3 bpm which means 85 % of the absolute maximum. This means that high values were detected and exceeded the given recommendation for pregnant women (Santos-Rocha et al., 2019; Tinloy et al., 2014). It is important that the woman was not instructed to reach this intensity necessarily, but to remain in a mode that would make her feel "comfortable". It seems that female athletes who are adapted to very intense training can continue in such a regime without adverse for both mother and fetus (Weaving, 2020).

Professional female athletes or physically very active women cannot be considered as a normal sample to which we could fully apply recommendation for physical activity in pregnancy. These women are able to achieve large training volumes and high physiological values. Such a regime is perceived positively, and it is not regarded as a risk (Clapp, 1990; Kardel, 2005; Sigurdardottir et al., 2019).

Strength training recommendation is limited to the use of therabands or dumbbells up to 10 kg (Anderson et al., 2021; Liddle & Pennick, 2015; Santos-Rocha et al., 2019). For female strength athletes, this represents rather warm-up activity, and they tend to exercise with a heavier load. Even in the third trimester, the woman practiced Olympic weightlifting and powerlifting with a barbell of 40-60 kg. There might be certain concerns about increased intraabdominal pressure which could represent a risk for the fetus (Cai et al., 2020). It has not been proved yet that there is a clear connection between weight training and a higher risk for the fetus. It is important to emphasize the fact that intraabdominal pressure during lifting reaches lower numbers than while for example running, and jumping and it can be compared to fast walking (Dietze-Hermosa et al., 2020; Gephart et al., 2018).

As shown in Figure 1, resting HR increased gradually which can be seen as standard. Resting HR tends to increase by about 16 bpm tends (Melzer et al., 2010). SDNN showed the opposite tendency. Although average values were normal during the whole pregnancy, a gradual decrease was observed. This trend is nothing unusual and it points to the fact that a growing fetus weakens a female body, and it is necessary to anticipate more time for regeneration or a resting period. The woman had higher SDNN values compared to other pregnant and non-pregnant women (Gandhi et al., 2014; Garg et al., 2020). It is obvious that the woman was used and adapted to HIFT and therefore, there was no significant decrease in SDNN.

There is more evidence that in healthy and physically active women, high-impact or high-intensity activities do not have any negative effect on pregnancy or childbirth (Barakat et al., 2008; Sigurdardottir et al., 2019). This is what this study proved as well (vaginal delivery without any complications, gestational age, Apgar score 10, normal fetal weight). It seems that the only typical consequence for women who are physically active while being pregnant, birthweight may be lower, but this is not considered harmful (Barakat et al., 2008; Kardel, 2005; Sigurdardottir et al., 2019).

In the third trimester of pregnancy, due to the current feelings of the woman, more training sessions were left out. The training sessions were replaced by other physical activities (walking,

gardening). The study has confirmed that the physical activity regime expressed as active energy burned depends on NEAT (non-exercise activity thermogenesis) (Chung et al., 2018). This conclusion resonates with the general view that high-intensity exercise is not a necessary condition for maintaining health during pregnancy and that measuring NEAT plays a significant role for pregnant women as well.

It has been confirmed that women practicing HIFT have a strong attachment to this activity and do not give it up while pregnant (Prewitt-White et al., 2018). Women need to maintain important elements of their lifestyle as it relates to their overall health and well-being. Nevertheless, it is necessary to consult a doctor and follow his / her recommendations for all procedures and exercises.

The conclusion of the paper must be taken with a grain of salt given the fact that this is a case study and, at the same time, the first monitoring of high-level HIFT in pregnancy. Another limiting factor is the history of the woman, she had many years of experience with HIFT. Therefore, movements like Olympic weightlifting, dynamic gymnastics exercises, etc. cannot be unequivocally recommended as safe. There are other significant factors (social, psychological, etc.) affecting pregnancy that this research did not consider. Even though there are strong indications that could draw certain conclusions, further research, following larger samples, or focusing on the fetus (fetal HR, fetal HRV, Doppler changes, etc.).

CONCLUSION

A significant number of women do HIFT and do not want to give it up while pregnant. HIFT is a young sports discipline, for which no effect on pregnant women has been observed. The present case study aimed to give a picture of the effect of HIFT on a pregnant woman. Her workout plan included Olympic weightlifting, gymnastics, running, etc., while the effort was set on "hard to very hard". The woman achieved cardiac activity at the level of 80-95% HRmax. This regime did not have any negative effects on HVR SDNN. Pregnancy and delivery were without complications as well. Taking the limitation of the research into account, HIFT can be set up appropriately as a safe activity without any adverse effects.

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Characteristics of the Menstrual Cycle According to the Sports Groups of the New Generation of Female Athletes

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ABSTRACT

PURPOSE To examine the characteristics of menstrual cycles in female athletes in different sports, comparison of possible deviations and changes associated with new generations of female athletes in training processes. METHODS The research included a total of 143 respondents (average age 17.46 ± 2.61; average training experience 8.67 ± 3.85) who were divided into three groups: sports games (n = 59), martial arts (n = 16) and aesthetic sports (n = 68). An anonymous online survey specially prepared for the needs of this research was conducted among the respondents. Ten questions were selected from the questionnaire examining demographic, training and menstrual cycle characteristics. The results were processed in the IBM SPSS program, v.26. Comparisons by sports categories were made using the Chi-square test for categorical variables and Kruskal-Walis analysis of variance for ordinal variables. In the case of significant differences obtained by Kruskal - Wallis analysis, the Dunn-Bonferroni post hoc test was performed to determine between which groups there is a difference. A logistic regression analysis was performed to predict the regularity of the menstrual cycle using age, length and duration of training and sport category. RESULTS The groups of sports do not differ from each other with regard to cycle regularity ($p = 0.088$). There are no differences between sports groups ($p = 0.935$) in cycle changes. There is also no difference in duration ($p = 0.883$) and abundance of bleeding ($p = 0.700$). CONCLUSION The examined characteristics of the menstrual cycle of the new generation of female athletes according to the sports groups in this research did not show significant changes except in martial arts (43.8 %). Although there is a common difference in the training duration of individual sports groups, future research and monitoring of the menstrual cycle in female athletes should be further reduced according to the possible effects on the reproductive and general health of female athletes.

Keywords: menstrual cycle, sport, women

INTRODUCTION

Monitoring the reproductive and general health of female athletes in sports through the menstrual cycle is an indicator of the modernity of training processes and a significant factor in achieving the desired sports results, especially during competitions. For women in sports, special attention should be paid to the menstrual cycle.

This research puts in focus the new, young, generation of female athletes as the majority of participants are younger than twenty and are not in the senior category of their sport.

Research has shown different effects of physical efforts in female athletes and women in sports in general (Nose et al, 2020; De Souza, 1990; Mhenni et al, 2017). The risk for the occurrence of disorders does not only refer to disorders of the menstrual cycle and the impact on the reproductive health of female athletes, but also to disorders of other systems (Roeder, 2021; Ellegård et al, 2007). Monitoring the menstrual cycle in female athletes affects the health of female athletes in general. The change in hormone levels during the menstrual cycle consequently affects the ability of female athletes. In the analyzes of competition strategies and training processes, the results of the same are related to the performances of female athletes in relation to the influence of menstrual phases on physiological performance components such as muscle strength, endurance and strength. The training process should be adapted to the cycle so that female athletes are ready for major competitions (Carmichael et al, 2021). During periods of intense competition, possible causes of menstrual cycle disturbances include excessive exercise or overtraining that causes an increase in muscle mass relative to fat tissue, which can cause menstruation to be absent (Dušek, 2001).

Recommendations and alignment of the menstrual cycle with the training or competition calendar show that aerobic training and strength training should be reduced during the late luteal phase of the cycle, while anaerobic performance should most often be reduced in the late follicular phase of the cycle. The late luteal phase of the cycle was also one of the phases in which the athletes themselves noticed that their strength decreased. Research (Janse de Jonge, 2003) that reveals that the menstrual cycle has a mediating role in physical performance shows that the phases affect strength, aerobic and anaerobic performance differently. When training is modified based on all phases of the menstrual cycle, the predominant performance variable used and training goals must be carefully considered (Janse de Jonge, 2003). According to the studies, some perceptual responses are affected during different phases of the menstrual cycle, but different methodological approaches and the variability of the phases assessed in different studies limit generalization and prevent precise conclusions to be made (Paludo et al., 2022).

Although there are few research on the menstrual cycle in women in sports, this research shows that monitoring the menstrual cycle would represent an important management tool in harmonizing training processes and competition calendars. But that, unfortunately, is not practical because right now, there is not enough evidence and studies that could justify the resources and money needed for monitoring the menstrual cycle for training periodization (Julian & Sargent, 2020).

In general, the concept of the menstrual cycle is not updated due to socially accepted attitudes and norms that were often associated with prejudices. However, opening the issue of women in sports and monitoring the impact of sports on the reproductive health of women in sports has

changed attitudes and acceptance. Discussions and analyzes in the research sense contributed to the acceptance of the physiological process of the menstrual cycle discount in the public, which indicated the possibility of accepting different views (Roberts & Garling, 1981). Prejudices about the non-significance of the menstrual cycle in the contribution of different performance improvements in the performance of female athletes were slowly abandoned.

The aim of this research was to examine the characteristics of menstrual cycles in female athletes in different sports, a comparison of possible deviations and changes associated with new generations of female athletes in training processes.

METHODS

Participants

The research included a total of 143 respondents who were divided into three groups: sports games (n = 59), martial arts (n = 16) and aesthetic sports (n=68). The group of sports included subjects from the following sports: athletics, running, volleyball, cycling, swimming, handball, football, basketball. In the group of martial sports: karate, taekwondo, wrestling and judo and in the group of aesthetic sports: gymnastics, dance and synchronized swimming. The participants were recruited online from the sport clubs in Zagreb, Croatia, except in the group of synchronized swimmers where 7 participants are from club in Rijeka, Croatia. The recruitment was from November, 2021. until March 2022. The inclusion criterion was that the participants were at least 12 years old and actively engaged in sports, and the exclusion criterion was that they did not have menstruation. The study has ethical approval (Ethical Commission "Medveščak" Synchronized Swimming Club; 01-2/2022-11) and all the participants were explained what is the study about and asked whether they want to participate.

Procedures

An anonymous survey was conducted among the respondents to collect information, which consisted of 27 questions, of which 10 questions were selected from the survey and processed for the purposes of this research. Selected questions collected demographic information about respondents (age, height and weight), their training characteristics (sport discipline, years of training experience, frequency of training and duration of single training) and charactestics of their menstrual cycle (having a regular cycle of 28 days, noticing any changes in the menstrual cycle, duration of bleeding in days and abundance of bleeding). Sport discipline, age, height, weight and years of training experience were open questions, frequency of training, duration of single training, duration of bleeding and abundance of bleeding were multiple choices questions and having a regular cycle and noticing changes in the cycle were yes/no questions. The survey was conducted anonymously with the consent of the respondents for the processing of research data.

Statistical analysis

The results were processed in the IBM SPSS program, v.26. Comparisons by sports categories were made using the Chi-square test for categorical variables (cycle regularity, changes in the cycle, sports group) and the Kruskal-Walis analysis of variance for ordinal variables (training frequency, duration of training, duration of bleeding, profuse bleeding). In the case of significant differences

obtained by Kruskal - Wallis analysis, a Dunn-Bonferroni post hoc test was performed to determine between which groups there is a difference. A logistic regression analysis was performed to predict the regularity of the menstrual cycle using age, length and duration of training and sport category. The significance level was set at $p < 0.05$.

RESULTS

Table 1 shows the values of the respondents in terms of age, height, weight and training experience depending on the group of sports they are training in and overall at the level of the entire sample.

Table 1. General characteristics of the respondents

	age (years)	**height (cm)**	**weight (kg)**	**training experience (years)**
sports games (n=59)	17.17 ± 2.26	172.66 ± 6.73	62.81 ± 7.27	8.55 ± 2.84
martial arts (n=16)	18.20 ± 1.15	168.19 ± 7.30	63.63 ± 8.89	7.58 ± 4.41
aesthetic sports (n=68)	16.78 ± 2.80	167.78 ± 7.24	58.02 ± 8.19	9.50 ± 3.39
total (n=143)	17.46 ± 2.61	169.46 ± 7.31	60.80 ± 8.75	8.67 ± 3.85

Table 2. Frequency and duration of training

	training frequency (x per week)				**training duration (hours)**		
	3–4	**4–5**	**5–6**	**> 7**	**< 2**	**2–3**	**> 3**
sports games	13.6%	18.6%	20.3 %**	47.5%	33.9 %	64.4 %**	1.7 %
average rank	76.79				64.51		
martial arts	25.0 %	12.5%	18.8 %**	43.8 %	81.3 %**	18.8%	0.0 %
average rank	70.72				32.38		
aesthetic sports	20.6 %	13.2 %	32.4 %**	33.8 %	8.8 %	76.5 %**	14.7 %
average rank	68.15				87.82		
H	1.54				37.62		
p	0.464				0.000		

** the category in which the median score is located

Table 2 shows that the frequency of training is the same for all three groups of sports, while martial arts have slightly shorter training sessions. The significance of these differences was confirmed by the Kruskal-Wallis test. The Bonferroni test showed that all three groups differ significantly in terms of training duration: martial sports have shorter training sessions than the sports game group training ($p = 0.003$) and aesthetic sports training ($p = 0.000$). Aesthetic sports have longer training sessions than sports games ($p = 0.000$).

It was checked whether female athletes differ in the regularity of the menstrual cycle and the perception of changes in it, according to their sports disciplines (Table 3) and the characteristics of the menstrual cycle (Table 4).

Table 3. Characteristics of the menstrual cycle with regard to the sport group

	cycle regularity		**changes in the cycle**	
	YES	NO	YES	NO
sports games	48 (81.4 %)	11 (18.6 %)	17 (28.8 %)	42 (71.2 %)
martial arts	9 (56.3 %)	7 (43.8 %)	4 (25.0 %)	12 (75.0 %)
aesthetic sports	47 (69.1 %)	21 (30.9 %)	18 (26.5 %)	50 (73.5 %)
X2 (p)	4.851 (0.088)		0.134 (0.935)	

Table 4 Differences in menstrual bleeding characteristics

	Kruskal-Wallis analysis of variance – duration of bleeding		**Kruskal-Wallis analysis of variance – profuse bleeding**	
	median	average rank	M	average rank
sports games	2.00	73.58	3.27	75.05
martial arts	2.00	72.56	3.13	67.38
aesthetic sports	2.00	70.50	3.13	70.44
H (p)	0.25 (0.883)		0.71 (0.700)	

The groups of sports do not differ from each other with regard to cycle regularity ($p = 0.088$), although it can be inferred that the proportion of girls with irregular cycles is slightly higher in martial arts, but this difference is not statistically significant at the 5 % level. As for the existence of changes in the cycle, there are no differences between the sports groups ($p = 0.935$). There is also no difference in duration ($p = 0.883$) and abundance of bleeding ($p = 0.700$).

It was checked whether the regularity of the menstrual cycle can be predicted using age, sport group and the frequency and duration of training. Logistic regression showed that there are no significant predictors for predicting cycle regularity (Table 5).

Table 5 Prediction of menstrual cycle regularity with age, sport group, duration and frequency of training

	Wald	**df**	**p**
age	0.020	1	0.889
sports group	4.117	2	0.128
training frequency	3.308	3	0.347
training duration	1.386	2	0.500

DISCUSION

This study showed no difference between groups of sport in frequency in training (p = 0.464), menstrual cycle regularity (p = 0.088) nor changes in the cycle (p = 0.935). Also, groups do not differ significantly in duration (p = 0.883) or abundance of bleeding (p = 0.700). All three groups differ significantly in training duration (p = 0.000): aesthetic sports have longest trainings and martial sports have shortest trainings. Age, sport group and training frequency and duration cannot succesfully predict menstrual cycle regularity. Several components are important for the health of female athletes of reproductive age related to the menstrual cycle. It includes the analysis of training duration, regularity of the menstrual cycle, the existence of changes in the cycle, especially related to the duration and abundance, and possible predictions of the regularity of the cycle, which are important for the competition calendar and planning the preparation of athletes for important competitions, i.e. the achievement of target results.

The phases of the menstrual cycle carry several psychophysiological changes; however, studies investigating the impact of menstrual cycle phases on training load or technical training are rare. Cristina-Souza et al. (2019) investigated the effect of follicular phase , ovulatory phase and luteal phase on training load and technical training in young athletes. Twelve female athletes performed regular daily training sessions with the rating of perceived exertion and duration recorded for each training session. These findings suggest that menstrual cycle disturbances were elevated during follicular phase, indicating that monitoring menstrual cycle phases may provide important feedback for training programming and expected performance during competition (Cristina-Souza et al., 2019).

All three groups of sports in this research showed a significant difference in the duration of training, which is expected due to the characteristics of different sports, but the duration did not show a connection with changes in the menstrual cycle.

Future martial sports have shorter training sessions than those from the sports games group (p = 0.003) and from aesthetic sports training (p = 0.000). In this research, a change in the menstrual cycle was observed in the athletes from the martial sports group, although it was not statistically significant. For now, no such observation can be linked, so future research will need to show the possible impact.

It was checked whether the regularity of the menstrual cycle can be predicted using age, sport group and the frequency and duration of training. Logistic regression showed that there are no significant predictors for predicting cycle regularity. Certain studies (Oliveira et al., 2021) show the development of models for predicting the regularity of the menstrual cycle in female athletes, such as a hybrid predictive model, but it is more focused on predicting the length of the menstrual cycle (Oliveira et al., 2021).

Meignié et al. (2021) state that during the menstrual cycle among top female athletes, various parameters related to sports performance are affected, but the parameters themselves and the size and direction of the effects are not convincing.

Women participating in a wide range of competitive sports are at higher risk of developing eating disorders, menstrual irregularities and osteoporosis, which are generally referred to as the 'female athlete triad' (Quah et al., 2009).

According to previous studies, the prevalence of the female athlete triad is relatively low, but the prevalence for individual triad component may be high, especially in athletes practicing sports that require a lean physique (Quah et al., 2009). On a group of 67 elite Malaysian athletes, Quah et al. (2009) registered a prevalence of 47.6 % of subjects who were at risk of menstrual irregularity among lean athletes, and 14.3 % among non-lean athletes.

The identification of the existence of any of the triad components is crucial since all of them are unequivocally linked and may lead to an accumulation of dysfunctions with a possible higher risk of injury (especially fracture). This is especially important for women participating in sports that emphasize a lean physique and in weight-restricting sports such as gymnastics and competitive martial arts (Quah et al., 2009). The influence of such changes is probably also the reason for the higher irregularity of menstrual cycles was observed in martial arts (43.8 %) in this study.

The results of research in this area are contradictory, and each new study is a step towards a better understanding of the complexity of the relationship between sports activity and the regularity of the menstrual cycle. It is a multifactorial phenomenon in which factors related to the athlete's health as well as those linked to the training load plays an important role. There is also growing evidence for a link between female sex hormones and health, including a relationship between melatonin, menstrual dysfunction and breast cancer, but the mechanisms for and consequences of these relations are yet to be elucidated (Dawson & Reilly, 2009). Recently, Adam et al. (2022) suggested that there are not differences in rates or experiences of menstrual function and dysfunction based on competition level, sport type, or sport category. Based on an online survey, conducted on a sample of 63 female athletes, between 14 and 39 years of age, they also state that most athletes experience some form of menstrual dysfunction, for which they usually do not seek assistance. This highlights two possibilities: a) the existence of additional "unregistered" disturbances related to the menstrual cycle, both in this and in previous research, and b) the importance of creating an atmosphere for open communication in the sports environment.

CONCLUSIONS

The groups of sports do not different from each other regarding regularity and changes in the menstrual cycle, duration and abundance of bleeding. A slightly higher irregularity of menstrual cycles was observed in martial arts (43.8 %). The research showed that for now there are no significant predictors for predicting the regularity of menstrual cycles in female athletes, and further research should include tests of different training durations and possible effects on the reproductive health of female athletes.

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Longitudinal Assessment of Physical Fitness of Students from the University of Defence in the Czech Republic

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ABSTRACT

Objectives: Cardiorespiratory fitness demands are placed on students of all military schools. The bachelor's study programmes usually include subjects which requires the high level of physical fitness. The study aims to give a comprehensive account of the level of physical fitness of a selected military school.

Design: Comparing of results of the physical activity tests were used in this study.

Methods: The sample consisted of bachelor´s students of University of Defence between the academic year 2008/2009 and 2015/2016. Testing took place in the second year of each proband´s study, i.e. different students were tested each year. The total number of participated students in our study depends on academic year and number of tested students (men from 102 to 111; women from 76 to 84 through years). A male group (the sum of all male probands during the testing years) (mean ± SD: 19.91 ± 0.29 years, 182.8 ± 7.2 cm, 82.9 ± 10.9 kg) performed all physical activity tests (12 min running, push-ups, sit-ups, pull-up on the crossbar, running the 100 m and throwing a hand grenade). A women group (the sum of all female probands during the testing years) (mean ± SD: 19.36 ± 1.23 years, 171.8 ± 7.2 cm, 66.9 ± 8.7 kg) performed physical activity tests (12 min running, sit-ups, running the 100 m and throwing a hand grenade).

Results: It has been found that study programme which includes physical activity subjects (> 7 hours per week) is highly effective because we did not observe statistical significance decrease of values in selected physical tests.

Conclusions: Summing up the results, it can be concluded good physical readiness and preparation for military duty in students of University of Defence in Czech Republic.

Keywords: Aerobic Exercise, Cardiorespiratory fitness, Exercise Testing, Physical Activity, Military Education

INTRODUCTION

It is broadly accepted that soldiers require a high level of overall physical fitness, to be able to complete demanding tasks both near and on the battlefield. The tasks such as carrying heavy backpacks on a long distance place a great demand on endurance capacity, in contrast short and more intensive activities such as sprints on the battlefield and traversing obstacles require a high level of speed, strength and agility. The manner in which soldiers perform those tasks may affect their effectiveness and survivability on the battlefield. Thus, there should be considerable focus on developing the most effective training program to prepare soldiers for action (Harman et al., 2008). Endurance, strength, mobility and flexibility are considered as key measurable fitness components for soldiers (Heinrich, Spencer, Fehl, & Carlos Poston, 2012).

Low physical fitness level is associated with increased prevalence of musculoskeletal injury among military recruits (Molloy, Feltwell, Scott, & Niebuhr, 2012). Musculoskeletal injury can be a burden for a military healthcare system and may result in decreased productivity of military recruits. Training related musculoskeletal injuries are the major reason for disability, long-term rehabilitation, functional impairment and early release from military service (Hua, Chen, Wan, Lu, & Xiong, 2018).

Not only fitness level, but even low BMI can be a risk factor for musculoskeletal injury. Low BMI could be an indicator of a lesser amount of muscle mass or bone mass, and underweight recruits may struggle with tasks requiring a high amount of strength (e.g. load bearing) (Blacker, Wilkinson, Bilzon, & Rayson, 2008). On the other hand, a high BMI index can be a result of accumulation of excess body fat. According to World health Organization (WHO) data from 2016, 39 % (1,9 billion) of adults aged 18 years and over were overweight and 13 % (650 million) obese (World Health Organization, 2020).

Obesity is also a growing concern in the military, survey estimates from 2015 have shown that 65.7 % of US military personnel are currently classified as overweight or obese (Meadows et al., 2018). The authors Omar, Leong, & Moy (2020) provided us with a systematic review in which they discussed the trend and prevalence of obesity among the military population in different states. The general trend between the analyzed studies was the increased prevalence of people who were overweight (30 %–50 %) and obese (2 %–30 %). Among males, the Czech Army had the highest prevalence of overweight with 57.1 % (in 2009); alternatively, the Greek Army recorded the lowest prevalence of overweight 26.6 % (in 1998), in the case of female there tended to be a lower prevalence of overweight with a maximum of 41 % in US Army and a minimum of 11,1 % in UK and Germany Army. The prevalence of obesity was recorded to be highest (18,9 %) in active duty personnel in the US in 2009, while the lowest prevalence of obesity (4,9 %) was observed in the Royal Thai Army in 2004 (Omar et al., 2020).

Although it is important to notice that BMI as a screening measure has a low specificity to distinguish between fat free mass and fat mass, hence a muscular person can be classified as overweight in spite of carrying a low amount of fat mass. This limitation of BMI measurement could be partly reversed by a concurrent measurement of a waist and hip circumference, those could be more accurate measurements of adiposity (Shams-White, Chui, Deuster, McKeown, & Must, 2020).

There are many approaches in testing overall fitness of military recruits, for example Leyk, Rohde, Gorges, Rüther, & Witzki (2017) in their study conducted on German military soldiers used The basic fitness test which measures parameters from three dimensions – endurance (1000m run), speed/ agility (110m shuttle run) and upper body strength (flexed arm hang in chin-up position). Another research team (Santtila, Pihlainen, Koski, & Kyröläinen, 2017) collected data from Finnish male conscripts and female recruits during the first week of their military service during 1975–2015. Measured data included for example mean body mass, aerobic capacity, mean distance of 12-minute running test and the standing long jump test (Santtila et al., 2017).

K. R. Kelly & J. T. Jameson conducted research with a goal to develop a physical performance and body composition profile of female active-duty marines (Kelly & Jameson, 2016). For this purpose, authors of the study used tasks including for example lifting a machine gun from the ground to overhead, pull ups, clean and press, crunches, 4,8 km (3 mile) run. Body composition was assessed by height and weight measurement, BMI, percent body fat and fat free mass was calculated for each individual (Kelly & Jameson, 2016).

Performance in the military fitness test or in the combat fitness test can be affected by many variables, for example cardiovascular warm-ups, dynamic stretching and dynamic warm-ups have positive outcomes for performance in chosen exercise tests, when static stretching was reported to have no beneficial or detrimental effect on performance (Zeno et al., 2013).

Armies of different states use various fitness tests as a part of recruiting new army members. For example, British Army new fitness test consists of the 2km run (after 800m warm-up), the 4kg medicine ball throw from seated position and the mid-thigh pull ('Home - British Army Jobs', n.d.). The new physical fitness standards for British army are now called "Physical Employment Standards", are role-related and no longer gender or age specific. Physical fitness assessment in British Army is now known as "Soldier conditioning review" and includes these tests – horizontal jump, med ball throw, deadlift, shuttle sprints, pull-ups and 2 km run (Coupe, 2019). IN 2020 US Army replaced Army physical fitness test with new standards of Army Combat Fitness. The test consists of six events that assess the ability to perform physical tasks army members may encounter during combat – strength deadlift, standing power throw, hand-release push ups, sprint/drag/carry, leg tuck, two-mile run. The minimum requirements for the above-mentioned tests vary by job or unit (Militaryonesource, 2020).

The New Zealand Defence Force is assessing fitness standards of their members once or twice per year, the Service fitness test differ between the Navy, Army and Air force and include Multi-Stage Fitness Test (beep test), simulated body drag, equipment carry and swim test (NAVY); 2,4 km run, press ups, curl ups (ARMY); 5 km weighted march, push-ups (AIR FORCE) (New Zealand Defence Force, 2020).

Spanish Army reviewed the Annual Fitness Test in 2009, and it resulted in a new evaluation system with four obligatory events. The event consists of two strength tests (sit-ups, push-ups), one endurance test (6 km run) and speed-agility test including zigzag circuit among cones ('Boletín Tierra' Newspaper Reports, 2012).

The German Army assesses the physical fitness of their soldiers through Basis Fitness Test. The test components are 11 × 10 m sprint, pull-up hang (chin over the bar in pull up position), 1 km run (Bundeswehr, 2020).

The main aim of the study was to assess physical fitness of students from University of Defence.

METHODS

Participants

The sample consisted bachelor´s students of University of Defence. The total number of participated students in our study depends of academic year and number of tested students (men from 102 to 111; women from 76 to 84). Different group of students was tested during each year. A male group (mean ± SD: 19.91 ± 0.29 years, 182.8 ± 7.2 cm, 82.9 ± 10.9 kg) performed all physical activity tests (12 min running, push-ups, sit-ups, pull-up on the crossbar, running the 100 m and throwing a hand grenade). Due to a physiological differences between the genders a women group (mean ± SD: 19.36 ± 1.23 years, 171.8 ± 7.2 cm, 66.9 ± 8.7 kg) performed physical activity tests (12 min running, sit-ups, running the 100 m and throwing a hand grenade).

Physical Activity Assessment

The physical fitness test was explained to all participants, and they were asked to sign a written informed consent. The study was approved by ethics committee University of Defence. All participants were included to the study if they have preparticipation examination proved by the sports medicine physician (necessary condition for studying at University of Defence and Faculty of Sport Study). Field tests were used to assess the physical fitness. Tests were conducted during autumn semester, on the same athletic stadium.

A. 12 min running

Each participant was asked for run as far as possible within 12 minutes. Test was conducted on 400 m athletic track with clearly marked distance. The distance of the participants was covered to the nearest 10 meters.

B. Push-Ups

Assessing of the upper body fitness was recorded via push-up test. The researcher instructed each participant about the content of the test. The initial position was set up and controlled by researcher (push-up position with fully extended elbow and knees off the ground). Subsequently, the participant was asked to go to 90° elbows flexed position with maintaining a straight trunk position. The total number of correct push-ups in one minute was recorded.

C. Sit-Ups

Assessing of the muscle endurance of the abdominal muscle via one-minute sit-ups test body. The starting position was precisely controlled by the researcher. The test started from sitting position with bent knees, the feet must be on the floor and the upper extremity crossed the chest. Subsequently, the test started from up position and the participant went to the position when the shoulder blades touched the floor. The total number of sit- ups in one minute was recorded.

D. Pull-up On The Crossbar

Assessing of the upper body fitness was recorded via pull-up on the crossbar test. The initial position was precisely controlled by the researcher. The researcher decided to use the wide technique. Subsequently, the participant grabs the bar with palms anteriorly and hands were on the lateral side of the bar. The participant´s arms were fully extended at the beginning of the test. Then, then

the participants started pulling upward to bring his chin over the bar. After this, he/she was going to the initial position of the test while maintaining full-body tension. The participant was asked to go to 90° elbows flexed position with maintaining a straight trunk position. The total number of correct pull-ups on the crossbar was recorded.

E. Running the 100m

The automatic timing system, dual-beamed photocells and laser guns were used to measure the exact time of a 100m performance. The testing took place on the athletic stadium. Each participant sets up the starting blocks according his/her preference. Also, the angle of the block pedals was set up according by each preference of the participant. Participants were instructed to run as fast as possible. The run started on the ….mark (doplnit)

F. Throwing a hand grenade

The distance of the test was covered to the nearest 5 cm. Each participant was asked to throw a hand grenade as far as possible from the standing position. The weight of the hand grenade was 283.49 grams. The longest attempt was recorded (each participant had three attempts).

Statistical Analysis

All analyses were conducted using version 12 of the STATISTICA software package (Statsoft Inc, Tulsa, Oklahoma, USA). Descriptive data are summarized as mean ± standard deviation (SD). A comparison between groups in the selected academic years were analyzed. Statistical significance was set at $p \leq 0.05$, and all data are expressed as mean ± SD. Analysis of variance were used to prove the statistical significance between the different student groups in individual years.

RESULTS

The overall measurement results are summarized in Table I and II

Table1. The average values of physical fitness in years in group of men bachelor studies

Academic year	12 min Running (m)	Push-Ups (n)	Sit-Ups (n)	Pull-up On The Crossbar (n)	Running the 100m (seconds)	Throwing a hand grenade (m)
2008–2009 (n = 102)	2841.54 ± 176,88	33.41 ± 4.36	53.94 ± 6.19	10.93 ± 2.87	13.98 ± 1.17	45.34 ± 7.24
2009–2010 (n = 108)	2822.83 ± 297.97	32.95 ± 4.34	54.17 ± 5.86	11.95 ± 4.18	14.17 ± 1.03	48.51 ± 5.45
2010–2011 (n= 108)	2839.50 ± 189.65	33.59 ± 4.51	55.25 ± 5.58	12.42 ± 4.28	14.10 ± 1.11	46.43 ± 4.45
2011–2012 (n= 107)	2836.56 ± 193.43	33.93 ± 3.67	55.87 ± 4.99	11.92 ± 3.42	13.87 ± 1.24	47.15 ± 4.01
2012–2013 (n= 104)	2810.37 ± 154.68	35.57 ± 5.28	55.77 ± 5.58	12.77 ± 3.64	13.73 ± 1.10	45.32 ± 5.09

2013–2014 (n= 111)	2853.29 ± 187.19	33.39 ± 4.62	54.85 ± 4.92	11.25 ± 3.59	13.56 ± 1.02	46.41 ± 5.11
2014–2015 (n= 109)	2854.35 ± 183.05	33.08 ± 4.65	55.14 ± 4.95	13.14 ± 3.91	13.51 ± 1.09	47.12 ± 4.99
2015–2016 (n= 108)	2878.20 ± 166. 12	32.44 ± 3.90	55.25 ± 5.09	12.54 ± 2.11	13.59 ± 1.07	47.48 ± 5.03
p-value	NS (0.1633)	**0.0004***	**0.0404***	**0.0010***	**0.0116***	NS (0.1255)

*p < 0.05; NS: not statistically significant

Table 2. The average values of physical fitness in years in group of women´s bachelor studies

Academic year	12 min Running (m)	Sit-Ups (n)	Running the 100m (seconds)	Throwing a hand grenade (m)
2008–2009 (n = 84)	2426.90 ± 156.49	52.20 ± 5.36	16.01 ± 1.02	29.30 ± 6.55
2009–2010 (n = 83)	2462.47 ± 180.69	52.19 ± 5.35	16.22 ± 1.13	29.03 ± 7.21
2010–2011 (n = 78)	2448.14 ± 178.94	52.07 ± 3.95	16.04 ± 1.06	29.70 ± 4.45
2011–2012 (n = 75)	2522.00 ± 190.66	53.77 ± 2.63	16.18 ± 1.24	29.71 ± 5.92
2012–2013 (n = 76)	2533.19 ± 156.08	51.23 ± 3.87	16.13 ± 1.21	28.59 ± 6.17
2013–2014 (n = 76)	2414.06 ± 118.76	53.72 ± 6.06	16.38 ± 0.54	27.43 ± 5.11
2014–2015 (n = 78)	2502.63 ± 149.10	48.20 ± 4.31	16.12 ± 0.82	28.12 ± 5.69
2015–2016 (n = 81)	2515.54 ± 190.44	54.66 ± 5.03	15.74 ± 0.72	27.56 ± 5.13
p-value	**0.0466***	NS (0.4123)	**0.0116***	NS (0.8405)

*p < 0.05; NS: not statistically significant

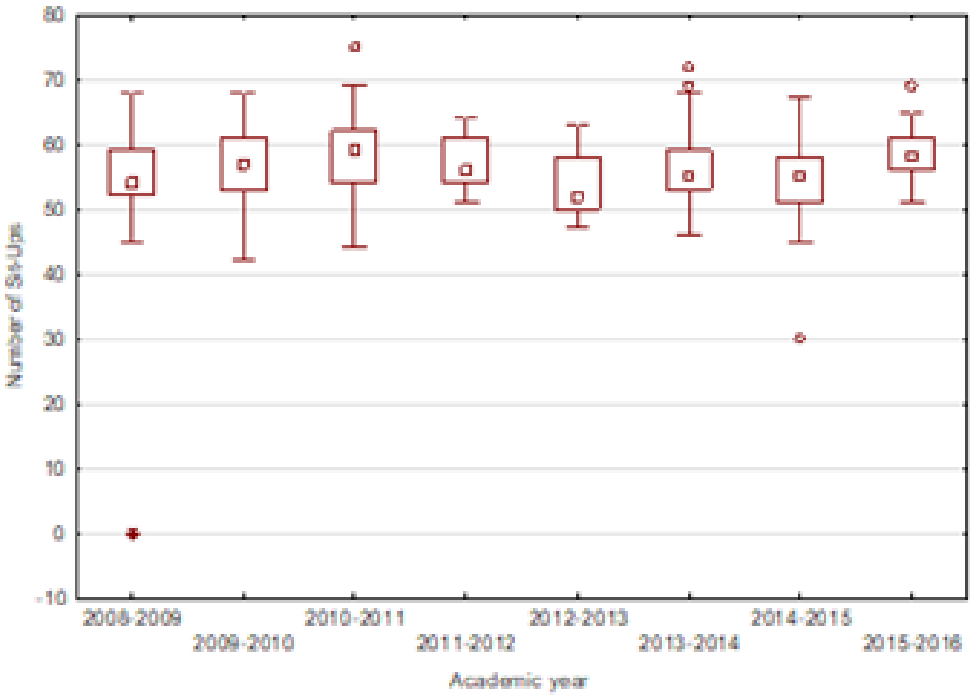

Figure 1 The values of Sit-Ups in years in group of men bachelor studies

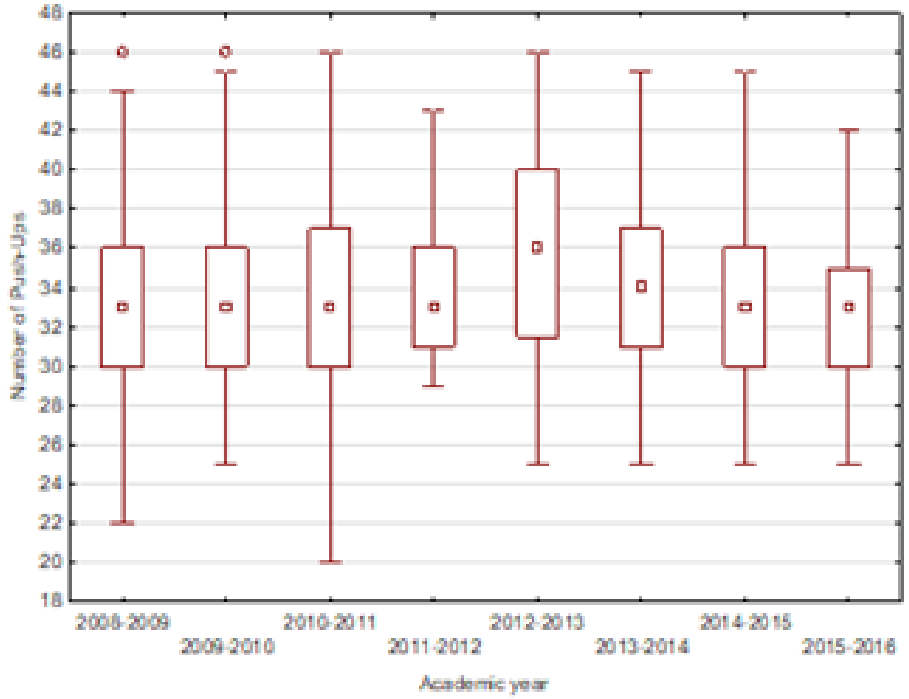

Figure 2 The values of Push-Ups in years in group of men bachelor studies

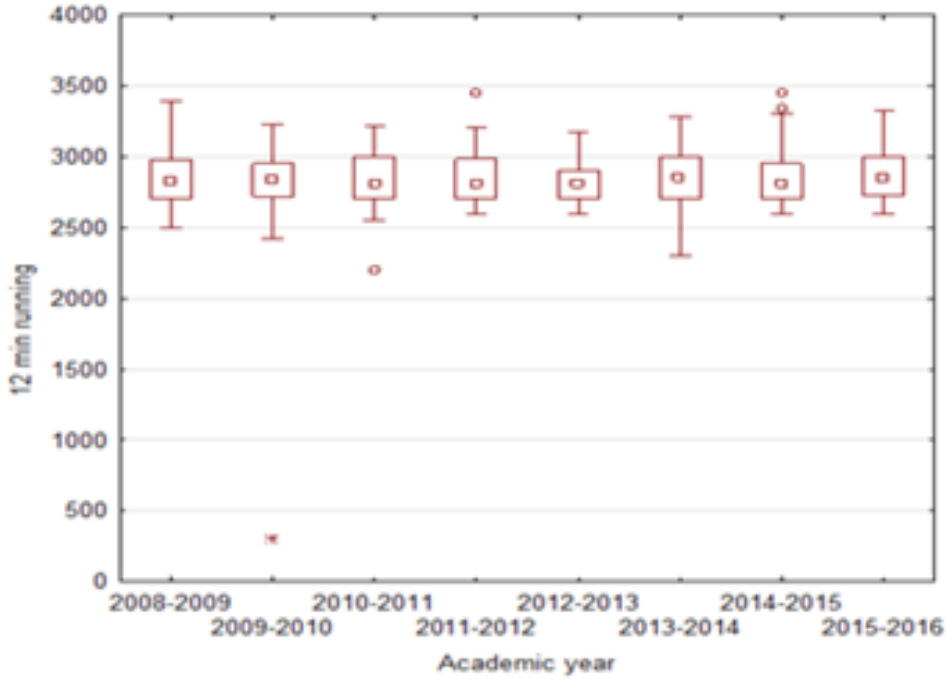

Figure 3 The values of 12 min running in years in group of men bachelor studies

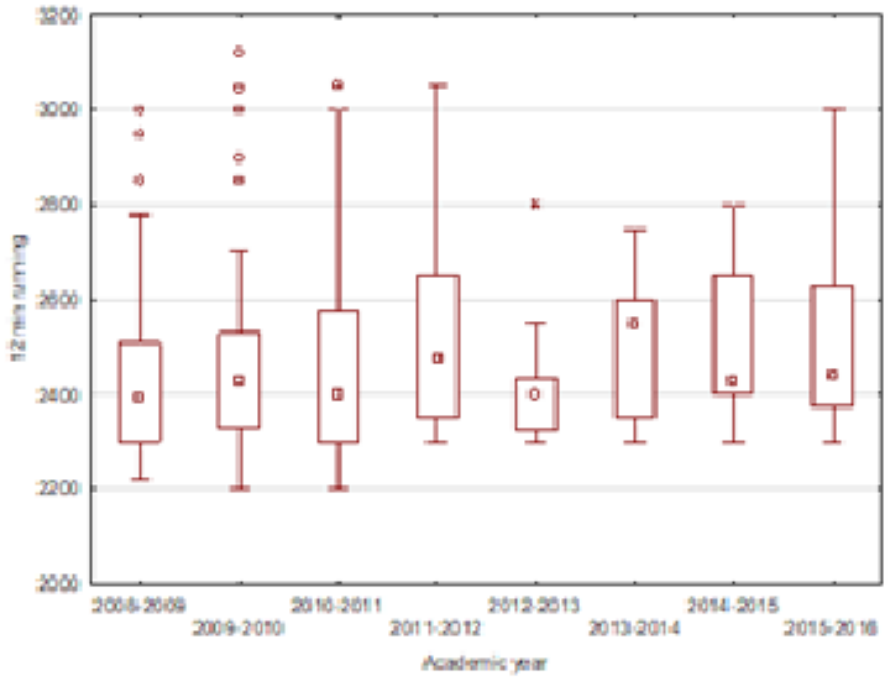

Figure 4 The values of 12 min running in years in group of women bachelor studies

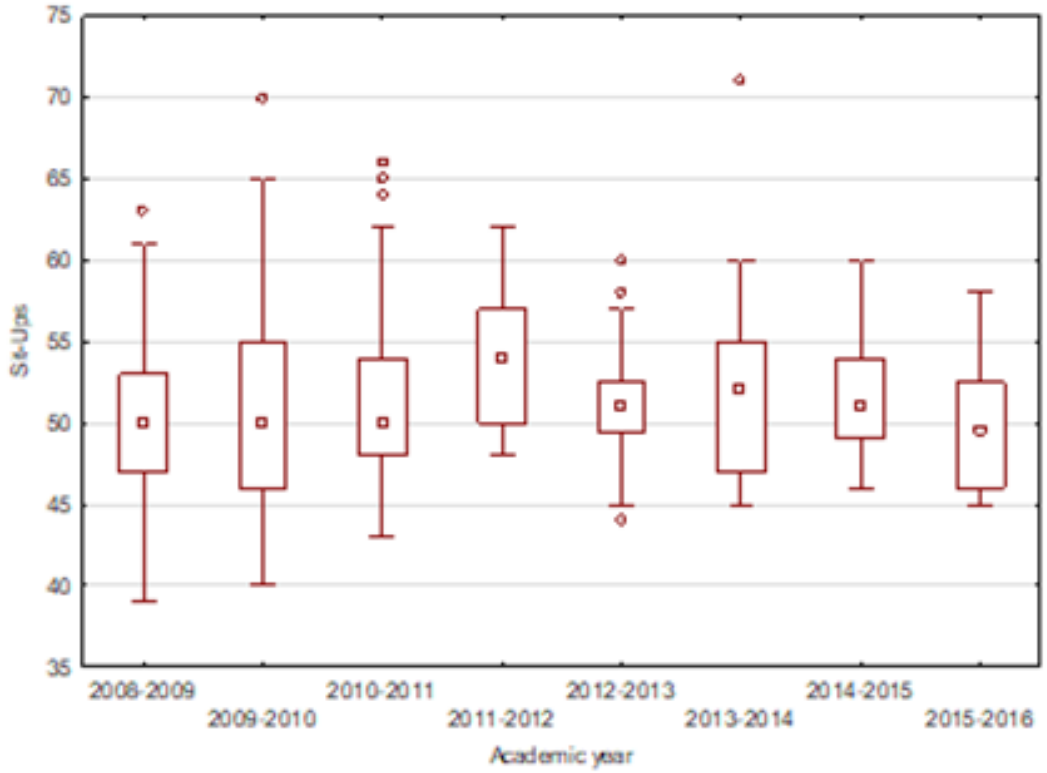

Figure 5 The values of sit-ups in group of women bachelor studies

DISCUSSION

The purpose of this study was to assess the physical fitness of a student from the University of Defence. Table 1. and Table 2. present mean results from chosen fitness test every student at University of Defence must undergo during the study. Low physical fitness often accompanied by obesity is a growing problem worldwide (WHO, 2020a). Furthermore, the WHO reported that 1 in 3 women and 1 in 4 men exercise not do enough physical activity to stay healthy (WHO, 2020b). Ultimately, these changes pose challenges for the army force to recruit physically capable soldiers (Kyröläinen, Pihlainen, Vaara, Ojanen & Santtila, 2018). In the literature there exists a general trend of lack of physical fitness as seen in other (eg, long jump from spot, 100m run, 12-minute running test) (Fotynyuk, 2017; Santtila et al., 2017). Although some studies do not fully support this (for example, trend in increasing muscle strength among US recruits between 1975–2013) (Knapik, Sharp, & Steelman, 2017).

The population of students at the University of Defence consists of both men and women. Tables 1 and Table 2 represent the average values of physical fitness of male and female students in bachelor´s studies throughout the years 2008-2016. In men, as well as in women, there is not present trend in declining level of physical fitness.

Therefore, the results of our study are not in agreement with general findings on reducing physical fitness. In contrast, there could be a trend in an increasing physical fitness in students from the

University of Defence between 2008-2016. However, there is a fluctuation in results in individual disciplines, which makes it difficult to clearly interpret the conclusion (Figure 1 -to Figure 5). The percentage changes in the distance covered in 12-minute run test between years 2008-2009 vs 2012–2013 and 2012–2013 vs 2015–2016 are –1,10 %, + 2,36 % and +4,2 %, -0,72 % for men and women, respectively. In case of number of sit-ups, the % changes between above mentioned years are +3,39%, -0,90% and –1,89%, +6,70% for men and women respectively. Performance changes in 100m run between the previously mentioned years were +1,82 %, +1,12 % and –0,74 %, +2,48% for men and women respectively.

When comparing 8-year average results from men and women, men generally performed better in disciplines common to both sexes. These results are not surprising as sex has been identified as a major determinant of athletic performance through the impact of many aspects (e.g. height, muscle mass, hormonal milieu, genetic difference) (Thibault et al., 2010). Although, as seen in the case of sit ups, the gap between performance of different genders can be minimal (8-year average number of sit up 55,03 and 52,26 for men and women, respectively.

In case of general weakening of physical performance, for example, Santilla et al. (2017) reported a decrease in aerobic capacity in male conscripts by 12.2 % from 1980 to 2015, our assessment of aerobic fitness, which was a 12-minute run, did not point to the same trend of decreasing aerobic capacity (Figure 3 and Figure 4 for men and women, respectively). It is necessary to mention that our analysis depicts the situation through 8 years, it is possible that because of analysing shorter time period there was no direct decrease in performance as mentioned in the work of the authors Santtila et al. (2017). Pihlainen et al. (2020) conducted the research with a goal to find out how 6–12 months (average time of the military service was 36 weeks) of military service influences the baseline fitness characteristics. For example, baseline 12- min run mean distance covered was 2461 m, after the end of the service this mean covered distance increased by 107 m. When compared to mean distance covered by students in our analyses (8 years average 2848,38 m), these numbers are still lower, indicating that aerobic capacity of students from University of Defence is slightly better, it must be mentioned that Pihlainen et al. (2020) analysed much bigger sample of participants (218 810 vs. 631 in our study). In terms of average population results in 12-min run test (also known as Cooper test) there exist many tables to help interpret the results. The original table pairing performance with fitness level in Cooper´s paper describes that covering distance of 1,75 miles (2,82 Km) or more is characterised as excellent fitness level (Cooper, 1968). It could be concluded from our results that through 8 years every year mean distance covered points to excellent average fitness level of participants from our study.

In case of sit-ups and push-ups both with time limit of 1 minute, conscripts after their military service improved mean number of repetitions to 40,8 (± 8,4) and 37 (± 10) for sit-ups and push-ups respectively (Pihlainen et al., 2020). If we compare these number of repetitions with numbers from our participants (mean 8 years average 33,54 push-ups, 55,03 sit-ups), the mean number of repetitions in push-ups is slightly higher and mean number of repetitions in sit-ups is perceptibly lower. Sit-ups and push-ups were used concomitantly with other measurements in study conducted by Dawes et al. (2017) on state troopers. Authors collected data as part of the agency's normal yearly fitness assessment. The mean numbers of repetition obtained by male officers in push-ups

and sit-ups test were 39.09 (± 15.61) and 34.46 (± 10.29) respectively, which implies that male officers performed better in push-ups and worse in sit-ups test when compared with students from University of Defence.

Pull-up test provide information about upper body-pulling strength. Lockie et al. (2018) used pull-ups test as a part of their physical fitness assessing battery of test on law enforcements recruits, their mean repetition number 13.86 (± 6.70) was slightly higher than mean number of repetitions achieved by participants in our study (8-year average 12,12 repetition). On the other side our participants achieved higher number of repetitions in pull-ups than members of Slovenian Armed Forces included in study from authors Šimenko et al. (2020). In this study mean repetition number achieved by participants in pull-ups was 5, authors reported that these data confirm their assumption about weakness in muscle groups involved in this movement and recommend that physical condition programs should focus on strengthening these lagging muscle groups (Šimenko et al., 2020).

Capacity to generate power, and a high ratio between body mass and power are the main variables influencing sprint performance (Perez-Gomez et al., 2008). In paper from (Smirniotou et al., 2008) male young sprinters (18,73 ± 1,79 years) participated in study when power parameters were associated with sprint performance, participants ran 100 m sprint with average time 12,00 ± 0,40 s. Their performance was better than performance of participants from our study (8-year average time 13,81 s), however, the participants were athletes that participated for at least 3 years in a sprint-specific training program (Smirniotou et al., 2008).

CONCLUSION

The main goal of the study was to assess physical fitness of students from University of Defence through years 2008–2016. Data indicates that during the observed period of time there was no decrease in physical fitness from the students of University of Defence. Physical performance in the chosen tests is quite stable throughout the monitored period and comparison with other papers indicated good physical readiness and preparation for military duty in students from the University of Defence in the Czech Republic.

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Mapping the Needs of Different Groups of Athletes of the City of Zagreb and the Republic of Croatia During Crisis Situations (Covid – 19 and Earthquake) – Athlete Perspective

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ABSTRACT

This paper was created as part of the project "Trešnjevka Wrestlers for Civil Society Sports Organizations (SOCD) in Crisis Situations." with a specific ambition – to pursue improving the capacity of civil society organizations to respond to the needs of the local community in crisis situations. For this purpose and as one of the project activities, the mapping of the needs of different groups of athletes and sports workers of the City of Zagreb and the Republic of Croatia during the crises of Covid – 19 and the earthquake is carried out. This research used a qualitative approach that includes focus group pre-research. To ensure broad coverage of the researched topic and for the purpose of heterogeneity, research deliberately focused on 17 different groups of sport. The structure of pre-research participants who were selected intentionally from 17 sports resulted in a total of 17 athletes. All respondents are athletes and adults who have consented to participate in the survey. Qualitative research was conducted through pre-questionnaires and semi-structured interviews and the survey was guided from February to April 2022. Each athlete belonging to a defined sports community (club or federation) was examined separately. Respondents were introduced to the aim of the research and general questions asked and were also informed about the confidentiality of the answers. Collected data materials were processed by comparative analysis. Alternate observation of the responses, similarities and differences among them, and according to the superior aspect of the research (improving the capacity of civil society organizations to provide an effective response to the needs of the local community in crisis situations) along with the intensity of life quality for athletes managing sport during the pandemic, led to the following question: What needs have been identified by different groups of athletes of the City of Zagreb and the Republic of Croatia during crises (Covid – 19 and earthquakes)? The most frequent declarations are associated with impaired training continuity or suspension of training due to epidemiological measures and earthquake-damaged infrastructure, cancellation of the competitions and a decrease in motivation.

Keywords: occurrences, crisis situations, athletes, needs assessment, quality of life

INTRODUCTION

Croatian athletes have faced many obstacles in training consistency, physical improvement, and achieving sports success regarding recent occurrences in Croatia during the past two years. The beginning of Covid – 19 pandemic in February 2020 conjoined with two earthquakes (5.5, and 5 according to the Richter scale) that happened on the same day in the capital city Zagreb with one hour difference (PMF, 2020) along with its manifestations generated whole spread crisis in Croatia. The capital was damaged, and the following vibrations in Zagreb and its surrounding caused by earthquakes became a regular circumstance daily. The same year, on December 28, an earthquake of magnitude five according to the Richter scale hit Petrinja, and several stronger earthquakes followed on the same day; on December 29, one of the strongest earthquakes in the Croatian history, of magnitude 6.2, occurred in the same area (PMF, 2020). The first coronavirus case was recorded on February 25, 2020, and this date denotes the spread of the pandemic to the Republic of Croatia (HZJZ, 2020). According to Oxford University research in 2020, the Republic of Croatia was one of the countries with the strictest restrictions and measures to reduce further virus infections. (Oxford University, 2020). In less than a month, educational institutions, for instance, kindergartens, primary and secondary schools, and high school and university institutions in endangered areas started closing due to large daily migrations of citizens exposed and exposed others to virus infections. By March 2020, all schools in the Republic of Croatia were closed. Considering that educational institutions and their assets are one of the prominent carriers of social events regarding sports competitions, cultural manifestations, and similar gatherings, they were all controlled or canceled, and sanctions for violating thetical epidemic measures were strict. (Official Gazette, 2020) Those mentioned above led to socio-economic consequences. All the measures implemented to control the pandemic caused socio-economic repercussions, which were primarily reflected in cultural and sports events while sports competitions were either canceled or held without the presence of spectators. According to the aforestated circumstances, Croatian citizens had to be constantly prepared for various forms of intervention, which is why the period from 2020 to 2022 is a justified period of general crisis in the Republic of Croatia. A crisis is, by definition, a situation whose occurrence is unforeseen and that is highly threatening to priorities and time and space limiting for urgent decision responses. Furthermore, crises represent narrowed fundamentals of the social system. Therefore, they can be lethal to overall aspects of life, causing malfunctions to significant assets and values on different fronts of the human organization, along with its uncertain impact on moral values and physical and mental health (Koutsoukis, Nikitas-Spiros & Farantos, Georgios, 2015). The crisis is interpreted by initiating factors. Concerning the circumstances, it originates from, it can be categorized as followed by internal or external forces (Koutsoukis, Nikitas-Spiros & Farantos, Georgios, 2015). Therefore, crises in Croatia were externally evoked by the Covid-19 pandemic and earthquakes, which initiated internal social malfunctions in everyday life, especially the quality of life of athletes anticipated in sports organizations. Sport-oriented quality of life for every active athlete is associated with Maslow's Hierarchy of Needs in the Theory of human motivation. A. H. Maslow (1943) claimed that motivated behaviors should be inferred as a connection through which many basic needs may be reciprocally expressed or satisfied.

Furthermore, "human needs arrange themselves in hierarchies of pre-potency. That is to say, the appearance of one need usually rests on the prior satisfaction of another, more prepotent need," as Maslow said (1943). Athletes long to fulfill the need for self-esteem, which is directly connected to sports achievement that leads to other aspects of described need, respect for others. However, under the circumstances of crises such as pandemics and frequent earthquakes, contentment with the pre-potent need for Safety and satisfaction is considered questionable, not to mention the fact that "practically everything looks less important than safety, even sometimes the physiological needs which are being satisfied, is now underestimated." (Maslow, 1943).

The requirements analysis establishes the characteristics required for the athlete, the sport, or both. The demands of the sport are frequently determined first since this enables the coach to determine what skills the athlete needs to excel in that sport. A needs analysis is sometimes divided into three sections: a sport-specific needs analysis, an athlete-oriented analysis, and a comparison study. In order to understand the demands of the sport in emergency conditions, we gathered the components and concentrated on comparison in this study. The in-depth analysis provides us with sport-specific needs at all levels that are essential for understanding and planning a holistic and practical approach or program in terms of the demands of the sport in uncertain times. Even though athletes are not considered a high-risk population, their health and performance could be directly affected in the event of being infected. Therefore, it is essential to have this information and to define solid (but allowing flexibility as new data becomes apparent) protocols to know if they can follow their training programs safely. In general, professional athletes are younger and have fewer comorbidities than the rest of the population, hence a lower risk of severe outcomes due to Covid-19. However, as they are part of the general population, they must follow the same prevention strategies to avoid spreading the virus and flatten the curve, so healthcare systems do not collapse. The same applies to those surrounding the athletes like coaches, physical trainers, team managers, team physicians, physical therapists, equipment managers, and other people working in the club facilities that are generally older and probably have more risk factors and comorbidities, but also to their coexisting relatives (Mann et al., 2020). Sports competition and regular training regimens were abruptly stopped by the ongoing Coronavirus pandemic, which led to considerable uncertainty about whether and how to properly resume sports. In order to maintain optimal levels of health and physical performance for all staff members during the current social distance requirements and the upcoming return of competition, despite ongoing hazards, concrete solutions distributed to performance staff, coaches, and athletes are necessary. Therefore, we aim for a thorough understanding of an athlete through the use of subjective and objective assessment provided in a conceptual model that relies on a few crucial components of the development and strategy approach, such as a thorough comprehension of the specific needs of the athlete, in-depth knowledge of the specific demands of the sport, integration of this information to identify the most important pedagogical and psychological factors that will affect performance, and the development of the most effective competitive preparation strategies for the specific athlete and its sport. The applied setting of this research goes beyond Taylor's (1994) definitions of motivation as the ability to persist at an activity in the face of boredom, fatigue, pain, and the desire to do other things; confidence is defined as how strongly athletes believe in their ability to

learn or execute a skill, compete at a certain level, or succeed in competition; intensity is the degree of physiological activation athletes experience instantly prior to and during competition, and the positive or negative valence occurred upon their physiological state; concentration as the ability to focus on performance-relevant aspects of the attentional field. As the conceptual model indicates, the purpose of assessment is to fully understand the athlete, thereby enabling consultants to provide effective interventions to respond to the athlete's specific needs. Acquiring an understanding of the athletes' needs assessments can be achieved in two general ways: a subjective and an objective assessment. Each means of assessment has strengths and limitations that must be considered in determining the value of the information that is obtained. As the conceptual model suggests, every sport has unique physical, technical, and logistical demands which require special preparation by participating athletes. These factors should be determined in line with specific circumstances like Covid-19 and earthquakes. Assimilation of the diversified reports commences with comparing the athlete's needs and the predominant demands of the sport.

METHODS

The research used a qualitative approach that included focus groups which served as a source to establish needed interventions in present and future times of crisis situations. Qualitative studies use non-quantitative methods used to provide new perspectives which can contribute to sport-orientated studies with the use of interviews and focus groups. (Tong, Sainsbury & Craig, 2007). To achieve the purpose of this qualitative research, to understand the experiences of individuals in context of training and competing during Covid-19 and earthquakes, 17 different groups of sport were chosen deliberately which provided adequate heterogeneity for analysis of the researched topic. In the class of all the 17 groups of sports, each sport was represented by a sport club or sport organization which complied to participate in the survey. Intentionally selected athletes from 17 different sports resulted in a total of 17 athlete participants. All respondents are competition active and professional athletes who are competing for sports clubs which are registered in national sports federations as a part of Croatian Olympic Committee. All the participants are registered as active athletes in international sports federations and adults who have consented to participate in the survey which was guided from February to April 2022. Each athlete was interviewed separately, on account of belonging to a defined sports community. Respondents were familiar with questions (appendix 1) asked and were also informed about the confidentiality of the answers. The research was carried by scientists and students selected from the fields of pedagogy and kinesiology who have experience in conducting this type of research. Collected data materials were processed by comparative analysis. We used MAXQDA program for Qualitative and Mixed Methods Data Analysis, 2020. Conducted answers, its content and data were observed and compared in pursuit of mapping the needs of different groups of athletes of the City of Zagreb and the Republic of Croatia during crisis situations from athletes' perspective by studying intensity of equalities, similarities and differences amid them. Questions asked served the purpose of identifying the needs of different groups of athletes during the time of crisis regarding sport oriented quality of life.

RESULTS

Qualitative research established on a focus group constituted of 17 athletes from different sports permitted to collect, analyze and describe the thoughts on occurrences in crisis situations and needs assessments from athletes perspective. Obtained results for each sport separately are shown in table 1. sorted by alphabetical order. They are observed with two-point perspectives: direct perspective refers to sport occurrences in crisis situations that made a direct impact on athletes training process and indirect perspective refers to other occurrences in sport organizations athletes are a part of that indirectly affected athletes training process.

Further analysis provided understanding the needs assessment that are crucial for providing the best plan and program applicable for demands of macro/micro cycles at all sport levels in uncertain and sudden situations.

Table 1. Occurrences in crisis situation and needs assessments from athletes' perspective

GROUP OF SPORT	Sport occurrences in crisis situation (direct)	Other occurrences in sport organizations (indirect)	Comparison based on need assessments
artistic gymnastics	The training hall was impaired due to the earthquake and due to safety reasons, indoor training was impossible. All training sessions were held on open sports fields or online (recorded exercises/training).	Health and social care were well organized through frequent disinfection of the premises. Protocols regarding evacuation plans had been formed and all the athletes were educated about what to do in the event of an emergency.	Athletes are in need of better organization of group training. They propose working in small groups for efficient training programs and creating more groups for different athletes.
basketball	The implementation of training processes was prevented due to the impossibility of entering school sports halls. Outdoor courts were used when the weather permitted. Competitions were reduced because of numerous cancellations.	The earthquake did not affect any athletes' activities. Athletes were free of paying membership fees.	Urgent necessity of providing a plan of work in emergency situations.
boxing	Athletes were engaged in organized training sessions on outdoor fields. Regular cooperation with a sport psychologist helped the athletes through hard times of motivation. Implementation of trips to the Croatian highlands and mountains under the guidance of mountain guides was a common part of the training cycle. The work with the athletes did not suffer due to the motivation and dedication of the trainers. All competitions were prohibited.	Material conditions of the training space meet all the basic requirements for athletes to be provided with the best practice and training experience in accordance with epidemiological measures.	Special needs assessments were not stated.

cycling	There were no difficulties in implementing training activities. All training workshops were conducted outdoors.	Safety protection and health hygiene standards are high, and athletes use their own equipment. The pandemic and earthquakes did not have a negative impact because of the specifics of the sport.	Athletes need to familiarize themselves with the protocol for emergency and crisis situations.
dance	The training was held regularly according to the guidelines of the headquarters and athletes are well informed about safety conditions.	Specific protocols of the sports organization about entering the hall and prescribed training time needed to be obeyed. The health and hygiene conditions are at a very high level and in accordance with the staff's recommendations. The earthquake had no impact.	The necessity of forming a protocol for work in emergency situations.
figure skating	The training was taken normally in accordance with recommendations. Athletes were traveling to competitions abroad. Additional activities regarding athletes were held online. Health and hygiene conditions at a high level.	Infrastructure was difficult to access, especially after impairment caused by the earthquake which prevented athletes from using one ice rink. As ice is not treated as a „closed space", there were not too many difficulties in the organization.	Athletes have a great need for normalization and continuity of training along with the protocol for working in emergency situations.
football	The training was held on outdoor fields or in sports halls when pandemic restrictions got restrained.	The pandemic affected restricting and canceling activities of the football sports communities. The earthquake did not affect at all.	A work plan in emergency situations.
handball	Competitions were not sustained during the pandemic and later competitions were held only with prior COVID testing of players who do not have COVID certificates.	The negative impact of pandemic was display in the termination of the competition while the earthquake did not affect negatively on training and competing cycle.	Athletes found the necessity for the normal functioning of the sport community as the most important. Furthermore, they lack a plan and education of behaving in emergency situations because superiors guarantee a quick and efficient resolution of any crisis situation.

judo	All regular competitions were canceled, and only national championships were held according to prescribed measures. Athletes conduct training in accordance with epidemiological measures and become engaged in outdoor activities in summer and winter camps and hiking. Every athlete participates in workshops on improving mental health.	Hygiene of the participants is the main focus to provide safe training conditions and especially important is the cleanliness of the material conditions before and after the training. Coaches inform athletes about safety protocols in case of crisis situations and teach them how to follow the evacuation plan.	Special needs assessments were not stated.
rhythmic gymnastics	Organization of regular training processes and competitions was impossible in Croatia and abroad for most of the crisis due to restrictive measures. The training was adapted to a small space so it could be also done at home. The regular program of training preparations needed to take place outside the club premises. Participation in competitions was absent or decreased and was limited to Croatia only.	The space where they were supposed to conduct training meets all hygiene standards and equipment is regularly cleaned and maintained. Athletes are obliged to take care of their equipment. Other conditions in the sports hall are in accordance with athletes' needs. Through online training, the level of motivation was maintained.	A necessity in forming a plan and program for conducting training in crisis situations.
rowing	The training was held outdoors and athletes were competing only in the Republic of Croatia. International competitions were not organized.	The Pandemic affected work to some extent, but the earthquake did not. Athletes are familiar with emergency protocols, and they follow health and hygiene instructions in accordance with pandemic measurements.	Specific needs assessments were not stated.
swimming	Competitions were canceled and training was conducted mainly for categorized athletes, while younger athletes were deprived of the training process.	Protocols for working and behaving in crisis and emergency situations in swimming pools exist and athletes are familiar with them. Athlete's health and hygiene conditions are frequently controlled.	The pandemic significantly complicated the work and implementation of the training process while it mainly depended on resolutions of the country authorities regarding the use of swimming pools.

taekwondo	Regular training process, as well as planning and programming the form of athletes is hardly maintainable due to the frequent postponement or cancellation of competitions. Athletes are encouraged to use other types of physical activity (outdoor activities) as a substitute for regular training.	Athletes are maintaining communication with their coaches and colleagues whereby they emphasize the importance of psychophysical development during the pandemic.	The lack of competitions excitedly initiated a decrease in athletes' motivation levels and a large number of them gave up training.
track and field	Common outdoor training continued to be implemented.	Pandemic and earthquake did not affect athletes training progress. They have existing protocols for crisis situations.	Specific needs assessments are not stated as track and field enable continuity of training process in terms of described situations.
volleyball	Athletes were separated to train in smaller groups following strict measures. In periods when pandemic has diminished training continued to be carried out in a normal volume as well as competitions, only without spectators. Training sessions were held on outdoor courts during indoor work bans.	Sport halls, equipment and athletes' hands were frequently disinfected before, after and during practice and they were all wearing masks. The earthquake resulted in a reduced number of spaces due to the impaired halls.	Athletes find necessity in normal functioning of the sports community regarding training and competition process and in activity plans for them to easily adapt to the situation and act within its capabilities.
water polo	Regular training programs were not held and all the athletes partly trained following online instructions. Competitions were modified to pandemic restrictions.	Protocols are currently being developed so that athletes can be educated on how to react to crisis situations in the future.	Urgent necessity in forming work protocols in urgent situations and adapting training processes by occurrences in crisis situations.
wrestling	All athletes were provided with online training and individual contact access was provided to top athletes.	Earthquakes did not impair infrastructure and the regular training for top athletes could be easily provided.	Since there is no written preparedness plan for work in crisis situations there is an urgent need in forming protocols and educating athletes about procedures during pandemic and natural catastrophes.

The listed results have scientific contributions and practical implications as they can provide specific information on how given circumstances affected athletes' quality of life. They can present essential matters for athletes, coaches and sports organizations in creating and implying training principles in training processes during crisis situations.

Differences amid given types of sports are predominantly seen whether the sport is oriented indoors or outdoors. Indoor sports were facing strict measures regarding work bans while outdoor sports continued regular training implementation as the crisis situation did not affect them.

Separate observations of sport organizations regarding the place of sports activity implementation, determine a 40.37 % decrease in the number of active members in clubs with indoor activities as opposed to a 12 % increase in active members in sports clubs with outdoor activities (Iličić, 2021). Survey provided by Washif, J. A., Sandbakk, Ø., Seiler et al. (2022) conducted on athletes from 142 countries contributed to important outcomes in relation to the effects of lockdown during training practices among athletes. Results displayed that more than 50 % of training processes were body-weight exercises while sport-specific and technical skills training was mostly practiced in parasports, combat and precision sports. Cardiorespiratory training was also regulated among 50 % to 75 % of participants. Study demonstrated a considerable decline in training volume and limited understanding of training knowledge among male and female athletes. Washif, J. et al. (2022) concluded that team sports were more affected by changes than individual sports during the lockdown and that athletes should be provided with specific training and educational resources for the individual implementation of home-based training. Comparable situation was studied among Filipino athletes during a lockdown, where significant reductions in training frequency and duration were recognized among middle-level athletes while professional athletes were less affected by the lockdown athletes. The study accentuates the challenges experienced by athletes during a lockdown, which has importance in forming adequate support for lockdown-affected athletes (Cayaban Pagaduan, Haddad & Chamari, 2022). Furthermore, research that interviewed athletes from countries that had similar COVID-19 contagion levels, concluded that those athletes were more oriented to home training and athletes from individual sports had more support from their coaches than athletes from team sports. That study demonstrated the importance of participation in sports competitions for professional athletes to retain current levels of an active lifestyle and due to quarantine athletes considered home training and e-training as useful sources during the lockdown. (Izzicupo et al., 2021). Jukic, I. Calleja-González, J., Cos, F. et al. (2020) propose recommendations for athletes to approach and achieve the ideal situation during restricted measures of lockdown: "The athlete's living space should be equipped with cardio and resistance training equipment (portable bicycle or rowing ergometer). Some forms of body mass resistance circuit-based training could promote aerobic adaptation. Sports skills training should be organized based on the athlete's needs. Personalized conditioning training should be carried out with an emphasis on neuromuscular performance. Athletes should also be educated about nutrition (Vitamin D and proteins) and hydration. Strategies should be developed to control body composition. Mental fatigue should be anticipated and controlled. Adequate methods of recovery should be provided. Daily monitoring should be established." What is more, studies regarding human health acknowledge the importance of regular exercise, playing sports, and participating in physical activities as one of the means for preserving human health (Dašić, Gregorić & Kos Kavran, 2021).

DISCUSSION

In the presence of the pandemic, all forms of sport-organized activities have been canceled or held according to restrictive measures. As training halls have been closed due to pandemic proceedings or earthquake impairment most of the training process needed to be transferred outdoors or online which caused organizational problems for different sports requirements. Most difficulties

originated in managing crisis occurrences as the pandemic significantly entangled the work of sports organizations and the application of the training process as daily activities mainly depended on resolutions of the authorities. Athletes have expressed the urgent necessity of providing protocols in emergency situations and the need for education regarding specific behaviors during crisis situations, but the most important need assessment is providing adapted training processes in terms of given circumstances. For some athletes, especially ones engaged in indoor activities with specific demands of space and equipment, this modified training lifestyle, distant from regular training forms, leads to specific deficits in the quality and quantity of training (Tayech et al., 2020). In cases where the training process was allowed in sports facilities, the use of training space and equipment, changing rooms and showers, as well as the hygiene of athletes was strictly controlled and under official requirements. (Steinacker, 2020). Cancellation of competitions and team sport matches threatened athletes' mental health and motivation and according to Drewesa et al. (2021) competing without the support of spectators does not have a pre-implied positive impact on the athletes. Jagustin (2021) also confirmed changes in the psychological state of athletes because many professional athletes struggled with anxiety, and self-doubt and reported depression. In addition, as the normal course of the season was disrupted by the pandemic, athletes exposed themselves to an increased risk of injury when returning to usual training and competitions. It is important that athletes maintain stable physical and mental conditions to be prepared for the resumption of regular planning and programming cycles (Tayech et al., 2020). Observing the influence of physical activity on mental health, it is considered that the psychological effects of the pandemic can intimidate a quick return to the previous state of training, therefore practical recommendation on the given statement is training at home to help avoid psychological problems in dealing with the quarantine situation during COVID-19 pandemic (Haddad, Abbes, Mujika & Chamari, 2021). According to Tayech et al. (2020) it is possible if athletes try to perform the technical movements of their sport. Knowing that each sport has specific requirements it is limited in many cases, however it is not recommended that training during home confinement is limited only to strength, power, and muscle endurance but extended to general physical preparation and stretching exercises amongst other isolation-limited activities (Tayech et al., 2020). What was necessary was a change in the planning and programming of training and competition activities (Jagustin, 2021). The effects of precarity, fear and insecurity also results in a shift of pedagogical affects. The participants especially struggled with education that does not include the significance of physical encounters with their colleagues. The new assemblage of sport also included encounters with digital technologies, which allowed for particular openings and closings for a re-alignment into the shifted trainings. Sport has been claimed to be socially constructed, that is, defined by what is said, written and done in its name (Kirk, 2010), so consequently the pedagogical encounters involve unpredictable relationships. When questioning whether online training is acceptable for regular training processes, the results of the research showed that virtual training contaminates the psychosomatic status of athletes and it is only partly an applicable reinstatement for the proper training process (Miocic, Androja & Bilic, 2020). It is strongly suggested to exercise during the isolation period depending on the equipment availability and with guidance and monitoring by a strength and conditioning coach and physiologist (Toresdahl & Asif, 2020). Preparation for resumption includes education of the

athletes and other personnel, assessment of the sport environment and agreement on training scheduling to accommodate all needs that might be left behind. Preventative measures should assure that sport participation at all levels and abilities makes an important contribution to the physical, psychological, and emotional well- being of individuals. At a population level, benefits of sport include direct economic benefits; healthcare benefits; educational benefits; and contribution to social capital through connectivity, resilience and creating stronger, cohesive communities (Hughes et al., 2020).

CONCLUSION

Athletes' lives were abnormally disrupted due to the quarantine of COVID-19 pandemic and the impairment of the sport organization properties. The major physical and psychological impact on athletes' careers caused by sports restraints modified specific lifestyles that together with the constant threat of infection and its outcomes affected their health in ways of impaired physical performance, increased risk of injuries and mostly, quality of life in general. Organization of regular training processes and competitions in the country and abroad was significantly challenging and demanding. Sports competitions were canceled or postponed and in the beginning, all activities outside of basic activities were left to individuals but with gradual adaptations to the current situation, training was taken online or outdoors. Only for the athletes who usually conduct their activities outdoors, the pandemic and the earthquake did not have a significant impact. By mapping the needs of athletes engaged in different groups of sports during crisis situations and observing direct and indirect occurrences they were facing in times of crisis it can be concluded that some sports organizations did better and some less well during periods of crisis. In new conditions, athletes have become aware of the importance of normal functioning of the sports community regarding training and competition process, the importance of creating activity plans for them to easily adapt to the situation and act within its capabilities, forming a work protocol in emergency situations and familiarize themselves with the protocol and behaving in emergency situations. As experienced athletes, they have their own ideas about adapting training processes to occurrences in crisis situations. Crisis situations, if unexpected, are in many ways challenging for athletes and all sports communities but with quick coordination of the needs and responses, they can be easily directed to being ordinary. It is necessary to determine the real picture of the situation because generalization, in this case, is not possible with regard to a random sample, although it allows insight into the differences in recognized needs according to different sports. The above conclusions are not an indicator of a new theory. Nevertheless, results and conclusions can help complete the starting points for selecting models of new theories regarding training processes during crisis situations and belonging recommendations.

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APPENDIX 1 – FOCUS GROUP QUESTIONS

1. How is your community (club, association) currently responding (at the time of the COVID-19 pandemic and the earthquake), to the following actions of the club

a. the main activity of the club (or association) at the time of the COVID-19 pandemic and the earthquake: organize regular training processes, a regular program of competitions in the country and abroad, a regular program of training preparations outside the club...
b. activities of the club (or association) in free time (outside the basic activities of the club) during the COVID-19 pandemic and the earthquake: for example, activities in free time (excursions, cultural and recreational activities, access to nature, etc.)
c. involvement in club (or association) activities during the COVID-19 pandemic and earthquake: availability of information on human rights, involvement in the community (club or association) planning, participation in community (club or association) projects, opportunities for activities for people with disabilities and similar.
d. activities of the community (club or association) related to safety and protection in their work during the COVID-19 pandemic and earthquake: is there knowledge and protocols on how to act in the event of an emergency (Covid-19 pandemic, earthquake, flood, fire, etc.)); how safe is the community (club/association), do members know whom they can turn to for help when they are in danger, safety from abuse, respect regardless of race, religion, origin or physical condition, access to justice, knowledge about the safe use of the Internet;
e. activities related to community (club/association) care for the health and social care during the COVID-19 pandemic and earthquake: access to a healthy environment (health and hygiene conditions of training equipment and space, etc.), availability and accessibility of health and social services in crisis situations, the degree of participation in the creation of programs and services related to health and social care.
f. activities related to the education of people in the community (club or association) during the COVID-19 pandemic and earthquake: access to regular education (schools, colleges...), participation in financing/co-financing of activities related to education, access to learning activities that are not in regular education (e.g. free workshops, instructions, access to libraries...);
g. activities related to the availability of sports infrastructure and the provision of financial resources for the regular functioning of the community (club/association) during the COVID-19 pandemic and earthquake: access to the affordable rental of halls, access to drinking water and electricity, heating, air quality, adequate living space and training space, access to financing for adequate training conditions for the poor and other vulnerable groups), membership fees and donations.

2. How much has the Covid-19 pandemic affected your community in terms of work before and during the pandemic? How much did the earthquake affect your community in terms of work before and during the pandemic?

3. In relation to similar sports communities (clubs or associations), what could be or already are the advantages of your community (club/association) in responding to needs during a) the Covid-19 pandemic and b) an earthquake?

4. Does your community (clubs or associations) have any experience in responding to the needs of members in crisis situations? What have been your experiences with it so far?

5. Describe in more detail how you involve colleagues from the sports community (club/association) in the activities of the community (club/association) during the Covid-19 pandemic and earthquakes? How do you involve other colleagues outside the sports community (club/association) in the time of the Covid-19 pandemic and the earthquake?

6. Does your community (club/association) have a written preparedness plan for working in any emergency/crisis situations?

7. How do you/your community (club/union) define needs during the Covid-19 pandemic and earthquake? And how do you define community?

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Differences in Height and Weight in Young Female Gymnasts

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ABSTRACT

Following the changes in basic anthropological characteristics of the young gymnast can help coaches to recognize how the process of training influences the growth and development of gymnasts. This also can be useful in the specialization of specific apparatus. The aim of this investigation was to find the differences in weight and height between young female gymnasts in compulsory and free program. The sample consisted of 26 female gymnasts: 10 years old who are competing at different levels – compulsory (16) and free (10) programs. Compulsory program training was three times per week, each lasting two hours. Training in the free program lasted two and a half-hour five times per week. The K-S test was used for testing the normality of distribution. Differences between height and weight are calculated by ANOVA at the level of statistical significance of $p < 0.05$. Results show that there is a statistically significant difference in height and weight between categories. Girls from the compulsory program are taller and heavier than girls in the free program. The free program is the hardest program and physically more demanding for execution than a compulsory program.

Keywords: artistic gymnastics, anthropological characteristics, children

INTRODUCTION

Height and weight are important measures in children not only for following the normality of growth and development, but also to see how each generation has own curve. Gymnasts are somewhat shorter than average on entering the sport (4–6 years of age), and have heights within the normal range (Malina et al., 2013). Peak height velocity and peak velocities in female gymnasts overlap those

for short- and late-maturing girls who are not athletes (Malina et al., 2013). A compulsory program is planned for girls who are unable to participate in the top FIG absolute program or free program, due to organizational, professional or financial reasons. Exercises in compulsory program are obligatory while free program are consisted of basic exercises with additional elements. This free program prepares gymnasts for FIG program. Differences in the elements, e.g., on the balance beam, free program has elements: press handstand mount, back handspring, back walkover connected with a handspring, round-off back somersault. The elements in the compulsory program are cat jump, turn, back walkover (front walkover), cartwheel, and round-off dismount. Compulsory program training lasted 2 hours/training, 3 times/week and totally 6 hours/week. Training hours in free program are 12,5 hours/week, 5 times/week, and 2,5 hours/training.

There is not a lot of investigation of anthropological characteristics in artistic gymnastics, especially since there is no investigation of children involved in competitive gymnastics and differences in categories and programs. We found, an investigation of body somatotype and the effect of gymnastics training. A group of authors Massidda, Toselli, Brasili & Calo (2013), investigated somatotypes of elite Italian gymnasts. Malina et al. (2013) investigated the effect of gymnastics training on growth and maturation. The influence of intensive training on adult final height in elite female artistic gymnasts was investigated by Georgopoulos et al. (2012). Anthropometric characteristic of young girls is mostly investigated. Authors Madić, Popović & Kaličanin (2009) investigated anthropometric characteristics of girls included in program of development gymnastics with girls who are not included in any sport. Similar investigations are done by Kutac, Jurkova & Farana (2019) which analyze the somatic parameters of artistic gymnasts in 625 girls (pupil competition category) and compare them with the general population. At the base stage of training in 8–9-year-old girls, authors Pilewska, Pilewski & Barczewska (2015) determine the specificity of somatic indicators. Genc & Cigerci (2020) examine the effects of 12-week gymnastics training on some physical and performance characteristics in 6–7 age group pre-school girls. Those anthropological investigations are also carried out on pubertal girls involved in elite gymnastics. Courteix, Lespessailles, Jaffre, Obert & Benhamou (1999) investigate skeletal and somatic developments in a group of highly trained 14 prepubertal girl gymnasts who had trained 12–15 h per week for 3 years before starting the study. Some preliminary work was carried out in the early 1990s prospectively studied elite gymnast training for a five-year in twenty-two female teenagers in a period of their pubertal development (Lindholm, And & Ringertz, 1994). A group of authors Kalichová, Hedbávný, Pyrochtová & Příhonská (2019) compared the attained and predicted height and length of body segments in 11 elite male gymnasts from the Czech Republic who have undergone intense training for 12 years or more. Theintz, Howald, Allemann & Sizonenko (1989) investigated growth and pubertal development of young female gymnasts. One old investigation performed by Malina et al. (1984) investigated growth status of young Olympic athletes.

Amigó, Faciabén, Evrard, Ballarini & Marginet (2009) investigated height, weight, somatotype and body composition in elite Spanish gymnasts from childhood to adulthood. In female gymnasts there is also an investigation of growth by Peltenburg et al. (1984) an also Malina (1999). Bacciotti, Baxter-Jones, Gaya & Maia (2017) investigated the growth and maturation in elite young female athletes. As there are no studies of the differences between competition categories in young female gymnasts, which will be useful to coaches in selection and one day in specialization.

The aim of this investigation was to find the differences in weight and height between young female gymnasts in compulsory and free program.

METHODS

The sample consisted of 26 young female gymnasts: 10 years old who are competing at different levels – compulsory (16) and free (10) programs. All girls were born 2011. and the biggest age differences between them were six months. Compulsory program training was three times per week, each lasting two hours. Training in the free program lasted two and a half-hour five times per week. Girls from both programs started with gymnastics training from six years old. Sample of variables was height (H) and weight (W) measured at the competition. Height was measured by an anthropometer (cm) and the weight with Tanita (Segmental Body Composition Monitor, Inner ScanV, Amsterdam The Netherlands) (kg).

The data were collected 2021. at the national competition, and the sample is small because some children did not want to participate in the research. In esthetic sport, especially in gymnastics it is difficult to obtain such data. Ethics Committee of the Faculty of Kinesiology approved the research and parents signed the consent for the children.

The software package Statistica 14.0.0.15 (TIBCO Dana Science Software) was used to process the obtained data. To determine the normality of data distribution, the K-S test was used, at the $p<0.05$ level. Basic descriptive statistics of all variables were calculated. Univariate analysis of variance, ANOVA was used to determine statistically significant differences in height and weight.

RESULTS

The basic descriptive indicators of compulsory program of height and weight are shown in table 1. The average height of the body (H) is 141.94 ± 9.50 cm, with the smallest value of 117.00 cm and the largest value of 156.40 cm. The average for the variable body weight (W) is 32.93 ± 6.48 kg, ranging from 17.40 kg to 42.30 kg.

Table 1. Descriptive statistics of compulsory program

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.
H	16	141.94	117.00	156.40	9.50
W	16	32.93	17.40	42.30	6.48

Table 2 is shown basic descriptive indicators of a free program of height and weight. The average height of the body (H) is 138.10 ± 5. cm, with the smallest value of 128.00 cm and the largest value of 148.10 cm. The average for the variable body weight (W) are 30.95 ± 3.99 kg, ranging from 24.40 kg to 38.80 kg.

Table 2. Descriptive statistics of free program

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.
H	10	138.10	128.00	148.10	5.40
W	10	30.95	24.40	38.80	3.99

The results of the Anova test (Table 3) indicate that there is a statistically significant difference between young female gymnasts in the variable body height (H), p = 0,00 and body weight (W), p = 0.01.

Table 3. One-Way Anova results of height and weight

Dependent Variable	Multiple R	Multiple R^2	Adjusted R^2	SS Model	df Model	MS Model	SS Residual	df Residual	MS Residual	F	p
H	0.66	0.44	0.39	754	2	376.98	952.54	23	41.41	9.10	0.00*
W	0.59	0.35	0.30	281	2	140.55	516.96	23	22.48	6.25	0.01*

Legend: *=statistically significant difference

DISCUSSION

When we compare the differences in height and weight between compulsory and free program, we can conclude that generally, girls from compulsory program are 3,84 cm taller than girls in free program and 1,98 kg heavier than free program girls. The reason can be in timing of peak height velocity, which happens about 10.55–14.52 years, and peak velocities, 4.58–9.23 cm/year, among individual gymnasts (Malina et al., 2013). Girls from compulsory program was (141.94 ± 9.50 cm), where 117.00 cm were the smallest one and 156.40cm where the highest one. As expected, girls from free program were smaller than girls from compulsory program with a mean value (138.10 ± 5.40cm) and the highest one was 148.10 cm and smallest one was 128.0 cm. Maybe the reason in height differences can be that some girls start with puberty earlier and some later, despite they are the same age (the highest differences are six months). Before more than 30 years researches Theintz et al. (1989) where found the smallest height values (144.7 ± 7 cm) in the youngest girls (12.6 ± 1.1 yrs), weighing 34.9 ± 5.5 kg. Also, older girls (16.8 ± 0.5 yrs), weighing 53.6 ± 3.1 kg and body height was (163.2 ± 4.5 cm) (Malina et al., 1984). It seems that today's children are taller and heavier than children before more than 30 years.

Apparatus requirements of free program are bigger than in compulsory program, e.g., balance beam exercises are composed of difficulty higher elements than compulsory program. There are statistically significant differences in girls included in development gymnastics with girls who are not included in almost all anthropometric measures (except body height) (Madić et al., 2009). We can say that weight can be under the influence of training, but height not. The high volume of gymnastics training of the gymnasts, influences body composition parameters, gymnasts have lower body fat (%), visceral fat (cm^2), and higher skeletal muscle mass (%), (Kutac et al., 2019). This can be the reason why

girls in free program are lighter than girls in compulsory program by almost two kilograms. When we compare general population with gymnasts there is a difference in somatic parameters. There are several possible explanations for this claim. 652 girls from the youngest competition category have a lower body height and lower body weight than the girls from general population (Kutac et al., 2019). Spanish gymnasts are shorter and lighter than the reference sample throughout the whole range of ages studied (Amigó et al., 2009). Russian male gymnasts' weight 56 to 70 kg and height as 160–170 cm and female gymnasts 150–160 cm and 38–50 kg (Arkaev & Suchilin, 2009).

Values of morphological indicators showed to be related to the gymnasts' technical level in 8–9-year-old girl in the early stages of training (Pilewska et al., 2015). Here the requirements of discipline in young girls do not match with somatic model of adult gymnasts because the demands of disciplines are not the same for beginners and adult gymnasts. In elite gymnast who trained for 12 years or more, they have lower body height, longer trunk, medium-long upper limbs, and shorter lower limbs (Kalichová et al., 2019). This state of some parameters is obvious just when looking at the competition. 12-week of gymnastics training has a positive effect on some physical and performance characteristics in 6–7 age group pre-school girls (Genc & Cigerci, 2020). In our investigation girls which trained 18 hours/week are lighter, but we do not know if they are better in some physical and performance characteristics. We can suppose that they already are better than girls from the compulsory program because the exercises are heavier, so this requires a good level of physical preparation. There is a lot of benefit to high-volume training. An investigation conducted by highly trained prepubertal girl gymnasts says that high-volume impact training could stimulate a higher annual gain in bone mineral acquisition in prepubertal girls without affecting somatic growth dimensions (Courteix et al., 1999). In Swedish gymnast girls, it is noted that they have significantly delayed age of menarche, less body fat, and were shorter and lighter than the control group (Lindholm et al., 1994). However, heights and weights have changed little from 1987 (154 cm, 45 kg) to 2000 (152 cm, 43 kg) and 2008 (153 cm, 45 kg) Olympic Games (Claessens, 2007; Malina et al., 2013). One of the newest investigations resulted in some constatations. Height in adult gymnasts (male, female) is not conceded by intensive gymnastics training, also gymnastics training does not reduce pubertal growth and maturation (Malina et al., 2013). Each external stimulus, like training, will change some physical and technical parameters, but some anthropological measures are under the influence of genetics. Previous work addresses that the smaller size of elite gymnasts is evident if we exclude any systematic training (Peltenburg et al., 1984), and is hereditary, i.e., gymnasts have parents who are shorter than average (Malina, 1999; Baxter-Jones, Thompson & Malina, 2002).

The characteristics of gymnasts are unique as the result of the selection of natural genetic characteristics, but the differences in body composition between competition levels was not well understood because of difficult to find (Bacciotti et al., 2017).

CONCLUSION

From obtained results, we can conclude that gymnast from the free program is shorter and lighter than girls from the compulsory program. These facts can be attributed to a high volume of training which mostly influences body weight. Height is obviously under the influence of genetics. In the free

program, coaches selected girls which are capable of a free program and have the predisposition to be in the FIG program. Since the requirements for items in the mandatory program are lower than in the free program, it is assumed that the body should be lighter and smaller. In artistic gymnastics are very hard to get to anthropometric measures, because girls are shy and usually refuse to take measures. In the future will be very helpful to monitor the progress of anthropological measurements so that we can say how should look like a gymnast in each competition program.

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Impact of Whole-Body Electromyostimulation and Resistance Training on the Level of Functional Fitness in Elderly Women

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ABSTRACT

Objective: This study aimed to investigate the effect of whole-body electromyostimulation (WB-EMS) and resistance training (RT) on the level of functional fitness in a group of elderly women.

Participants: 63 women (60-65 years) were randomly divided into 2 experimental groups (19 in WB-EMS, 22 in RT) and one control group (22 women). Both experimental groups underwent a ten-week lasting interventional program, the control group was asked to maintain their usual daily regimen and lifestyle.

Methods: Senior fitness test battery (SFT) determined the level of functional fitness in participants, and the dual-energy X-ray absorptiometry (DXA) assessed the body composition.

Results: The RT group reported a statistically significant difference between pre-and post-test in values of the Chair Stand test ($p = 0.04$), 8 Foot up and Go ($p = 0.03$), in the Back Scratch test left side ($p = 0.02$) and the Chair Sit and Reach test right side ($p = 0.05$). The WB-EMS interventional program had a positive statistically significant effect only on the level of flexibility of the lower limbs measured by the Chair Sit and Reach test left side ($p = 0.05$).

Conclusions: The results of all individual components of functional fitness measured by SFT in both experimental groups (WB-EMS, RT) show an improving tendency. Comparing WB-EMS and RT groups, better results were confirmed in the RT group.

Study limitations: Extending the length of intervention programs could have a more significant effect on the level of functional fitness in elderly women.

Keywords: ageing, functional fitness, Senior fitness test, DXA, resistance training, WB-EMS

INTRODUCTION

The world population is ageing. It is projected that adults over 65 years will be doubled in 2050 (United Nations, 2021). Despite the longer life expectancy, it is necessary to maintain a high quality of life to be included in society. It includes the ability to move freely and be self-sufficient. One of the most evident facts of ageing is the loss of muscle mass and, thus, the associated loss of muscle strength. (Romero-Arenas et al., 2013). Severe loss of muscle mass, together with decreased muscle strength and/or decreased functional fitness, is defined as sarcopenia (Cruz-Jentoft et al., 2019). Sarcopenia has an estimated prevalence of 10 % in adults over 60 years, rising to > 50 % in adults older than 80 years (Shafiee et al., 2017). Women are more susceptible to the occurrence of sarcopenia due to lower initial levels of muscle strength and also due to hormonal changes during menopause (Brady et al., 2014).

A crucial element for maintaining self-sufficiency in activities of daily living is functional fitness. Functional fitness is multifactorial and is influenced by genetic predispositions, disease manifestations and their consequences, previous lifestyle, environmental influences, and psychological state (Kolar, 2009).

One of the effective methods to prevent sarcopenia is physical exercise. Physical exercise has the potential to improve physical function and thus the quality of life of the elderly. There is indisputable scientific evidence for the benefits of physical activity and exercise in the prevention and treatment of many chronic diseases such as sarcopenia, among many others (Chodzko-Zajko et al., 2009; Pedersen & Saltin, 2015). More specifically, resistance training is an effective method for preventing the manifestations of sarcopenia - loss of muscle mass and muscle strength or fitness in the elderly (Dent et al., 2018; Fragala et al., 2019; Papa et al., 2017). Resistance training is an exercise method that operates with a gradual increase in load that involves muscular work against an external load (Papa et al., 2017). For the optimal adaptation of the musculoskeletal system, it is recommended to perform resistance training 2–3 times a week, including 1–3 sets of 8–12 repetitions for each exercise. It is recommended to focus on the main muscular parts of the body (Izquierdo et al., 2021).

Although resistance training is an effective method to prevent the manifestation of sarcopenia (Papa et al., 2017; Romero-Arenas et al., 2013), it may not be suitable for everyone. One of the disadvantages is the time required for exercise, lack of motivation, as well as the inability of an individual to perform exercises due to decreased mobility or fatigue (Kemmler et al., 2016, 2017). Whole-body electromyostimulation has been shown to be an alternative method to the effects of resistance training (Kemmler et al., 2018, 2021). The WB-EMS method uses weak electrical impulses transmitted through electrodes on the skin, which have the potential to activate a large number of motor units in muscles (Kim & Jee, 2020). The WB-EMS basic training session provides a 20-minute training protocol using intermittent stimulation (4 s pulses, 4 s rest; 85 Hz, 350 ms). The recommended frequency of WB-EMS training is 1 per 7 days to 3 per 14 days. WB-EMS is a highly individualized and time-efficient exercise technology that does not burden the joints (Kemmler et al., 2021). In general, studies examine the effect of WB-EMS on body composition, muscle strength (Kemmler et al., 2018) and functional fitness (Jee, 2018) in young athletes and untrained elderly people (Kemmler et al., 2021).

The purpose of the study is to investigate the effect of whole-body electromyostimulation (WB-EMS) and resistance training (RT) on the level of functional fitness in a group of elderly women. Due

to the nature of the intervention program, we assumed that both types of training would result in a statistically significant increase in the level of strength abilities of the upper and lower limbs, while no statistically significant improvement would be recorded in the other monitored parameters.

METHODS

Study sample

The study sample was recruited from several sources. The printed leaflets were available at various sports grounds and rehabilitation centres in the city of Brno, informative emails were sent through the University of the Third Age of Masaryk University, and the faculty's social networks and websites were also used. Women who contacted us on the basis of the offer subsequently received detailed information and filled in the entry form (name and surname, age, contact, contraindications, and other restrictions). Based on these data, they were included/excluded in the research.

Our sample consisted of 63 elderly women that met the inclusion criteria:

- age 60–65 years old, without regular physical activity (< 60 minutes of regular physical activity per week), and no health contraindications (epilepsy, cardiac pacemaker implant, severe circulatory system, abdominal or inguinal hernia, cancer, advanced arteriosclerosis, severe neurological, disease, acute bacterial or viral disease, diabetes mellitus, bleeding disorders (haemophilia), liver disease, tuberculosis, severe circulatory system disorders (e.g. unstable angina pectoris), untreated hypertension, uncontrolled heart rhythm disturbances, heart failure, valve stenosis, hypertrophic cardiomyopathy, reduced mobility and metal implants (due to using of DXA).

All participants were asked to sign an informed consent form approved by the Ethics Committee of Masaryk University, Brno. The Ethics committee application number was EKV-2021-010.

The study sample was randomly divided into three groups – one group underwent a whole-body electromyostimulation training program (WB-EMS), another group underwent resistance circuit training (RT) and a control group (CG). The interventional program lasted for ten weeks. Participants were asked to maintain their usual daily regimen with the same amount of physical activity during the interventional program. Table 1 presents the base anthropometric characteristics (age, body weight, body height, BMI, body fat) in all followed groups.

Table 1. Base anthropometric characteristics in all groups

Variable	***WB-EMS*** (n=19)	***RT*** (n=22)	***CG*** (n=22)
Age (years)	62.68 ± 1.66	62.64 ± 1.85	62.61 ± 1.52
Bodyweight (kg)	72.61 ± 13.43	75.54 ± 8.61	77.412 ± 16.92
Body height (m)	165.26 ± 5.19	167.86 ± 5.73	166.73 ± 5.34
Body mass index (kg·m)	26.59 ± 4.81	26.86 ± 3.23	27.80 ± 5.63
Body fat (%)	39.81 ± 4.69	39.85 ± 3.12	39.42 ± 4.89

Note: WB-EMS - whole-body electromyostimulation group, RT – resistance training group, CG – control group. n – number of participants

Measurements

All participants underwent two identical experimental tests and measurements before and after the ten weeks of the intervention program. Firstly, the body composition was assessed using dual-energy X-ray absorptiometry (DXA). Then, the senior fitness test battery (SFT) determined the level of functional fitness in older women. All tests and measurements lasted about 40 minutes and were performed by trained personnel. The body composition measurements (DXA) were carried out in a laboratory.

Senior Fitness Test (SFT) was created to evaluate the individual components of functional fitness in older adults (Rikli & Jones, 2013). All Senior fitness subtests were performed in a gym:

- 30 Chair stand test: assessing the level of the strength of lower limbs,
- 6 Minute Walk test: assessing the level of endurance,
- 8 Foot up and Go test: assessing the level of agility, dynamic balance and reaction speed,
- Arm Curl test: assessing the level of the strength of upper limbs,
- Chair Sit and Reach test: assessing the level of flexibility of the lower limbs. The fingertips touching the toes is considered "0", overlapping is considered "+" and not touching "-".
- Back Scratch test: assessing the level of flexibility of the upper limbs. The tip of the middle fingers touching is considered "0", overlapping is considered "+" and not touching "-".

The dual-energy X-ray absorptiometry (DXA) assessed the body composition (BMI characteristics, muscle mass, body fat). This non-invasive method uses a very small dose (0,001–0,015 mSv) of ionising radiation. The body composition measurements were carried out in a laboratory using the whole-body scanner.

Interventional program

Whole-body electromyostimulation program

Whole-body electromyostimulation works on the principle of weak electrical impulses that stimulate motor units in muscles. The Miha Bodytec device is used, which consists of the main control panel and a training vest with electrodes that produce a weak electrical impulse to the muscles.

The WB-EMS group completed the exercise once a week and included 10 sessions. Those participants whose attendance was lower than 80 % were not included in the data analyses. The first training lasted 60 minutes when the tested persons were informed about the exercise method, and then the participants prepared for the first training. The intensity of the pulses was set up individually and was initial for the following exercise units. Following training sessions lasted 20 minutes and the basic whole-body exercise program was used. The program uses the traditional 4 s interval with gradual onset and 4 s interval of rest.

Table 2 describes the WB-EMS interventional training protocol in more detail.

Table 2. Whole-body electromyostimulation training protocol

WB-EMS unit	
Introductory part	Basic static position
Main part	
Workout 1	Half-Squat
Workout 2	Trunk Rotation (both sides)
Workout 3	Lunges (right leg to the front)
Workout 4	Lunges (left leg to the front)
Workout 5	Reverse Flies (forearms up)
Workout 6	Chest Flies (forearms up)
Workout 7	Side Lunges (both sides)
Workout 8	External Arms rotation
Workout 9	Back Extension
Workout 10	Triceps Kickback

Circuit resistance training program

The resistance training was carried out twice a week and included 20 sessions. Those participants whose attendance was lower than 80 % were not included in the data analyses. One week before the intervention, two trial training units took place, during which the test persons were instructed in the setting up of exercise machines and were shown the correct exercise technique. The individual load for individual exercises according to the ten-repetition maximum (RM) was set (= modification 1 RM for the elderly, the load they can lift 10 times). A load of 65–70 % 1RM was used for the first week of the intervention, and a load of 70–75 % 1RM was used from the second week of the intervention.

The training unit lasted 60 minutes. Table 3 describes the RT interventional training protocol in more detail.

Table 3. Resistance training protocol

Resistance training unit	
Introductory part	Warm-up Joint mobilization exercise, dynamic stretching
Main part	
Workout 1	Activation of the deep stabilization system
Workout 2	Bench press
Workout 3	Lunges back
Workout 4	Reverse Pec deck
Workout 5	Squats (with gymnastics ball supported by the wall)
Workout 6	Lat Pulldown
Workout 7	Leg Extension
Workout 8	Triceps Pulldown
Workout 9	Lying Leg Curls
Workout 10	Biceps Cable Curls
Final part	
	Static stretching

Data analysis

All analyses were conducted using Statistica 12.0 program. Data are presented as arithmetic group means, and the standard deviation (SD) of the mean. Data were examined for normality using a Kolmogorov-Smirnov test. Subsequently, two-way, repeated-measures ANOVA was undertaken for variables of the Senior Fitness Test between the groups. Statistical significance was set at $p \leq 0.05$.

RESULTS

Table 4 shows the basic descriptive characteristics (mean, standard deviation, minimal and maximal values) and the statistical significance values of individual Senior fitness tests measured before (pre-test) and after a ten-week lasting intervention program (post-test) in both interventions (WB-EMS, RT) and the control groups (CG).

Table 4 Descriptive statistics of Senior Fitness Test in all groups

	WB-EMS (n = 19)	***RT*** (n = 22)	***CG*** (n = 22)
6 Min Walk (m)			
Pre-test (M±SD)	649.00 ± 67.45	675.00 ± 29.94	621.90 ± 65.27
Pre-test (Min/Max)	537.5/780	625/738	513/744
Post-test (M±SD)	657.28 ± 52.2	688.43 ± 32.33	655.35 ± 70.94
Post-test (Min/Max)	582/775	631/734	535/775
p-value	0.95	0.59	0.14
Chair stand (number)			
Pre-test (M±SD)	17.73 ± 4.24	17.18 ± 3.71	17.47 ± 4.35
Pre-test (Min/Max)	12/27	12/29	11/26
Post-test (M±SD)	19.52 ± 2,98	21.00 ± 4,85	19.09 ± 4.08
Post-test (Min/Max)	14/25	15/31	13/28
p-value	0.12	0.04 *	0.00 *
8 Foot up and Go (s)			
Pre-test (M±SD)	4.36 ± 0.49	4.00 ± 0.58	4.42 ± 0.59
Pre-test (Min/Max)	3.5/5.28	3.4/5.94	3.4/5.94
Post-test (M±SD)	4.02 ± 0.41	3.70 ± 0.34	4.28 ± 0.48
Post-test (Min/Max)	3.2/5.1	3.23/4.41	3.49/5.5
p-value	0.34	0.03 *	0.13

Arm Curl Right (number)			
Pre-test (M±SD)	21.68 ± 3.84	22.86 ± 3.58	24.52 ± 3.44
Pre-test (Min/Max)	15/28	19/31	15/31
Post-test (M±SD)	24.31 ± 2.90	26.95 ± 3.42	25.33 ± 2.90
Post-test (Min/Max)	19/29	22/34	19/30
p-value	0.22	0.10	0.13
Arm Curl Left (number)			
Pre-test (M±SD)	21.00 ± 3.17	22.90 ± 3.25	24.23 ± 3.14
Pre-test (Min/Max)	14/27	16/29	17/30
Post-test (M±SD)	23.73 ± 2.64	26.40 ± 3.67	24.85 ± 2.74
Post-test (Min/Max)	19/30	21/34	20/31
p-value	0.70	0.67	0.50
Back Scratch Right (cm)			
Pre-test (M±SD)	-2.47 ± 8.66	-0.52 ± 7.36	-1.69 ± 8.05
Pre-test (Min/Max)	-24/9	-22/11	-17/14
Post-test (M±SD)	-0.50 ± 7.50	0.22 ± 6.63	-1.26 ± 7.92
Post-test (Min/Max)	-16/9.5	-18/8	-18/9
p-value	0.06	0.69	0.16
Back Scratch Left (cm)			
Pre-test (M±SD)	-6.65 ± 8.63	-4.54 ± 7.65	-7.90 ± 7.96
Pre-test (Min/Max)	-25/5	-20/9	-20/7
Post-test (M±SD)	-5.52 ± 8.59	-3.90 ± 7.98	-6.85 ± 8.12
Post-test (Min/Max)	-23/5	-21/11	-21/9
p-value	0.22	0.02*	0.13
Chair Sit and Reach Right (cm)			
Pre-test (M±SD)	7.60 ± 8.31	6.86 ± 9.69	8.71 ± 8.55
Pre-test (Min/Max)	-10/21	-14/20	-16/22
Post-test (M±SD)	9.13 ± 8.65	6.90 ± 8.73	8.19 ± 8.21
Post-test (Min/Max)	-4/27	-13/21	-15/24
p-value	0.57	0.05*	0.07

Chair Sit and Reach Left (cm)			
Pre-test (M±SD)	6.34 ± 10.76	7.25 ± 10.61	9.09 ± 8.38
Pre-test (Min/Max)	-19/21	-16/23	-16/21
Post-test (M±SD)	8.73 ± 9.24	7.59 ± 8.89	7.59 ± 9.19
Post-test (Min/Max)	-8/28	-13/21	-15/24
p-value	0.05*	0.18	0.00 *

Note: WB-EMS – whole-body electromyostimulation group, RT – resistance training group, CG – control group. n – number of participants, M - Mean, SD – standard deviation, SFT – Senior fitness test, p-value – statistical significance, * $p \leq 0.05$

The results demonstrate that both interventional programs (WB-EMS and RT) had a positive effect on the level of functional fitness. As can be seen from the data in Table 4, the RT group reported a statistically significant difference between pre-and post-test in values in the Chair Stand test assessing the level of the strength of lower limbs ($p = 0.04$), 8 Foot up and Go test assessing the level of agility, dynamic balance and reaction speed (0.03). Also, in the Back Scratch test (left side) evaluating the flexibility of the upper limbs and the Chair Sit and Reach Test (right side) evaluating the flexibility of the lower limbs we found statistically significant results ($p = 0.02$ in the Back Scratch test left side, $p = 0.05$ in the Chair Sit and Reach test right side).

The results reveal that the WB-EMS interventional program had a positive statistically significant effect only on the level of flexibility of the lower limbs measured by the Chair Sit and Reach test left side ($p = 0.05$). In all other SFT subtests in the WB-EMS group, same as in the RT group, we can observe an improving trend.

The statistically significant results indicated an increase in the level of the measured variables we also found in the control group in the Chair Sit and Reach test left side ($p = 0.00$) and in the Chair Stand test ($p = 0.00$).

It is interesting to follow the SD, minimal and maximal values reached in pre-and post-tests. SD values decreased almost in all subtests in the WB-EMS group (except the test Chair Sit and Reach right). This fact testifies to the equalization of the performance of individual tested persons. In contrast to the WB-EMS group, individual differences increased for the RT group after completing IP; SD rose for 3 subtests (6 Min Walk Test; Arm curl left; Back Scratch left). The same trend occurred in CG (6 Min Walk Test; Back Scratch left; Chair Sit and Reach left).

DISCUSSION

Old age is a period in a person's life in which many changes occur in the human organism. Consequently, these changes often have a negative effect on the quality of life and the level of self-sufficiency in the elderly. One of the means for maintaining them at a sufficient level is physical activity. However, due to health reasons, not all older adults can engage in regular physical activities in that positive way could affect the above-mentioned parameters. For this reason, one

of the interventional programs chosen in our study was the whole-body electromyostimulation (WB-EMS) which is also suitable for the elderly with various types of health restrictions (e.g., after surgery, injury, physical disabilities…). The second type of IP was, already more used, resistance training.

So, the study was aimed at investigating the effect of WB-EMS and resistance RT on the level of functional fitness in a group of elderly women. We supposed that for both types of IP, there would be a statistically significant improvement in the level of strength parameters of the lower and upper limbs (measured by tests: Arm curl and Chair stand). Based on the results, we reject the established hypothesis.

In comparison to WB-EMS and RT groups, better results were confirmed in the RT group. Despite the fact, that the development of agility, dynamic balance and reaction speed were not the main aim of the IP, the RT group achieved precisely the best result in the 8 Foot up and Go test ($p = 0.03$). This positive result could be caused by the learning effect in the post-test measurements or the application of dynamic stretching exercises more demanding on the balance abilities in the warm-up.

The training units of the RT group focused on hypertrophy and increasing the level of strength. Due to the principle of specificity, the second most visible improvement appeared in the tests assessing the strength of the lower extremities measured by the Chair Stand test ($p = 0.04$). The resistance training included specific exercises for the Chair Stand Test (squats with a gymnastic ball, lunges back) which probably increased the effect of training on SFT. Although leg extensions and lying leg curls are not specific exercises to increase the effectiveness of squats and the Chair Stand Test, their inclusion may have a favourable effect on the level of flexor and knee extensor strength that is essential to the Chair Stand Test.

Also, in the parameter of the flexibility of lower and upper limbs in the RT group, we monitored the statistically significant enhancement. Although, as with the 8 Foot up and Go test, the IP was not aimed at developing the level of flexibility, the joint mobilization exercises (preparation before circuit training) included as a necessary part of the unit, may have influenced the result. The significant change in flexibility can also be caused by sufficient frequency and intensity of static stretching at the end of the exercise unit. Static stretching is effective enough to compensate for the unfavourable effects of resistance training on flexibility levels (Marques et al., 2009) and also to faster the regenerative processes after this type of training load.

Even if the other tested parameters did not show statistically significant results, we can observe the improving tendency. The study conducted by Todde et al. (2016) applying resistance training, confirmed the statistical improvement of all tests, except the 8-Foot Up and Go Test, despite the low specificity of the training units, especially in terms of flexibility. Participants achieved high heart rate values during the training, which could be a decisive factor leading to maximum training efficiency.

The results of our research slightly differ from the results of the research led by Liuet et al. (2009), whose intervention program consisted of progressive resistance training. Their conclusions indicated an increase in the level of muscle strength of the upper and lower extremities. The improvement of the remaining functional parameters was minimal. A statistically significant improvement of some functional parameters, a slight improvement and stagnation indicate

a positive effect of this intervention on the level of functional fitness. Recommendations for improving the level of functional fitness suggest repeating resistance training three times a week with an individual load intensity of 80% of the one-repetition maximum (1RM) (Papa et al., 2017). Ferguson (2014) also states that high-intensity training performed 2–3 times per week is the best method to reduce the prevalence of sarcopenia.

The results show the WB-EMS group increased significantly only the level of flexibility of the lower limbs measured by the Chair Sit and Reach test left side ($p = 0.05$). The other abilities revealed only a positive trend of increasing the level of the monitored parameter. However, it must be remembered that due to the natural decrease in the level of functional fitness with increasing age, stagnation or slight enhancement of parameters of functional fitness could be assessed as a positive result.

The synthesis of the findings does not show that many studies focused on the effect of WB-EMS on the level of functional fitness in the elderly, which could be a question for further, long-term research. Kemmler et al. (2021) mediated a meta-analysis dealing with the effect of WB-EMS on various parameters, which showed a statistically significant change in muscle mass, lower extremity strength, and back extensor strength. However, it did not show a positive effect on body fat, which is affected by caloric intake. We also know from the synthesis of knowledge that long-term training with progressive overload continues to have a positive effect on the level of functional fitness and reduction of sarcopenia, and individuals can improve this rate with some speed and to some extent. Sufficient volume and progressive overload are needed for strength adaptation and muscle tissue hypertrophy. Even after the interruption of physical activity, the adaptation does not completely disappear. Individuals after three years without physical activity, who trained for two years in the form of resistance training, had more strength after these five years than before the start of strengthening (Smith et al., 2003).

The statistically significant results indicated an increase in the level of the measured variables we surprisingly found also in the control group, more precisely in the Chair Sit and Reach test left side ($p = 0.00$) and in the Chair Stand test ($p = 0.00$). The results could be influenced by the season in which the measurements and interventional program took part. The interventional programs were held in spring or in autumn when older adults are engaged in gardening walking or cycling in nature. As already mentioned in the text above, also the learning effect or the level of motivation could positively influence the results. Despite the random division of the tested persons into groups, we have to state that the control group achieved very good results already in the pre-test. Due to this fact, in future research, we think about the division based on other criteria.

CONCLUSION

To conclude, this study tried to determine the effect of a ten-week lasting RT and WB-EMS interventional program on the level of functional fitness in a group of elderly women.

The results of all individual components of functional fitness measured by SFT in both experimental groups (WB-EMS, RT) show an improving tendency. Comparing WB-EMS and RT groups, better results were confirmed in the RT group. Some of the followed parameters indicate

statistically significant improvement ($p < 0.05$) – the level of the strength of the upper and lower extremities, the level of agility, dynamic balance and reaction speed and the level of flexibility of the upper and lower limbs in the group of RT. In the group WB-EMS, we found statistically significant results only in the level of mobility of one side of the upper extremities. We also consider the fact that both groups improved in all other tests to be very positive. Apart from the importance of maintaining the level of physical fitness in older adults at a sufficient level, the positive impact of physical activity on some other anthropometrical (e.g., maintaining the amount of muscle mass as a prevention of osteoporosis) and physiological aspects (e.g., lowering of blood pressure) must not be omitted. The following study could be focused on determining the effect of these two interventional programs on bone mineral density and T-score values in women at risk of sarcopenia.

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Construction and Validation of Newly Developed Triangle Test of Reactive Agility in School Children

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ABSTRACT

PURPOSE: Agility is described as a rapid whole-body movement with change of velocity or direction in response to the different stimuli. Scientific research identified two independent types of agility performances: pre-planned agility (CODS) and non-planned agility (RAG). CODS represent generic movement patterns. They can mimic the demands of a sport but all of the movements are pre-planned. In CODS there is no response to a stimulus like in RAG where movements are in response to cues such as the movements of the ball or actions of the opposition players. Literature review show lack of studies that assessed CODS and RAG in children, most probably due insufficiency in quality testing protocols. Hence, the purpose of this study was construction and validation of newly developed agility test that measures RAG performances in children. METHODS: For this purpose, the Blaze Pod system (BP) was used. Three lighting pods were mounted on three 50 cm cones in triangle formation with 4,5 meters distance between cones (TRGA). Results were collected via BP app. Four movement patterns were used to test RAG. Start and finish of the tests were conducted with the tap on BP pods. The sample comprised of 80 elementary school children (boys; n = 39, age = 14.88 ± 0.36 yrs, height = 174,3 ± 7,46 cm, mass 67,86 ± 16,78 kg, and girls; n = 41, age = 14.85 ± 0.31 yrs, height = 167.49 ± 5.72 cm, mass = 59.34 ± 10.54 kg). Statistical analysis included calculation of normality of distribution, reliability coefficients, correlations and analysis of variance. RESULTS: Tests showed acceptable reliability with CA = 0.58, ICC = 0.32 for boys and CA = 0.78, ICC = 0.55 for girls. Inter-item correlations were higher in girls' sample (r = 0.49–0.64) than in boys (r = 0.27–0.41). Also, test showed good sensitivity, normal data distribution and good homogeneity with no differences between items (boys; F = 0.07, p = 0.93; girls; F = 0.13, p = 0.88). Better reliability of TRAG test for girls is most probably caused by gender morphological differences. Namely, we observed greater standard deviations (SD) of height (BH) and mass (BM) in boys (boys; BH = 7.37, BM = 16.97; girls; BH = 5.68, BM = 9.7) and scientific research confirmed negative influence of BM and BH on reactive agility performance. CONCLUSION: Altogether, newly constructed TRGA test seems to be reliable instrument for measuring reactive agility in pubescent boys and girls.

Keywords: non-planned agility, metric characteristics, pubescents, gender

INTRODUCTION

Agility can be described as ability to effectively change movement direction, accelerate and decelerate, without losing balance. According to Sheppard & Young (2006) agility is whole-body movement with change of velocity or direction in response to a stimulus (Sheppard & Young, 2006). It has been suggested that agility is a key condition for optimal performance in sports (Jeffreys, 2006). According to literature, two types of agility has been defined; change of direction speed or pre-planned agility (CODS) and reactive, non-planned agility (RAG). CODS have been described as preplanned movements with no decision making, while on the contrary, RAG appear in response to a stimulus, commonly from opponent's action. Both of these agility types occur in majority of sport activities. In more complex activities, such as team sport games, RAG is more important for successful performance (Young & Willey, 2010).

During everyday play, children find themselves in situations which require change of speed and direction in response to some external stimuli. In their sport games or unstructured games, they have to regulate speed and movement direction and to anticipate the actions of others to avoid bumping into each other. In order to do so they have to develop motor skills but also perceptual skills essential for agility (Serpell, Ford, & Young, 2010). In a similar way, tests to assess agility should be constructed in a way to provide similar stimulus as during a game or sport.

The majority of previous literature show lack of studies that assessed RAG and has more closely examined CODS in children and adolescents who participate in/train different sports. In the study of Eler & Eler (2018) authors concluded that set of agility exercises conducted for 10 weeks has positive effect on COD speed performance (Eler & Eler, 2018). Furthermore, in the study of Acar & Eler (2019) authors have investigated effects of 8-week balance exercises on the speed and agility in 10-12-year-old children in physical education lessons to have a positive effect on speed and CODS (Acar & Eler, 2019). Study made by Sekulic et al. (2014.) investigated the influence of balance, jumping power, reactive-strength, speed, and morphological variables on five different CODS performances in early pubescent boys (Sekulic, Spasic, & Esco, 2014). Authors have concluded that reactive strength was found to be the most important predictor of agility.

However, the lack of research of RAG in school children could be due to insufficiency in quality testing protocols. Furthermore, testing RAG for the mentioned population can be complicated, difficult and technologically demanding. The last one could be the reason why RAG testing started to appear in last few years. Also, most of the testing was done in sports clubs as a result of improving sport performance. As change of direction ability is considered primordial quality in many activities and important physical component related to youth health status (Sporis, Jukic, Milanovic, & Vucetic, 2010; Vicente-Rodríguez et al., 2011; Young, McDowell, & Scarlett, 2001). The purpose of this study was construction and validation of newly developed agility test that measures RAG performances in school children.

METHODS

The study included 7^{th} and 8^{th} grade children (n = 80; boys; n = 39, age = 14.88 ± 0.36 yrs, height = 174,3 ± 7,46 cm, mass 67,86 ± 16,78 kg, and girls; n = 41, age = 14.85 ± 0.31 yrs,

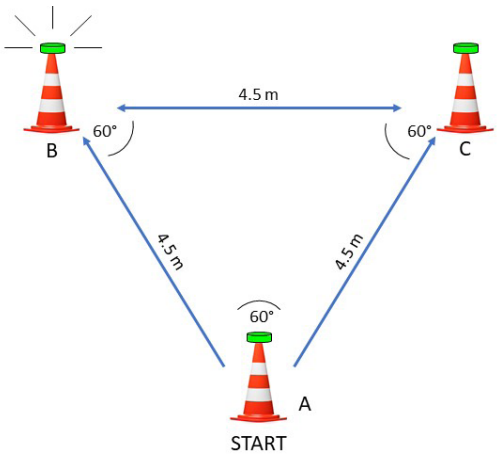
height = 167.49 ± 5.72 cm, mass = 59.34 ± 10.54 kg), all of them attending the same elementary school in Split, Croatia. Testing was performed during physical education classes. All participants were in a good health and none of them reported any current injuries specific to the ankle, knee or hip joints that might be expected to affect performance during the test. All parents of students gave their written informed consent before inclusion in the study. Informed consent was also obtained from the school principal.

Subjects performed newly constructed "Triangle" RAG test (T RAG) at the beginning of their physical education (PE) class. The test was performed in the school gymnasium on the wooden floor and all PE classes were held in the morning shift. Before testing, the participants had completed a 5 min warm-up which consisted of jogging, skipping, lateral running and light jumping. All students were familiarized with T RAG test procedure before data collection. Also, before T RAG test student made two running patterns of CODS test to additionally familiarize with Blaze Pod (BP) system which was used for the purpose of the study. Three lighting pods were mounted on three 50cm cones in triangle formation with 4,5-meter distance between cones which is convenient distance for lighting pods to be in their visual perception field without looking down. The height of the cones forces the participants to be in athletic position which is suitable for fast change of direction. The participants were instructed to begin the test standing next to the starting cone, with their preferred foot forward. The foot of the front leg was placed laterally in relation to the cone. To start the T RAG, students would tap the first lighting pod (A), run to the next lighted cone, touch the designated pod, which triggers the last one. The testing was arranged in groups of 4-5 participants, which allowed for appropriate rest period between the tests. The rest interval was not was not less than 20 s between trials. For the TRAG test, participants did not know the scenario and were tested by the same four templates; (first trial: A–C–B, second trial: A–B–A, third trial: A–C–A, fourth trial: A–B–C). Each participant conducted three random trials. Results were collected via BP application.

Statistical analysis included calculation of descriptive statistics, means and standard deviations for each "Triangle" attempts. The Kolmogorov – Smirnov (KS) test was used to check the normality of data distribution. Reliability of the newly developed test T RAG was calculated with correlation analysis, inter-item correlation and Crobmach's alpha coefficients.

For all the analyses, Statistica 14.0 (TIBCO Software Inc., Palo Alto, CA, USA) was used.

Figure 1. T RAG test



RESULTS

Results of descriptive statistics are shown in table. From KS test results can be noticed that all variables have normal data distribution. As so, they are suitable for parametric statistical calculations. Results of distributions' skewness and kurtosis refers on good test sensitivity since all its results fits in normal range except third item in male subjects (skew = 1.14; kurt = 3.34).

Table 1. Descriptive statistics

Variables	Mean	Min	Max	SD	Skew	Kurt	KS	p
T RAG 1 M	3.68	2.77	5.09	0.58	0.57	0.00	0.11	p > .20
T RAG 2 M	3.63	2.10	5.47	0.68	0.56	0.94	0.12	p > .20
T RAG 3 M	3.67	2.10	6.15	0.72	1.14	3.34	0.13	p > .20
T RAG 1 F	3.87	2.92	5.32	0.58	0.56	-0.09	0.11	p > .20
T RAG 2 F	3.88	2.77	6.20	0.62	1.01	3.69	0.10	p > .20
T RAG 3 F	3.86	3.22	5.05	0.43	0.63	0.28	0.09	p > .20

Legend: T RAG - "Triangle" RAG test, **M** – male student, **F** – female student, **1** – first attempt, **2** – second attempt, **3** – third attempt, **Mean** – arithmetic mean, **Min** – minimum, **Max** - maximum, **SD** – standard deviation, **Skew**– skewness, **Kurt** - kurtosis, **KS** – Kolmogorov-Smirnov test

Table 2. shows correlations between the items of measurement of newly constructed test for reactive agility in school children (T RAG). Significant correlations were found between all items of measurements in both samples. In male sample they ranged from 0.27 to 0.41, and in female sample from 0.49 to 0.64. Obviously, higher correlations are between items in female sample.

Table 2. Correlations between the items of newly constructed test

Variables	T RAG 1 M	T RAG 2 M	T RAG 3 M	Variables	T RAG 1 F	T RAG 2 F	T RAG 3 F
T RAG 1 M	1.00			**T RAG 1 F**	1.00		
T RAG 2 M	0.41 *	1.00		**T RAG 2 F**	0.64 *	1.00	
T RAG 3 M	0.27 *	0.29 *	1.00	**T RAG 3 F**	0.49 *	0.53 *	1.00

Legend: T RAG - "Triangle" RAG test, **M** – male student, **F** – female student, **1** – first attempt, **2** – second attempt, **3** – third attempt, ***** – significant correlation

Reliability coefficients (inter-item correlation and Crobmach's alpha) and results of analysis of variance between items of measurements are shown in table 3. Inter-item correlation coefficients (0.32-0.55) and Crobmach's alpha coefficients (0.58–0.78) show average to good reliability of newly constructed test for male and female respectively. When connected with results of correlations shown in table 2, and respecting sample size and specificity we may state that new test T RAG has good reliability and that has the ability of the scorer to produce the same result each time for the same T RAG test performance. Similarly, results of analysis of variance between items of measurements indicate that there are no significant differences between them in both samples. This means that results in different items don't depend on systemic errors. Generally, that test has good homogeneity and can be used as valid diagnostical tool for assessing reactive agility.

Table 3. Inter-item correlation, Crombach's alpha and analysis of variance

VARIJABLE	II r	Crombach's alpha (α)	F	p
T RAG M	0.32	0.58	0.07	0.93
T RAG F	0.55	0.78	0.13	0.88

Legend: T RAG M – Male "Triangle" RAG test, **T RAG F** – Female "Triangle" RAG test, **II r** – inter item reliability coefficient

DISCUSSION

Results of the study indicate three important findings: (i) newly designed reactive agility tests has good sensitivity, (ii) newly designed reactive agility tests has average reliability, and (iii) newly designed reactive agility tests has good homogeneity.

Sensitivity

A sensitive protocol is one that is able to detect small, but important, changes in performance (Paul & Nassis, 2015). In our study, we observed consistent changes in performance between subjects in different items of measurement and therefore concluded that test has good sensitivity. Anyhow, bigger data dispersion was noticed in T RAG 3 M sample and in T RAG 2 F. Cause for this could be searched in previous test that was used as familiarization protocol in which students had determined movement mode and which has been conducted as non-reactive test (T CODS). Most probably, because of its' similarity, this test confused some of the students and they were focused on "wrong" cone, late noticed mistake and consequently performed weaker in this item of measurement. Also, T RAG 2 F sample was conducted in the left side. We can assume that for majority of female students this was "weak side" and they reacted/performed slower than in other items of measurement. "Weak side" slower performance in agility tests was reported before in football, futsal, basketball and handball players, and we assume that this phenomena was present in our study also (Krolo et al., 2020; Pokrajčić, Marić, Foretić, & Uljević, 2021; Sekulic et al., 2019; Sekulic et al., 2017).

Reliability

The reliability of a test is an elementary prerequisite of the test's applicability because it directly indicates the error of measurement (Uljevic, Esco, & Sekulic, 2014). Significant correlation between the three T RAG movement patterns (II r) indicate good reliability of the T RAG test. Also, good value of Cronbach-alpha coefficients (α) for T RAG F and average value for T RAG M shows satisfactory reliability and reduced error of measurement. Reliability of newly constructed T RAG test is similar to reactive agility test in other studies (Krolo et al., 2020; Pojskic et al., 2018). But, like in before mentioned studies, T RAG test has lower reliability than it was reported in studies dealing with CODS tests (Dugdale, Sanders, & Hunter, 2020; Krolo et al., 2020; Serpell et al., 2010). Reactive agility tests are more complex and dependable on different physical features of the athletes (Sheppard & Young, 2006). Most of the time they demand sophisticated measurement tools, are consisted of short and fast movements that appear after cognitive and motor reaction/activity of the athlete. Unlike during CODS testing, every small mistake in test performance by

athlete (e.g. inadequate sport shoes, slippery surface, etc.) or assessment by measurer (fuzzy test instruction, lousy control of measurement equipment, etc.) can significantly influence final result in performance. When having in mind that subjects in our study were elementary school students with very low exposure to agility stimuli lower reliability than in CODS testing protocols is not unexpected.

Homogeneity

Homogeneity is feature of test whish shows how results in all items of measurement are dependable on the same subject of measurement. T RAG test show good homogeneity since there wasn't noticed significant difference between items of measurements. Obviously, no systemic error, such as "learning effect" or subjects' fatigue, appeared during test performance. Hence, we conclude that T RAG test has good homogeneity and is valuable protocol for diagnosing reactive agility.

CONCLUSION

The purpose of this study was construction and validation of newly developed agility test that measures RAG performances in children. Tests showed acceptable reliability and therefore may be used as appropriate test in evaluation of RAG in pubescent boys and girls. Also, test showed good sensitivity, normal data distribution and good homogeneity with no differences between items. Better reliability of constructed T RAG test for girls is most probably caused by gender morphological differences. Namely, we observed greater standard deviations of height and mass in boys and scientific research confirmed negative influence of BM and BH on reactive agility performance. In future research, it might be important to separate children which are involved in agility saturated sports and familiar with running technique than kids who are not, which could be considered as possible limitation of this study.

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Pilot Study: Effect of Developmental Dysplasia of the Hip on the Gait.

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ABSTRACT

Background: The objective of this pilot study was to assess the effect of Developmental Dysplasia of the Hip (DDH) on gait, in pediatric participants, between the age of one to four years. Few studies are investigating the effect of DDH on the walking pattern within the pediatric rehabilitation practice. From an early age, children are developing a longitudinal foot arch. Constantly changing pediatric foot posture must be assessed. Gait pattern and foot posture are one of the most common parental concerns.

Methods: The retrospective review of gait analysis, performed on 410 lower limbs, took place in King Abdullah Specialized Children Hospital (KASCH) in Riyadh, Kingdom of Saudi Arabia, from April 2020 until September 2020. All participants were diagnosed with DDH by pediatric orthopedics physicians in KASCH. Gait analysis was done by a physical therapist twice within three months, using The Wee Glasgow Gait Index (WeeGGI) and foot assessment was done once using Foot Postural Index (FPI-6). The WeeGGI compares eleven gait parameters. Each parameter has a choice of three figures, where each one has a clear explanation and/or value. The FPI-6 evaluates the foot as multi-segmental complex, in double leg support, characterizing pronation with + (plus) and supination with - (minus) numbers. Scoring is 2 (two) points in all six factors it is divided into rearfoot and forefoot assessment in transverse, frontal/transverse, frontal, and sagittal planes.

Results: From all gait analyses (n = 410). We included only 292 (71%) lower limbs with DDH and had to exclude 60 (15%) after hip surgery, 30 (7 %) with another diagnosis, 18 (4%) without conservative treatment of DDH, and 10 (3%) with age above 48 months. According to the scoring of the Wee Glasgow Gait Index within the optimum/normal limits (score 0 – zero), we had 50 (17%), mild deviation (score 1–11) 236 (81%), and gross deviation (score 12–22) had 6 (2%) limbs within first gait analysis. With second gait analysis, 40% of lower limbs

were within optimum/normal limits, 60% with mild deviation in gait, and zero within gross deviation. Every limb assessment for gait had the Foot Postural Index as well. Within normal limits (0 till +5) 143 (49%) feet, pronation (+6 till +9) was presented in 97 (33%) and high pronation (more then +10) had 52 (18%) pediatric feet. This sample did not present supination (-1 till -4) or high supination (-5 till -12). Limping was observed within 102 (35%) of the legs. The frequency of W-sitting presented in 47% of the results. The first and second gait analysis suggest an effect of DDH on the gait with a small difference between the right and left leg, although the left side was affected more within both gait analyses.

Conclusion: Pathological gait pattern with DDH was detected in 83% within the first gait analysis, 60% within the second gait analysis, and Foot Postural Index revealed pronation of 51% feet. Among Saudi participants, a relatively high effect of DDH on gait patterns is reported in this pilot study.

Keywords: DDH, gait, FPI-6, physiotherapy, WeeGGI

INTRODUCTION

Developmental Dysplasia of the Hip (DDH) can be described as an abnormality of the articular or/and periarticular structures. The biomechanical point of view is defined by hip instability, acetabular abnormalities, and capsular laxity (Marinela, 2013). The posture of the pediatric foot had been explained by footprint in many published research. From early childhood, children are developing a longitudinal foot arch, in compare with the adult arch. Constantly changing pediatric foot posture must be assessed, during every milestone stage, and any change in patient health, such as hypotonia, hypermobility - developed as non-specific, or other syndromes, such as Down syndrome, must be noted in a patient chart (Gijon-Nogueron, Martinez-Nova, Alfageme-Garcia, Montes-Alguacil, & Evans, 2019).

Zgoda et al. in 2009, published a study, about the effect of DDH conservative treatment, with abduction braces, and the effect on locomotion, in comparison with the healthy group. The conclusion revealed that conservative treatment of DDH does not cause locomotor delay and participants with DDH start to walk, only three weeks later than healthy participants (Zgoda, Wasilewski, Wasilewska, & Golicki, 2009).

Pediatric patients with treated DDH in comparison with healthy children are showing abnormal gait pattern with its effect on posture, knee and ankle joints. Repetitive high loading rates at lower limb joints were presented at heel-strike phase (Lee, Chen, Hung, Wang, Chang, & Lu, 2021).

Evans (2012) critically reviewed, in her commentary, the importance of foot screening for pediatric candidates based on screening programs developed by the World Health Organization (WHO). It's revealed that screening for flat feet in a pediatric patient, should be as important as screening for DDH (Evans, 2012). Gijon-Nogueron et al. (2019) mentioned the absence of flat feet definition, which is leading to different opinions and a lack of unity on the best treatment plan. Gait pattern and foot posture are one of the most common parental concerns. Regardless of the evidence, that flat feet at pediatric age are a concern of many parents, the published treatment plan is weak (Gijon-Nogueron,

Martinez-Nova, Alfageme-Garcia, Montes-Alguacil, & Evans, 2019). Limping gait is another reason for a parent to make an appointment with a general physician or other health care professionals (Raja, Khan, & Waheed, 2020). Every foot deviation may indicate the pathology or dysfunction in other body sections (Oleksy, Mika, Łukomska-Górny, & Marchewka, 2010).

Early physical therapy for DDH infants presents an extensive role in developing proper milestones. Parent plays an essential role in physical therapy treatment plan, especially with Vojta therapy, as a home program. The results revealed improvement in complex factors in local and general milestone development (Marinela, 2013).

The aim of this pilot study was to assess the effect of DDH on gait and feet posture, in pediatric participants, between the age of one to four. Project hypothesis were: H1 DDH affect gait and foot posture of children from one to four years. H2 DDH affects lower limb and feet unilaterally. There are few studies investigating the outcome of DDH on gait appearance within the pediatric rehabilitation practice. They focused on a different part of the gait pattern.

METHODS

The pilot study was conducted at the Pediatric Rehabilitation Clinic at King Abdullah Specialized Children Hospital (KASCH) Riyadh, Kingdom of Saudi Arabia (KSA). King Abdullah International Medical Research Study, Riyadh, KSA we obtain IRB approval number SP21R/364/06 and the Ethics Committee, approval EKV-2021-018 by The Masaryk University Research Ethics Committee, Brno, Czech Republic. We retrospectively reviewed 410 gait analysis from April 2020 until September 2020. All participants were followed by one of the outpatient physiotherapists, with a physician referral from one of the outpatient clinics in KASCH. We suggest using gait and foot analysis to improve pediatric physiotherapy outcome measures and enhance patients' discharge. Physical therapists performed gait analysis at least twice within three months using the Wee Glasgow Gait Index (WeeGGI).

- Including criteria:
    a) participants one to four years of age,
    b) DDH diagnosis,
    c) at least two gait analyses within three to six months.
- Excluding criteria:
    a) hip surgery,
    b) less than two gait analyses,
    c) age above four years,
    d) participants with other diagnoses.

The corridor of the Pediatric Rehabilitation Unit in KASCH was prepared for gait analysis, and foot posture was observed in one of the treatment rooms. Participants were assessed barefoot on a hard floor, walking for at least ten steps independently without support or holding a wall/parent/walker, and with no specific equipment. Parents agreed with gait and feet analysis by signing informed consent Ethical approval.

The WeeGGI is a gait assessment and screening tool intended for the clinical setting and any clinicians. It is an easy observational tool to assess any gait deviation from normal at specific phases of the cycle, a demonstrative form on two A4 pages (Tennant, Wiggins, Read, & Meadows, 2012). The WeeGGI is comparing eleven gait parameters. Each parameter has a choice of three figures, where each one has a clear explanation and/or value. Scoring is for every parameter or figure is a must, optimum/normal position is marked by zero (0), a mild deviation is one (1), and two (2) is for gross deviation. The scale of 22 points considers scoring of all eleven parameters. The highest score suggests affected gait pattern, and it should be the indication for physical therapy (Tennant, Wiggins, Read, & Meadows, 2012).

The FPI-6 evaluate the foot as multi-segmental complex, in double leg support, characterizing pronation with + (plus) and supination with - (minus) numbers. Scoring is 2 (two) points in all six factors it is divided into rearfoot and forefoot assessment in transverse, frontal/transverse, frontal, and sagittal planes. Rearfoot analysis content Talar head palpation in the transverse plane, curves above and below the lateral malleolus in frontal/transverse position, and inversion/eversion of the calcaneus in frontal view. Forefoot factors were prominence in the region of the talonavicular joint (TNJ) in the transverse face, congruence of the medial longitudinal arch in the sagittal plane, and abduction/adduction forefoot on rearfoot in transverse view (Redmond, Crane, & Menz, 2008) (Gijon-Nogueron, Martinez-Nova, Alfageme-Garcia, Montes-Alguacil, & Evans, 2019).

DDH was diagnosed by the pediatric orthopedics clinic in KASCH using pelvic radiographs. In Saudi Arabia, a pelvic radiograph was performed by a radiography technician supervised by a radiology consultant, and the results are inserted in Best Care Medical System by a radiographic physician (Vasilcova, et al., 2022). The acetabular angle using the Hilgenreiner line should be <28º at birth. It should become progressively shallower and measure <22º beyond one year of age (Weerakkody, 2005).

The collected data were entered, reviewed, and analyzed. Descriptive statistics are presented as frequencies and percentages (%). Statistical analysis was carried out using Statistical Package for Social Science version 24 (IBM Corp., Armonk, New York, USA).

RESULTS

We review 410 gait analyses done by the pediatric physiotherapy team in KASCH. Each reported assessment was for the right or/and left lower limb. From all gait analyses (n = 410), only 292 (71%) with DDH included and 60 (15%) after hip surgery, 30 (7%) with another diagnosis, 18 (4%) without conservative treatment of DDH, and 10 (3%) above 48 months we excluded (Table 1). Among attendants with DDH were 56 (19%) males and 236 (81%) females (Table 2).

Table 1 Demographic information

Gait analyses	Total sample (%)
DDH	292 (71%)
Hip surgery	60 (15%)
Another diagnoses	30 (7%)
No conservative treatment	18 (4%)
Above 48 months of age	10 (3%)

The youngest attendant had 11 months of age, one male and three females, and the oldest was male 29 months old. The median age for males was 13,5, and the median for females was 14 months. Right side DDH presents in 128 (44%), left DDH in 140 (48%), and bilateral DDH had 24 (8%) hips. We Collected demographic information on avascular necrosis of the femoral head, which presented in only 0,5%. Limping was observed within 102 (35%) of the legs. Lower limb discrepancy is present in 8 (3%). According to our collection of demographic information the frequency of the W-sitting presented in 47% of the results. More demographic data are in Table 2.

Table 2 Demographic information

Demographic information	Categories	Total sample (Median, %)
Age	Male	13,5
	Female	14
Gender	Male	56 (19%)
	Female	236 (81%)
Side of DDH	Right side	128 (44%)
	Left side	140 (48%)
	Bilateral DDH	24 (8%)
Step position	In-toeing	14 (5%)
	Out-toeing	68 (23%)
Coxa valga/vara presentation	Coxa valga bilateral	8 (3%)
	Coxa valga Rt	4 (1%)
	Coxa valga Lt	4 (1%)
	Coxa vara Rt/Lt/bilateral	0
Avascular necrosis of the femoral head	–	2 (0.5%)
Limping gait pattern	–	102 (35%)
Lower limb discrepancy	–	8 (3%)
W-sitting position	–	138 (47%)

According to the scoring of The Wee Glasgow Gait Index within the optimum/normal limits (score 0 zero), we had 50 (17%), mild deviation (score one until 11) had 236 (81%), and gross deviation (score 12 till 22) had 6 (2%) lower limbs within first gait analysis. With second gait analysis, we received 242 filled forms with results: 40% with optimum/normal limits, 60% with mild deviation in gait, and zero with gross deviation (Table 3). Every leg assessment for gait had the Foot Postural Index too. Within normal limits (0 till +5) we had 143 (49 %) feet, pronation (+6 till +9) was presented in 97 (33%) and high pronation (more then +10) had 52 (18%) pediatric feet. Supination (-1 till -4) or high supination (+5 till -12) was not detected within this sample (Table 3).

The project hypothesis assumes the effect of DDH on gait and foot posture. Another hypothesis concludes that DDH affects the feet unilaterally results described in graphs 3 and 4. We assess both lower limbs for gait analysis separately to see if DDH affects gait unilaterally. In line with our results no big difference between the right and left limbs. Within the first gait analysis (n = 292), optimum/normal results had 24 (8%) right and 26 (9%) left legs, mild deviation presented 119 (41%) right and 117 (40 %) lower limbs, and gross deviation showed 2 (0,5%) right and 4 (1%) left legs (Table 3). During the second round of gait analysis from the same sample, we had 242 (first gait n = 292) results for evaluation.

Optimal/normal results were observed in 49 (20%) the right and 48 (20%) left lower limbs, mild deviation presented in 65 (27%) right and 80 (33%) left legs, and gross deviation of zero on the right and left limbs (Table 3). The first and second gait analysis suggest effect of DDH on the gait with a small difference between the right and left leg, although the left side was affected more within both gait analyses. These results support our hypothesis. However further studies are required and needed.

Table 3 Right and left lower limb with first and second gait analysis.

Lower limb side	WeeGGI 1 normal	WeeGGI 2 normal	WeeGGI 1 mild deviation	WeeGGI 2 mild deviation	WeeGGI 1 gross deviation	WeeGGI 2 gross deviation
Right LL	24 (8%)	49 (20%)	119 (41%)	65 (27%)	2 (0.5%)	0
Left LL	26 (9%)	48 (20%)	117 (40%)	80 (33%)	4 (1%)	0

*Results are in total number of lower limbs and %.

Every leg with gait analysis (n=292) had FPI-6 as well. Within normal limits (0 till +5) we had 143 (49%) feet, pronation (+6 till +9) was presented in 97 (33%) and high pronation (more then +10) had 52 (18%) pediatric feet. Supination (-1 till -4) or high supination (+5 till -12) was not detected in this sample (Figure 4). FPI-6 was done separately for the right and left foot. Results in normal range had 70 (24%) right and 73 (25%) left, pronation was measured in 49 (17%) right and 48 (16%) left and high pronation had 27 (9%) right and 25 (9%) left feet (Table 4, Figure 4). The right foot posture was more affected than the left foot. Although more research is needed, these results support our hypothesis that DDH affects foot posture unilaterally.

To detect the effect of DDH, we divide both analyses for the right and life sides and compare them (Table 4, Figure 4). The highest difference was within the result of gross deviation and high pronation. WeeGGI for the right lower limb was 2 (0,5%) FPI-6 high pronation in 27 (9%) of right feet. 4 (1%) left pediatric legs had gross gait deviation, and 25 (9%) had high left pronation. The result suggests no effect of high pronation on the gait pattern. Outcomes for mild gait deviation and feet pronation, the right WeeGGI 119 (41%) and right FPI-6 49 (17%), for left WeeGGI 117 (40%) and left FPI-6 48 (16%) with outcomes that mild gait deviation is not affecting the foot posture on either side. These results suggest that feet posture may not affect the gait and vice versa, but both gait and feet posture might be affected by DDH.

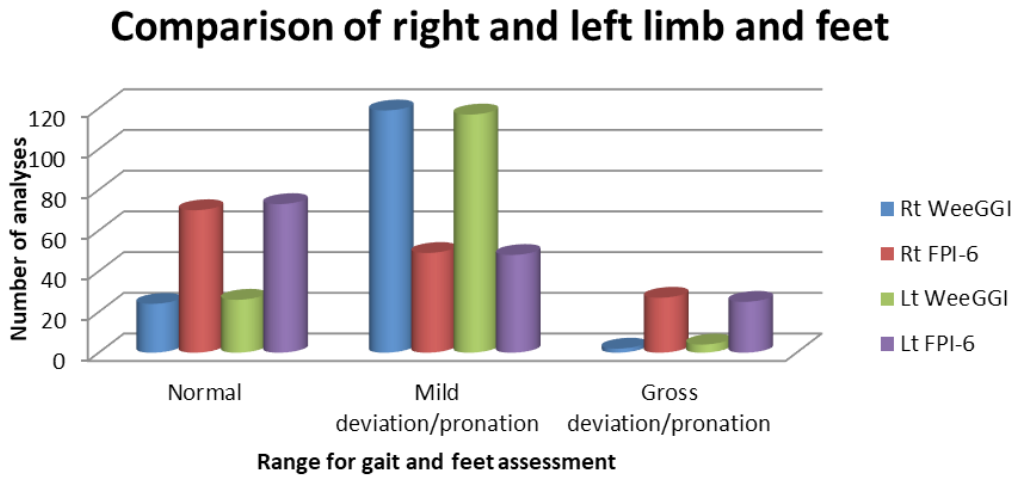

Figure 4. The Wee Glasgow Gait Index and Foot Postural Index analysis comparison

Table 4 The Wee Glasgow Gait Index and Foot Postural Index analysis comparison

Results description	Right WeeGGI	Right FPI-6	Left WeeGGI	Left FPI-6
Normal	24 (8%)	70 (24%)	26 (9%)	73 (25%)
Mild deviation/pronation	119 (41%)	49 (17%)	117 (40%)	48 (16%)
Gross deviation/pronation	2 (0.5%)	27 (9%)	4 (1%)	25 (9%)

*Results are in total number of lower limbs and %.

DISCUSSION

This Pilot study revealed the effect of DDH on gait in pediatric participants between the age of one to four years. Zgoda et al. (2010) focused on DDH's influence on sitting and walking according to milestones. In our study, we did not collect data for sitting, but our youngest patients for gait analysis were one male at 11 months old and three females' same age. Zgoda et al. (2010) mean age of walking for DDH patients was 12 months and two weeks, with considerable difference between males and females. Another study by Kamath (2004) states the delay between DDH and the healthy group for one month. Our study did not notice a delay in walking. Where Dunn's (1990) publication states that 53% with abnormal gait pattern and walk delay up to 18 months (Zgoda, Wasilewski, Wasilewska, & Golicki, 2009) (Kamath & Bennet, 2004) (Dunn, 1990).

Oleksy et al. (2010) highlight the importance of foot assessment and the effects of other deformities in the body. They are not specifying diagnoses or other pathology. Oleksy et al.(2010) article describes the efficiency of FPI-6 and suggests its accuracy. Together with other authors, they demonstrate an easy use for any clinic and profession (Oleksy, Mika, Łukomska-Górny, & Marchewka, 2010). We were able to use only one FPI-6, as the second analysis contain missing information due to rotation of the staff in our services or covering primary therapist during vacation or leave, that is why we agree with the statement of Oleksy et al. (2010) that one of the crucial aspects on proper measurement is "the experience of each therapist" for a particular age of participants.

Our gait and foot pathology correlates with a description of gait pattern for DDH patients in Lee at all (2021) publication. Heel-strike transition increased the swift in the ground reaction force (GRF) with the impact of the foot when the velocity dropped to zero. By revising the force at which the foot (endpoint) and the limb proceed to the floor, we can control the GRF. Besides, the inaccurate swing phase of lower limb joints leads to elevated loading of GRF (Lee, Chen, Hung, Wang, Chang, & Lu, 2021). Toddlers and preschoolers are growing and learning gross motor skills. Therefore, with any diagnosis or disease, they are exposed to compensation movement. With DDH, a problem in the hip joint, their gait pattern is affected. The foot control is significant for heel contact during the heel-strike phase to reduce GRF loading rates on other joints.

Our study includes patients after conservative treatment of DDH. De Pellegring et al. (2021) research focused on double diapering for a newborn to avoid adduction and extension of lower limbs at newborn age (De Pellegrin, Damia, Marcucci, & Moharamzadeh, 2021). Their article describes the difference between some populations and the occurrence of DDH. African population

culture keeps newborns in flexion, abduction hip position, without DDH presence in newborns or adults. But cold climate countries such as Canada, Japan, and Northern China are swaddling newborns with extended and adducted hips/lower limbs with increased risk of DDH. The same swaddling technique is popular in Saudi Arabia as well. To improve the awareness of swaddling DDH and foot pronation among the kids, it's necessary to start with parents and public education at the clinic and through social media too (De Pellegrin, Damia, Marcucci, & Moharamzadeh, 2021) (Para, Batko, Ippolito, Hanna, & Edobor-Osula, 2021).

These publications, research, and projects are opening doors to many new ideas in preventing possible complications for all pediatric patients with DDH or with a high risk of DDH. After reviewing gait analysis for DDH patients within this pilot study, it is clear that participants with left hip DDH are at risk of developing gait pathology on the same lower limb. Comparison of gait analysis between participants with DDH and healthy participants will be the most appropriate next step within this project.

Further studies should include all participants with developmental dysplasia of the hip, diagnosed with other diagnoses after surgery, and referred orthopedic and other clinics. One of the projects is to create a gait screening tool for all patients at rehabilitation practice in KASCH, to prevent further complications and to establish a discharge tool.

Limitations

As with any analysis study, this study has limitations. The main limitation was that multiple therapists analyzed gait and foot posture and missing information in patient documentation. This study was carried out during the Covid-19 pandemic. The follow-up booking for patients was limited to acute patients, and many booked appointments were canceled. A therapist with different experience levels may need help analyzing gait or foot pathologies, what was during the Covid-19 pandemic problem due to limited therapists at the pediatric physiotherapy outpatient clinic.

CONCLUSION

Pathological gait pattern was detected in 83 % within the first gait analysis, 60 % within the second gait analysis, and Foot Postural Index revealed pronation of 51 % feet. Among Saudi participants, a relatively high effect of DDH on gait patterns is reported in this pilot study.

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Diagnostics of Motor Abilities in Primary School Pupils in the Hradec Králové and Pardubice Regions

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ABSTRACT

Motor fitness is seen as a prerequisite for efficient physical functioning of the body and contributes to an active lifestyle. The aim of the research was to use 4 motor tests (standing long jump; sit-up test; 4 × 10 m shuttle run; Leger test /Beep test/) (1) to assess the level of motor fitness in comparison with UNIFITTEST, (2) to assess the significance of the difference in performance between the sexes, and (3) to assess the current status of the mean values of body height (BH) and body weight (BW) with the values of the National Institute of Public Health's National Anthropological Research (NIPH's NAR), in CZ: Celostátní antropologický výzkum (CAV) Státního zdravotního ústavu (SZÚ). Testing was conducted among 2nd grade primary school students (boys: n=129; girls n=99) in the Hradec Králové and Pardubice Regions. Comparison with the UNIFITTEST values for boys showed average performance in the sit-up test, below-average performance in the standing long jump, 4 × 10 m shuttle run and Leger test. For girls, the comparison showed average performance in the sit-up test, below-average performance in the standing long jump and 4 × 10 m shuttle run tests, and significantly below-average performance in the Leger test. The results of the statistical analysis (Mann-Whitney U test, T-test, effect size) showed a significant difference between sexes in 4 × 10m run test ($p = 0.018$) and Leger test ($p = 0.041$); the magnitude of substantive significance (Cohen's d) was between small and medium effect ($d = 0.321$, resp. $d = 0.386$). Comparison of the mean BH and BW values of the pupils with the NIPH's NAR values showed that the pupils tested by us achieved lower BH and higher BW than the NIPH's NAR values: boys 131.5 cm (NIPH's NAR) × 127cm; 27 kg (NIPH's NAR) × 29.2 kg, girls 130 cm (NIPH's NAR) × 125.5 cm; 27kg (NIPH's NAR) × 27.7 kg.

Keywords: motor fitness, motor testing, younger school age, UNIFITTEST

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INTRODUCTION

Motor fitness has a demonstrable effect on health and contributes to the quality of life. These are the reasons why it is perceived as a significant value in human life. Influencing motor fitness through physical activities of school youth within physical education classes as well as creating a positive attitude in the context of whole human life is one of the basic goals of physical education across all grades of schools.

Motor development has an individual course and uneven pace during ontogenesis. According to Laigmeier and Krejčíková (2006), child's motor skills improve significantly during younger school age; in terms of motor fitness, the muscular strength increases significantly, aerobic performance increases too and there is also a gradual and substantial improvement in coordination skills. During this age and due to these facts, there is a growing interest in competitive sports activities, after-school sports clubs as well as spontaneous physical activities and games in which all the motor skills are developed depending on motivation, level of biological development of individuals and external conditions for carrying out physical activities – family, place of residence, etc. (Davison & Jago, 2009). Motor performance is not limited only by the age, but also by environmental influences which have to be positively influenced and children sufficiently supported. In such conditions, faster growth of motor skills is taking place depending on the type of physical activities of the individuals. Differentiation usually occurs with the level of support by parents or degree of success (good results or mastering skills), which increase internal motivation of children to get involved in physical activities. One of the key places is generally occupied by the level of motor fitness of young organism as well as individual motor skills as a basis for the implementation of motor activities. For the period of younger school age, Vágnerová (2012) formulates the so called early school age, starting from the beginning of school attendance and lasting approximately two years (usually from the age of six to the age of eight or nine), when the development of motor skills depends on physical growth, while both gross and fine motor skills significantly improve, movements are faster and more coordinated and the level of fitness skills – muscle strength and gradually also endurance – increase.

A large number of previous researches in monitoring the motor development of children of younger school age have been focused on individuals with a high level of motor performance (talent management focused at individuals talented in sports). The issue of children with a low motor performance has been processed only marginally, even though the renown professional public of this field strongly encourages regular diagnosis of the state of motor fitness especially in the children of younger school age (Moravec et al., 1996 and 2002; Thomas & Nelson, 2001;

Suchomel, 2003; Rubín et al., 2020, etc.). The point is that the low level of motor performance at this age foreshadows the potential danger of an unhealthy development of the individual and places such children into a significant risk group from the health perspective (Portmanová, 1995; Vrbas, 2010). Moreover, for a high percentage of children with low level motor performance, school physical education is not fun; frequently experienced failures have a significant influence on building relationship to physical activity in general (Bunc, 2000; Ignico & Mahon, 1995; Poole, 1996; Růžička, Agricola, & Růžičková, 2021, etc.).

Approximately at the age of eight, younger school-age children reach such a physical maturity that their motor manifestations are relatively stable. Current research shows that the structure of motor skills of eight-year-olds is already similar to adults; from the results of motor tests, it is possible to assess the level of motor skills as well as motor fitness, and also differences by sex; eventually, it is even possible to predict further motor development (Vobr, 2013). This specific issue of the relationship between somatic parameters and motor performance was in our country intensively addressed by Suchomel (2002, 2004). Somatically and motor-talented children usually look for physical activities themselves, while motorically non-talented children often have very low physical activity. This ultimately leads to further deterioration of their often disadvantageous somatic and functional characteristics.

Motor skill testing and diagnostics of various age groups in the area of motor fitness and performance have been addressed since the second half of the 20th century (e.g. Mechelen et al., 1986; McCloy & Young, 1954; Ranganathan, et al., 2004; Reiser, 2005; Salcman, 2015; Scott et al., 2017; Thomas & Nelson, 2001; Yue & Cole, 1992). So far, the most comprehensive studies of a long-term monitoring of the level of the physical fitness of children and youth are based on research carried out in 27 countries in all the continents from 1958 to 2003 (Tomkinson, Léger, Olds & Cazorla, 2003, Olds, Tomkinson, Le´Ger & Cazorla, 2006) and demonstrate an unfavourable state at the level of strength and speed abilities during the monitored period – a slight improvement between the end of the 1950s and approximately the year 1970 is followed by a permanent decrease in the level of the above mentioned motor prerequisites during all the ensuing decades. In particular, however, one can observe a continuous and alarming regression of the state of endurance abilities manifesting themselves significantly since the mid-70s of the 20th century (Tomkinson, 2007). In the Czech and Slovak language area, the issue was studied by Štumbauer (1990), Kovář and Měkota (1995), Moravec, R., Sedláček, J., & Kampmiller, T. (1996), Gajda and Měkota (2000), Chytráčková (2002), Zapletalová, Ľ. (2002), Neuman (2003), Měkota and Cuberek (2007), Psotta (2012), Čillík, I., Kremnický, J., & Kollár, R. (2016), etc. The current broader view of the possibilities of motor testing was addressed by Rubín, Suchomel & Kupr (2014), who compared test systems which can be currently used in the Czech Republic to assess physical fitness in school-age pupils: Eurofit, Fitnessgram, Indares, OVOV and Unifittest. Their paper helps to clarify in a unique way the meaning and development of the concept of motor fitness and health-oriented fitness; and it can help especially physical education teachers with the practical decisions which test system or specific tests from the given test batteries they should select for testing under specific school conditions.

Monitoring and evaluating the state of selected motor skills and fitness levels can provide a significant functional basis for the effective work – most importantly – of physical education

teachers, whose goal is to create a basis for healthy motor development, positive attitude towards physical activities and required level of physical literacy – i.e. understanding the importance of physical activities for health and overall quality of life.

METHODS

The aim of the research was: with the help of 4 motor tests (standing long jump; sit-up test; 4x10 m shuttle run; Leger test /Beep test/) *(1)* to assess the level of motor fitness in comparison with the values of UNIFITTEST (Kovář & Měkota, 1995); *(2)* to assess the significance of difference in performance between the sexes; and *(3)* to assess the current status of the mean values of body height and body weight with the values of the National Institute of Public Health's National Anthropological Research (NIPH's NAR 2001). (CZ: Státní zdravotní ústav, SZÚ – Celostátní antropologický výzkum, CAV).

Based on the set goals, three research questions (RQ) were formulated:

RQ1: *What is the level of physical fitness of the tested pupils compared to the UNIFITTEST standards?*

RQ2: *What is the difference in the results of individual motor tests between the sexes?*

RQ3: *What is the level of the values of body height and body weight of the tested pupils compared to the values of NIPH's NAR 2001?*

The research methodology was based on empirical scientific approach with the use of quantitative approach based on the deductive process of implemented testing and measuring. The main aim was to obtain objective data and results based on them, subsequent interpretations and answers to the formulated research questions with final conclusions.

To obtain the necessary statistical data and evaluate the current status of motor fitness in the pupils of selected primary schools in Hradec Králové Region and Pardubice Region, the method for measurement and testing was used to determine motor and somatic parameters as well as statistical and factual analysis of data and comparison of the obtained results. The originally planned expected number of surveyed respondents was 500 pupils of the 2nd grade of primary school. To obtain complete data from one school class, 2 to 3 PE teaching units were necessary. Due to the epidemiological situation linked with the SARS-CoV-2 / Covid 19 and the implemented pandemic restrictions during the school year 2020–2021, only a part of the planned scope was realized. Some incomplete sets of measurement results which did not allow for a meaningful statistical evaluation of the results had to be excluded from the evaluation. The results of the survey, which was carried out as pilot research with a planned continuation in the form of complete testing of the given regions (with possible future coverage of the whole territory of the Czech Republic), may provide not only the necessary verification of methodology and organizational approach, but also an initial current picture of the level of health-oriented physical fitness of primary school children in the selected regions of the Czech Republic. The conclusions can be also helpful for determining a recommended exercise regime of school children depending on the degree of ontogenetic development of the individual.

The research group consisted of boys (n = 129; average body weight 29.18 kg; average body height 127.01 cm; average BMI 18.09) and girls (n = 99; average body weight 27.69 kg; average body height 125.53 cm; average BMI 17.49) attending the 2nd grade of primary school (PS). Pupils come from a total of 6 primary schools in Hradec Králové and Pardubice Regions. Testing took place in the week of 21st to 25th June 2021, always in the gym of the relevant PS.

The obtained results of arithmetic mean in individual motor tests in boys and girls were then compared with the Czech UNIFITTEST standards (Kovář & Měkota, 1995) for the general population of the given age category. Although Rubín et al. (2014) in their comparative study consider FITNESSGRAM to be the most advantageous battery, which best reflects modern approaches to the assessment of physical fitness, its usability is limited mainly by the absence of normative standards related to our population (the standards were designed for the needs of the US population). Moreover, use in PE teaching units is also limited by the high cost of acquiring a test set containing special equipment. Even though UNIFITTEST – as a specifically Czech test battery with its current software version for processing the resulting values and supplementing the test system with the evaluation of results in relation to the growth age in children and youth categories (Chytráčková, 2002) – does not provide the possibilities of comparison with other countries, it does offer an objective evaluation of the results within the framework of domestic monitoring thanks to the existence of national standards (Rubín et al., 2014).

For the results of current level of motor fitness based on the results of individual motor tests, the difference between sexes and the calculation of substantive significance (effect size = ES) were evaluated. According to several authors (Blahuš, 2000; Ellis, 2010; Soukup, 2013), the correct interpretation of the results of the intentional set should be made with the help of the coefficients of substantive significance; statistical significance should be only a tool to confirm substantive significance. To determine whether the distribution of the obtained data can be considered normal, we used the Shapiro-Wilk test of normality. For the sets where the normality test showed a normal distribution, we used the T–test. In contrast, for the sets where the normality test did not show a normal distribution, we used Mann-Whitney U–test for further data analysis. Significance level was set at $\alpha = 0.05$. We used Cohen's d as substantive significance coefficient. According to Cohen (1988), we can interpret the value of effect size as small ($d < 0.20$), medium ($d = 0.50$) or large ($d > 0.80$). Data analysis was performed in the Statistica software (Tibco Software, Inc.). The found current state of the mean values of body height and body weight in pupils of selected primary schools was compared with the mean values of body height and weight of the NIPH's NAR 2001 national research. We used the Microsoft Excel software (Microsoft Corporation) to calculate arithmetic means and we subsequently compared the results with values based on the percentile graphs of NIPH's NAR used in the Czech Republic in common paediatric practice.

Our research sample included probands aged 7.1 to 7.9 years; therefore, we used standards for 8-year-old pupils. Probands outside the stated age limit were excluded from the set before processing data. The calculation of arithmetic means was performed again in the Microsoft Excel software (Microsoft Corporation). Evaluation of somatic parameters (body height and body weight) was performed – to record all the data during data collection in motor skills testing – according to the percentile growth charts commonly used in paediatric practice in the Czech Republic (NIPH's NAR).

Theoretical background, together with the experience gained by testing motor performance and fitness as well as using professional resources, has brought to existence a set of tests, which contains four items. The basic principle was the choice and creation of a procedure enabling a simple and practical execution of appropriate measurements with the emphasis on maximum efforts to standardize the conditions for a future large-scale testing as well as for increasing the accuracy of the results obtained. An overview of the tests together with their brief characteristics is given in Table 1.

Table 1. Description of the used tests

Test	Description	Evaluation of results
Standing long jump	By jump and two-foot take-off from the spot to reach the longest distance possible	Distance in cm (accurate to 1 cm) 2 attempts, both are recorded, only the best attempt is evaluated
Sit-up test	Perform the maximum number of repetitions of position changes from lying to sitting and back (with legs held)	Number of repetitions in 1 min
4 × 10 m		
shuttle run	Overcome the distance of 10 m four times in the prescribed way in the shortest possible time	Time in s (to 1 decimal place)
Leger test (Beep test)	Continuous running at a given pace on a defined track	
for as long as possible	The number of shuttles determines time in test	

For the needs of the realization of measurements at schools, informed consent was obtained from the legal representatives of all tested pupils as well as approval of the field testing of children by the UHK ethics committee.

RESULTS

Table 2 shows the arithmetic mean (M) values for individual tests in boys. As mentioned above, these values are compared with the UNIFITTEST values (Kovář & Měkota, 1995) for the Czech general population of this age category.

Table 2. Comparison of measured mean values with UNIFITTEST standards for boys

Motor test	Mean values	UNIFITTEST	Evaluation
Standing long jump (cm)	123 cm	113–130 cm	Below average
Sit-up test (number of repetitions)	28	22–31	Average
4 × 10 m shuttle run (time in sec.)	14:23	13:90–14:40	Below average
Leger test (time in min.)	3:08	2:76–4:00	Below average

We did the same with the girls. In Table 2 below we can see the results of comparison with the UNIFITTEST standards for girls of the same age from the Czech general population.

Table 3. Comparison of measured mean values with UNIFITTEST standards for girls

Motor test	Mean values	UNIFITTEST	Evaluation
Standing long jump (cm)	120 cm	107–124	Below average
Sit-up test (number of repetitions)	27	22–30	Average
4 × 10 m shuttle run (time in sec.)	14:46	14:30–14:80	Below average
Leger test (time in min.)	2:07	2:00 – 2:50	Significantly below average

Tab. 4 shows the results of comparison of individual motor tests between sexes. T-test was used for the comparison of standing long jump test and sit-up test; for the remaining two motor tests, i.e. 4 × 10m test and Leger test, we used Mann-Whitney U–test. We expressed the level of substantive significance with the use of effect size (ES), which allows us to decide if the result has practical consequences. A statistically significant difference was found in the motor test of 4 × 10 m shuttle run and in the Leger test. The results in the standing long jump test and sit-up test show that there is no significant difference in performance between boys and girls; the difference in performance is rather small in the 4 × 10 m shuttle run and Leger test.

Table 4. Results of comparison for individual motor tests and effect size values

Motor test	P	ES
Standing long jump	0.320	0.135
Sit-up test	0.513	0.094
4 × 10 m shuttle run	0.018	0.321
Leger test	0.041	0.386

Notes: *p = level of statistical significance; ES = effect size*

Figure 1 shows the NIPH's NAR percentile graphs for body height and body weight for boys (0–18 years). As the solid lines show, the mean body height in the general population for the 8-year-old category is 131.5 cm. The average height of boys tested by us was 127 cm (dashed line), which means a lower value than the population average. The average weight of 8-year-old boys in the population is – again according to the NIPH's NAR – 27 kg. Our results show a value of 29 kg, which is above the population average.

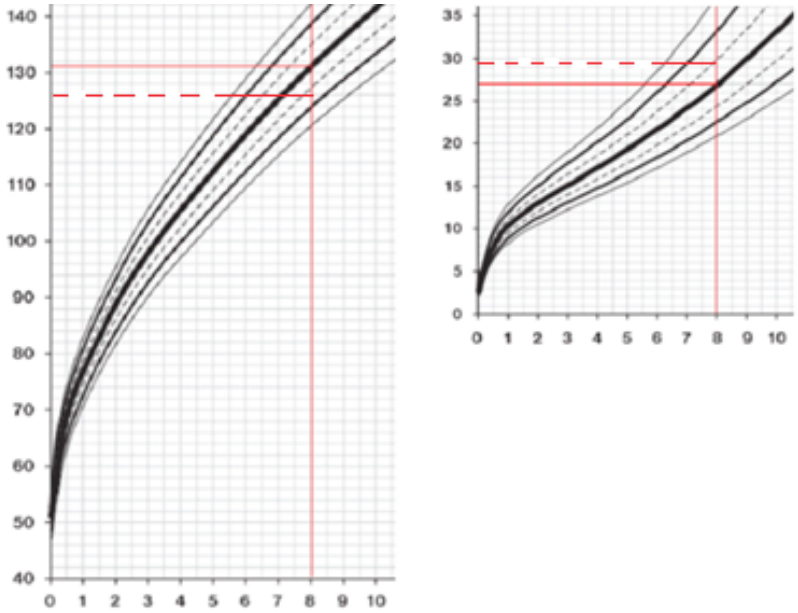

Figure 1. Percentile graph for body height (left) and body weight in boys (NIPH's NAR 2001)

Figure 2 shows the NIPH's NAR percentile graphs for body height and body weight for girls (0–18 years). The solid lines again show that the average body height in the general population for the 8-year-old category is 130 cm. The average height of girls tested by us was 125.5 cm, which means a lower value than the population average. The average weight of 8-year-old girls in the population is – according to the NIPH's NAR – 27 kg, the same as for boys. Our results show a value of 27.7 kg, which is above the population average.

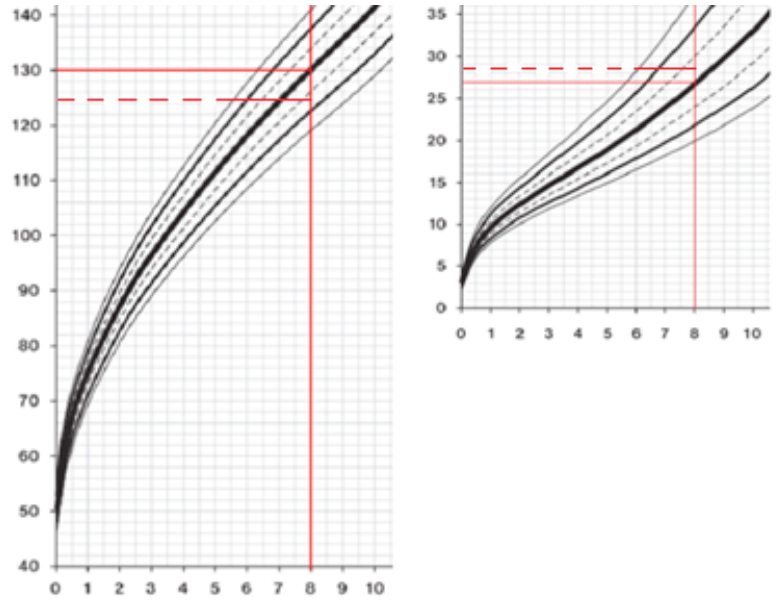

Figure 2. Percentile graph for body height (left) and body weight in girls (NIPH's NAR 2001)

DISCUSSION

At the present time, there are conflicting views in the professional circles about the state and level of motor skills of today's school generation. Testing the motor preconditions of children and comparing their current performances in selected standardized test items with valid standards can help with mapping the actual state of the current generation of primary school children as a tool for finding measures and ways for their healthy and effective motor development. It provides physical education teachers in schools with a methodological apparatus for regular diagnostics as well as data on the basis of which they can model the content of their teaching in such a way as to bring the necessary comprehensive effect. The evaluation of the state of given motor preconditions of children before the age of 9 is also important from the point of view of the selection of talented children to be included in athletic training within high performance sports (Perič, 2012; Vobr, 2013; Holm et al., 2013; Kita et al., 2016; Paška et al., 2018).

The aim of our research was to evaluate the level of motor fitness in comparison with the UNIFITTEST values (Kovář & Měkota, 1995), then evaluate the significance of difference in performance between the sexes and evaluate the current state of the mean values of body height and body weight with the values of the National Institute of Public Health's National Anthropological Research of 2001 (NIPH's NAR 2001). Based on the set goals, the research questions were formulated thus:

RQ1: *What is the level of physical fitness of the tested pupils compared to the UNIFITTEST standards?*

In standing *long jump* test, *below-average* values were achieved in comparison with the UNIFITTEST standards (Kovář & Měkota, 1995) for the Czech general population of the given age category, both in the monitored group of boys (Table 2) and in the group of girls (Table 3). Although similar testing results can be found in similar observations of 8-year-old pupils (Čillík et al., 2012 – 121 cm, Paška et al., 2018 – 120 cm), the arithmetic mean found by us, i.e. 121.5 cm, is significantly below the limit of Moravec et al, 2002 (133 cm); this is true even in comparison with the results of monitoring 7-year-old pupils (Zapletalová, 2002 – 130 cm; Sedláček and Cihová, 2009 – 125 cm). It can be stated that the current trend of motor readiness in the area of muscle strength of the lower limbs of 2nd grade pupils of primary school has been on the decline, resp. stagnation, during the last 20 years.

In *4× 10 m shuttle run* test, we must again state, in comparison with the UNIFITTEST standards (1995), *below-average* evaluation both in boys and girls. Compared to similar researches, the arithmetic mean of by us monitored performance of both boys and girls, which is 14.35 s., represents a better achieved value than research by Čillík et al., 2012 (14.64 s.) or Paška et al., 2018 (15.67 s.). Only Sedláček & Cihová, 2009 recorded a better time (13.60 s.) even among 7-year-old pupils.

Comparing the performances in *Leger test* with the UNIFITTEST standards (1995), we must state again that *below-average* evaluation was achieved in boys, and even *significantly below-average* evaluation in girls.

Sit-up test is the only by us observed test item in which at least *average* evaluation was achieved, in comparison with the UNIFITTEST standards, in both monitored groups (boys and girls).

RQ2: *What is the difference in the results of individual motor tests between the sexes?*

The presented results of the comparison for individual motor tests and the values of effect size (Table 4) show a statistically significant difference in the *4 × 10 m shuttle run* motor test and *Leger test*; no statistically significant difference between the sexes was confirmed in the remaining tests. The effect size values show only a small effect in the *standing long jump* and *sit-up* motor tests; the values are in the range of small and medium effect in *4 × 10 m shuttle run* and *Leger*. From this point of view, we can therefore state that there is no difference in performance between boys and girls in the *standing long jump* and *sit-up* motor tests; the difference in performance is rather small in the *4 × 10 m shuttle run* and *Leger test.*

RQ3: *What is the level of the values of body height and body weight of the tested pupils compared to the values of NIPH's NAR 2001?*

The results of testing showed an average value of body height (BH) in the boys we tested – 127 cm, which means a *lower* value compared to the population average (131.5 cm). And while the average value of BH in the general population of girls is 130 cm, it was 125.5cm for the girls we measured, which also means a *lower* value than the population average. The result of 29 kg in the parameter of body weight (BW) for by us monitored boys in comparison with the value of 27 kg for the Czech general population of 8-year-old boys according to NIPH's NAR 2001 means *above-average* values in relation to the general population. The average mean of BW for 8-year-old girls in the population is 27 kg, which is, according to NIPH's NAR 2001, the same as for boys; the result of our monitoring with the value of 27.7 kg shows an *above-average* result for girls (similarly as for boys) in relation to the general population.

The connection between the results of the level of physical fitness and the measured selected somatic parameters of the pupils tested by us indicate – similarly to the conclusions of Tomkinson's study (2007) in the field of longitudinal trends between 1958 and 2003 – a possible connection between the decrease in the level of motor skills and the simultaneous increase in the body weight of individuals.

In the area of monitoring body composition – body mass index (BMI arithmetic mean), a comparison can be made with the international data of similar age category due to the evaluation of children and youth groups of all continents carried out in 2003–2013 (Suchomel & Rubín, 2017). In this context, our group from Hradec Králové and Pardubice Regions with the resulting values of 18.0 $kg \cdot m^{-2}$ (boys) and 17.5 $kg \cdot m^{-2}$ (girls) ranks approximately as an average position between the results of the Canadian group (Tremblay et al., 2005) with relatively high values of 19.8 $kg \cdot m^{-2}$ (in both boys and girls) and research group from Belgium (Cardon et al., 2007) with lower values of 17.1 $kg \cdot m^{-2}$ (boys) and 17.6 $kg \cdot m^{-2}$ (girls), while the lowest values of 14.6 $kg \cdot m^{-2}$ (boys) and 15.0 $kg \cdot m^{-2}$ (girls) were found in African children from the Republic of South Africa (Monyeki et.al, 2006). The results of our investigation showed basically identical BMI values with the results of the Liberec regional research of 10–12-year-olds with values of 18,2 $kg \cdot m^{-2}$ for boys and 17,3 $kg \cdot m^{-2}$ for girls (Rubín et al., 2014), which would indicate rather a negative trend Currently, according to Kalman (2022), more than a fifth of the population of Czech children aged 11–15 have problems with their weight (15% of adolescents are overweight and 6% are obese), while the worst values

are reported in the Hradec Králové Region. Considering the target group of 8-year-old boys and girls monitored by us, a study of ongoing changes in the exercise and dietetic regime of children aged 8–11 as well as on the reasons for the increase in BMI during this period would be a very valuable material in this context. The most likely reason is the beginning of school attendance and its subsequent impact causing a significant change in the children's lifestyle.

In the area of comparing the current state of average means of BH and BW with the values of the National Institute of Public Health's National Anthropological Research of 2001 (Figure 1 and 2), it can be stated then that while the BH of both boys and girls monitored by us records a slightly lower value compared to the Czech Republic standard, on the other hand, BW shows a higher value. It can be assumed that one of the main reasons is insufficient physical activity and wrong exercise regime of children and subsequent effect on BW due to hypokinesis; ultimately, it has the potential to cause imminent deterioration of health and future quality of life of the young generation. Regular monitoring of the given parameters of physical development of school-age children thus also provides an early detection of possible disorders and can prevent more serious complications at a later age (NIPH's NAR 2001).

The main purpose of testing pupil's physical preconditions is to provide a picture of the state of physical readiness of today's school children as a starting point for purposeful motor development within school physical education; but, last but not least, to encourage also physical activity in families. In addition, monitoring the development trend in the given parameters and its evaluation underlines the correctness of the perceived need of extensive testing of primary school pupils in the Czech Republic with a planned start in autumn 2022 which would provide a comprehensive picture of the level of necessary change in the area of physical literacy of children as well as in work of teachers of school physical education; eventually it would enable better talent selection and could provide a motivation element for an active family life aiming to a higher quality of life (for instance Bunc, 2000; Vrbas, 2010; Psotta et al., 2012; Rubín et al., 2020).

CONCLUSION

The aim of the research was to evaluate, with the use of selected standardized motor tests, the level of motor fitness in comparison with the values of UNIFITTEST, to assess the significance of difference in performance between the sexes and to compare the current state of the mean values of body height and body weight with the values of the National Institute of Public Health based on its 6th National Anthropological Research according to the percentile growth graphs commonly used in paediatric practice in the Czech Republic. Testing took place in pupils of 2nd grade of primary school (boys: n=129; girls n=99) in Hradec Králové and Pardubice Regions. Comparison with the UNIFITTEST values in boys showed average performance in the sit-up test and below-average performance in the standing long jump, 4x10 m shuttle run and Leger test. For girls, the comparison showed average performances in the sit-up test, below-average performances in the standing long jump and 4 × 10 m shuttle run tests and significantly below-average performances in the Leger test. The results of statistical analysis made with the Mann-Whitney U test, T-test and effect size showed a significant difference between the sexes in the 4 × 10 m shuttle run test ($p = 0.018$) and in Leger test ($p = 0.041$);

the magnitude of substantive significance (Cohen's d) was in the range of small and medium effect (d = 0.321, resp. d = 0.386). Comparison of the mean values of selected somatic parameters (BH and BW) in tested pupils with the NIPH's NAR (2001) values showed a lower BH and a higher BW compared to the NIPH's NAR percentile graph values: boys 131.5 cm (NIPH's NAR) x 127 cm; 27 kg (NIPH's NAR) × 29.2 kg; girls 130 cm (NIPH's NAR) × 125.5 cm; 27 kg (NIPH's NAR) × 27.7 kg.

The results of the monitoring of our tested sample (n = 228) provide only a partial picture of the state of child population of the given parameters in the Czech Republic and it is not possible to draw very significant conclusions from it. We are, however, convinced that comparison with the valid UNIFITTEST standards and percentile NIPH's NAR graphs allows to express at least partially the current state, but also to voice the necessary appeal regarding the current need for overall testing and subsequent work with the obtained conclusions towards the support of better development of motor skills of school children not only in the process of teaching physical education. We can also find its significance in the field of verification of the used testing methodology created in 2018–2020 within the working group of experts in sport science representing physical education university departments in the Czech Republic in cooperation with the University Sports Centre of the Ministry of Education, Youth and Sports; methodology having its application in monitoring children within the school environment in the Czech Republic.

Due to the Czech government's measures linked with the SARS-CoV-2/Covid-19 pandemic, which caused major limitations in the area of field research at the time of the planned data collection and thus influenced also the possibility of data processing and presentation of results, we perceive these outputs as pilot ones. The given methodology is currently used for comprehensive monitoring of the level of motor fitness and relating somatometric parameters at Czech primary and secondary schools; this monitoring is to be launched in this year 2022 by the Czech School Inspectorate (Česká školní inspekce) in organizational cooperation with the Czech School Sports Clubs Association (Asociace školních sportovních klubů).

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The Selfish Gene as a Possible Driving Force Behind HIIT

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ABSTRACT

Purpose: High-Intensity Interval Training (HIIT) is a training method aimed at increasing the fitness of individuals. It is based on a combination of periods in which high-intensity alternate with low-intensity exercise or passive rest. The topic of this paper is a reflection on the benefits and risks of HIIT health use in recreational athletes. We investigate humans' conscious and unconscious motivations for choosing this specific method in the philosophical discourse. Problem: HIIT is a method that, in some ways and with particular approaches, strongly reflects the imperative of the postmodern age - to get as much as possible, as quickly as possible. Martin Heidegger perceives three fundamental existentials in the context of temporality – historicity, everydayness, and within-time-ness. Here conscious motivation may be linked to the temporal characteristic of human being. As Richard Dawkins presents, unconscious motivation may be related to the application of the selfish gene theory. The philosophical approach to the problem: The Heideggerian concept of temporality leads us to research the authenticity and inauthenticity of the Dasein phenomenon. Some features of motivation for applying HIIT can be examined as inauthentic forms of being. In focusing on possible elements of unconscious motivation, the concept of evolutionary biology, namely Dawkins's theory of the selfish gene, provides a unique platform. It is primarily (a human) effort to spread genes. Here, in connection with HIIT, we build on the concepts of replicator and vehicle and deal with the basic selection unit of evolution and its form. Conclusions: HIIT presents an exciting training method that is examined in the context of effectivity of sports training, social benefits, or health aspects. Here we would like to offer the HIIT concept as the reflection of philosophical (mainly ontological, partly ethical) discourse.

Keywords: selfish gene, High-Intensity Interval Training, replicators, vehicles

INTRODUCTION

In this article, we try to look for some possible elements of motivation of individuals for the selection and implementation of the HIIT training method (high intensity interval training) and explore the philosophical background of this motivation. HIIT method is physically demanding. It also carries some health risks. At the same time, it contains a kind of impression of our times: to get as much as possible in the shortest possible time and to achieve maximum profit with as little time as possible. However, the use of this method by recreational athletes, who are not usually under systematic medical supervision, can lead to short-term successes while at the same time posing certain long-term health risks. However, as part of our article, we will not be looking at the analysis of health risks. Still, we will be looking at possible deeper causes that lead to the growing popularity of this training method and its uptake within the general population.

PURPOSE

We believe examining the motivation for using the HIIT method in philosophical discourse makes sense. Such reason can be both conscious and unconscious. As Martin Heidegger explains in his book Being and Time (Heidegger, 1996), the temporal characteristics of being human can be used to place conscious motivation in a particular frame. The time frame may present one of the keys to understanding the elements of authenticity and inauthenticity of being human, through which one can see an effort to make as much profit as possible in a short time. As Cimino (2019) emphasized, Heidegger attempted to grasp the phenomenon of the truth of being (Heidegger, 1996, 208) differently from Kierkegaard and reinterpreted questions of existential analysis through, among other things, temporal characteristics of human being.

In this regard, Martin Heidegger refers to three temporal aspects, which he describes as existentials. This is about Historicity, Everydayness, and Within-Timeness. The Within-Timeness (Heidegger, 1996, 371–390) characteristic is strongly associated with measuring time (ibid, 382–384) and falling into the instant mode of everyday caterers. There is a danger of ceasing to be ourselves and losing authenticity because everything we do is for us pre-programmed and planned. In effect, we are carrying out some instructions which have already been finished and which we cannot continually correct in their form.

Simple examples of situations where we are trying to accelerate processes requiring more time by default artificially could serve as a lay first-plan explanation for why being in such a mode can be a problem. This directly touches on our theme: to profit as quickly as possible from the HIIT training method. However, we believe that the root of the problem is much deeper here and that the temporal issues of being in a more sophisticated context can be perceived. The preference for choosing hard-line scientific and technologically conditioned methods to achieve maximum effect can also be seen as a philosophical problem, which Heidegger paid attention to in his late work and is directly linked to his term Gestell (Roozbahani & Moinzadeh, 2020). Undoubtedly, there are more reasons why Heidegger's analyses may present a good platform for a better understanding

However, the aim of our article is not to assess the motivation for implementing the HIIT method from the perspective of the authenticity of human being. This would be an issue for a much more comprehensive study. We use the aspects of temporality described by Heidegger only as a starting point for our reflections on the potential influence of the selfish gene on this motivation. Temporality, and in this case the existence of within-time-ness, seems to us only to draw attention to the fact that trying to make a quick profit with as little time as possible can not only be counterproductive in its outcome but that it carries problems relating to the meaningfulness of our actions. In other words, this problem has a strong philosophical dimension.

All of this relates to a conscious motivation in which the individual is reasonably well aware of what they provide and want to gain from it. However, we felt it necessary also to mention the need to go under the first-time profit-versus-loss perspective. We wanted to draw attention to the fact that, in the context of the pursuit of a meaningful human being, processes tend not to work as quickly and as simply as they might look based on a kind of balance sheet of individual segments of these processes.

As part of our study, we focused on a possible subconscious motivation for the implementation of the HIIT method, which may be related to the theory of the selfish gene by Richard Dawkins. Since the first publication (in 1976) of The Selfish Gene (Dawkins, 1989), this theory has become a highly influential and, at the same time, frequently criticized concept, explaining the splenetic evolution from the gene-centered view.

For the needs of our text, we first tried to define the typology of people practicing HIIT. We know that exact scientific research would need to be undertaken for a relevant practical empirical study. However, the core of our text is not empirical; we are merely creating a particular model construct here as a starting point for subsequent abstract imaginings. This construct is based on practical experience and observation directly in the specific conditions of the gyms. Such a construct cannot be flat-lined, and we also have no intention of doing so; we are concerned about the disability of some selected distinctive personality aspects.

Therefore, based on instructors' observations and practical experience, specific typical attributes can be given, which (from the point of view of many instructors, typically) are the characteristics of HIIT practitioners. These are often those in a dominant society (possibly with an epoch attempting to gain dominance), competitive and trying to break out of the mean and gain a specific advantage over a particular rage by their admission. They are also often maximalists, sometimes with a tendency to megalomania. These are purposeful people, continually pursuing benefit and effect in a shorter time frame. The Choleric temperament predominates. About the opposite sex (concerning Dawkins's theory, it is a substantial thing), these are attractive individuals or individuals trying to gain some attractiveness. This may be accompanied by an additional attribute, an above-average number of partners in relationships where a dominant role often prevails.

It is the specific experience with HIIT seekers under the background of this study.

PROBLEM

We will now try to present a direct link between the issue of the selfish gene and exercising by HIIT method. For Dawkins, as an ethologist, observing the behavior of animals is a fundamental starting

point for explaining ontogenetic and phylogenetic development, innate and acquired behavior, and their patterns for species survival. In the context of attractiveness, he cites as an example the garish color and long tail in males, which attracts attention and gives males a better chance of reproducing. This is true of patterns that also run a greater risk of being eaten by predators. However, the male is willing to take the risk, even at the cost of being eaten, as he may have a more significant number of offspring in the relatively short time of his existence. By contrast, an unobtrusive, unattractive male can live as long as a female but will not pass on any genes.

It should be pointed out that the HIIT method is not only a means of increasing physical fitness (this part may not always be visually apparent) but, above all, promotes muscle growth, physique formation, and body fat loss (which are already visually noticeable aspects). On the non-visual side, the individual becomes more attractive and gains a more dominant position through their higher fitness over others, for example, in group exercise. It is typical of HIIT that exercise tends to be mixed (often in the representation of men and women, which is close to 50:50). He gains dominance through his superior performance and "pays" for it by making a big effort, possibly by damaging the locomotor apparatus in an effort to do more repetitions, lifting heavier weights, etc. Devolved, such behavior may work favorably in the short term from a reproduction perspective, and here an analogy to Dawkins' concepts can be observed. This example may work within a limited group of people in which an individual tries to gain a certain status and refers to a non-visual component (performance).

The second plane is the visual aspect (musculature, well-developed body), which can also work externally outside a limited group of individuals. Also, here, of course, is the pursuit of targets in the short term, the spending of large amounts of energy, etc.). This idea is supported by the fact that HIIT is practiced overwhelmingly by people who are reproductive and capable of reproduction.

The approach to the problem – the principles of the Game Theory

Now we would like to follow up on previous thoughts. As a premise, we can suggest that two types of individuals can be identified in a model construct (and understandably very simplistic). One of them practices HIIT, and the other doesn't. If we relate these constructs to game theory, we can devolve these individuals by choosing each different strategy.

Even before we start considering possible strategies in the context of game theory, referring to Dawkins, we can give an example of a study of elephant seals in which it was found that 4% of males held 88% of all copulations. For this species, there is an enormous surplus of free males who do not get a chance to reproduce, and because they use resources like other seals, they can be taken as social parasites. In the context of HIIT, the low percentage of the copulating can theoretically be thought of as those who practice HIIT. In practice, the situation is significantly more complex due to cultural influences in human society. However, in a model working with the principle of the selfish gene (the essence of which is to spread as widely as possible in the gene pool), the body can be seen as a selfish tool that tries to do as much as possible for its genes and whether females or males are trying to ensure maximum reproduction. The selection of some activities or strategies may be subconscious and may be instinctively driven. In this context, we mention the choice of the HIIT method as one of the possible manifestations.

We will now return to the choice of strategies within the Game Theory. Individuals compete for living space; according to Dawkins, nothing can stop them from spreading genes. If they are part of the same environment, they also compete for partners, and the consequence of this competence in general among organisms is evolution (according to Darwin). Thus, in an individual practicing HIIT, the choice of strategy is determined by the selfish gene and the interest in taking advantage of the short-term selfish benefit, even though it might not be advantageous in the long run. Specifically: If a person trains very intensively, he/she is likely to be more efficient than individuals who do not train intensively. This can be accompanied by a more attractive appearance, higher performance, privileged societal position, etc. An individual chooses a strategy that favors him in the short term (intensely impossible to train to infinity). Still, this strategy may not be advantageous (for example, due to damage to the locomotor system and health). Moreover, the choice of this strategy is both energy and mentally exhausting. Choosing a strategy makes a completely glamorous difference between working on your physical condition (generally sports training) and working on it through intensive training with an immediate effect but during a short application phase.

There are several analogies in Dawkins's book based on the ethological basis. See the chapter "Nice guys finish first" (Dawkins, 1989, 147). Specifically, killing a male who is also my rival will cause exhaustion, and eventual death while favoring a third rival, as well as choosing a drinking strategy by the stream, etc. Dawkins agrees with Axelrod and Hamilton that many wild animals and plants are engaged in endless games of Prisoner's Dilemma, played out in evolutionary time.

Dawkins also describes what Maynard Smith calls 'symmetric' contests in some detail. As part of a game called "Hawks and Doves," he discusses the model situations that can occur in a hawk-dove encounter.

Ridley (1996) goes on to describe a number of different model tournaments in which various strategies based on a model of "hawks and doves" faced each other. These model situations were also tested frequently in later game theory using modern IT technologies with different intentions (Yang, 2021; Deng & Deng, 2015; Feltovich, 2011).

Dawkins himself drew attention to the relatively "optimistic" feel of tournaments (1989, 172), in which cooperative strategies, typically those he calls "Tit for Tat family of strategies" (ibid, 168), tend to be more successful in the long run. In addition to ethology discourse, this topic can also be scanned in ethical discourse (Hurych, 2013, 83).

The choice of aggressive strategy (or ostentation from the point of view of the chances of spreading the gene pool) may be, and in many cases seems to be, advantageous. Especially in the short term, as a simple analysis of the scheme of The Prisoner's Dilemma shows.

However, as Dawkins stresses, this concept will be true for developmentally simpler animal species (an example of the elephant seals as mentioned above) rather than for humans, where numerous cultural influences are included, and long-term developments are also more observable. Dawkins created a "meme theory" on this topic (Dawkins, 1989, 140–148). On the other hand, the idea of memes was even more often criticized by many authors (West, 2020; Schrempp, 2009; Benítez-Bribiesca, 2001) than the theory of the selfish gene itself.

Replicators and vehicles

At this point, it should be noted that we are building on Dawkins' conception of genes and memes also in the sense that we view them metaphorically. Obviously, the replicator (gene) is a molecule and as a molecule it wants nothing, it cannot want anything and accordingly it cannot be selfish. Dawkins's term for selfishness, then, is more like coding.

The basic reasoning is that replicators are genes (Dawkins, 1989, 16), and we humans are their survival tools. The genes have created us, which means they have created a particular box. The better the box, the more successful the genes are in their competencies. The clipboard can be described as a vehicle. At least again, in a metaphor, it can be broken down into parts: a part visible/tangible, invisible/intangible, and a transition between these (intersections). In the field of genetic research for grasping what this vehicle is, we find a number of problems, for example in the functioning of cell structures (Jalasvuori, 2012).

A slightly different view is also possible. The box in general may have a physical form and boundary, but it may not. Her likeness can be abstract. In terms of graspability (visibility/tactileness), the interpretation is relatively simple. The replicators themselves are not visible, and the vehicle is a tool for moving replicators. For example, it is the body as a gene broker, with its form influencing the chances of the replicator spreading (increasing or decreasing these chances). His selection and propagation of the replicator are two aspects of the same process. Animals in general have become gene tools whose basic functional unit is muscle.

In the context of HIIT and this grasping (or transition) component, the advantage of HIIT for practicing individuals can be assumed in the selection process, as musculature creates a feeling of higher chance of survival (in combat, in foraging, in the ability to work more efficiently, etc.).

Nevertheless, there is also a component that is elusive (or at least not fully graspable), which theoretically can also be considered a vehicle. Here we come more into abstract space. If a receptacle is the basis for propagating a replicator and enlarging a gene pool, and may not be graspable, a social status box, an intellectual ability, or a luxury car (or what the owner is showing the surroundings) can be. In the context of HIITs, one could then speak at this level, for example, of the will of an individual undergoing high-intensity training, purpose, the ability to organize time, competition, etc. This consideration is supported by the fact that the body's ability to respond to changes in its surroundings is often of higher importance than physiological properties. Thus, the means of persistence does not necessarily have to be material in nature. Replicators alone cannot create survival programs (because of the number of eventualities). However, they work with analogy, and survival tools need to equip more with general capabilities and, in turn, strategies. Here we return to the follow-up to the principles of The Theory of Games.

A model construct of the "hawk" as a practitioner of the HIIT method

As mentioned earlier, we will try to present a model construct of the HIIT method "client" with a setting in the context mentioned in the previous text. First, in a simple table, we show the scoring of Axelrod´s tournaments, in which the model dove co-operates and the model hawk defects.

Table 1. Axelrod's computer tournament: payoffs to me from various outcomes (simplified and adapted from Dawkins, 1989, 151).

		What you do	
		Cooperate	**Defect**
What I do	**Cooperate**	REWARD FOR MUTUAL COOPERATION **3 POINTS**	SUCKER´S PAYOFF **0 POINTS**
	Defect	TEMPTATION TO DEFECT **5 POINTS**	PUNISHMENT FOR MUTUAL DEFECTION **1 POINT**

In this constructed matrix, we can think that the hawk is the dominant in society, according to Dawkins, the aggressive type. Again, all attributes must be understood metaphorically. This is demonstrated by the orderly tournaments in which strategies free from emotion were fought, in principle it could be said to be a battle of computer programs, or if we want, programmed strategies.

A person who practices HIIT (superior with his performance, strength, musculature, etc.) so in this model construct can be considered a hawk. We can then think of non-aggressive, incongruous individuals in society as a dove. Thus (in fact, in accordance with Dawkins' theory of ethology), we pit two players equipped with a dove-and-hawk strategy, where the hawk is a HIIT practicing type and the dove is a non-athlete or recreational athlete.

In the short term, a hawk's strategy might seem preferable to that of a dove (a selfish gene predominates) in terms of attention-getting, dominance, and, by extension, gene-spreading. This corresponds both to the logical solution of the one-off situation at The Prisoner's Dilemma (when it is preferable to betray) and to the results of the meeting of the hawk and the dove in fewer matches (when the hawk gets more than the dove.

Nevertheless, two basic moments put the problem in a different light. The first is that "purebred" hawks and "purebred" doves represent only a fraction of the players, while the others build their strategies on a combination of collaboration and rejection. This is broadly similar to human society and the behavior of individuals in different situations, where we are also more likely to encounter quite distinct types.

The second point is that the game is played for a high number of rounds, with players equipped with "memory" which means they have a record of their hitherto flawed matches and can adapt their strategies to that. It also corresponds significantly with the reality that people experience. A typical example is the Tit for Tat strategy, which responds to the opponent's behavior in a simple algorithm (it cooperates in the first round, and reacts in the next rounds in the same way as the opponent did in the previous game).

As mentioned earlier, attributing human characteristics to strategies is only a certain type of metaphor, but one that Dawkins relates to the real behavior of animals within ethological theories and then relates to cultural patterns in human society. If we are talking about egotism or altruism in this vein, we must make yet another abstract ingratiating leap towards the realm of ethics. But this, at least in a first-line way, can be done if we accept the idea that judicious cooperation pays off in the long run (Ridley, 1996) and thus that altruism can be justified both logically and ethically (Hurych, 2013, 83).

Now we come to the very point of our text, which is a modest reflection on the motivation for operating the HIIT method through models combining philosophical, ethological and mathematical approaches.

Before we draw conclusions, we feel it necessary to draw attention to the fact that we are not concerned with assessing the suitability of the HIIT method for exercisers from the perspective of health risks. Nor, however, are we concerned with any kind of warning about the method as such. The main idea is for those who choose to implement the HIIT method to think carefully about why they want to pursue this method and what possible benefits and complications such a decision may bring. From this we exclude the issue of health risks and the changes/improvements in physical fitness or performance itself, we believe that there are enough relevant studies available in these respects, on the one hand, and on the other hand this question is quite well understood in simple consideration.

CONCLUSIONS

We will try to draw an intelligible conclusion; however, this effort, in the case of disjointed exits and mixed discourse, may seem largely simplistic. In the model case of the hawk as the operator of the HIIT method, we have attempted to point to certain pitfalls that hide the choice of this method when driven by the desire to dominate and control our surroundings. The reality is, of course, different, with almost all of us alternately assuming the roles of hawk or dove in certain situations.

Although we have largely based ourselves on philosophical and game theory, our conclusion goes into the field of kinanthropology. HIIT is one effective method and can produce very good results in some circumstances. At the same time, we consider it beneficial to take into account some of the circumstances mentioned in this text when deciding on the choice of this method.

For one thing, there is the risk in applying the effort to get the most too quickly and at all costs, and to overestimate the short-term benefit. This can lead to a lapse into Within-Timeness mode (based on the ideas of Heidegger's temporal analyses) and deficits in the authenticity of being. There is a much greater risk if such an effort is associated with taking over the position of a hawk, if the HIIT method becomes a way for us to build our dominance in society, and if we want to build our attractiveness and potentially our social position through this method. To some extent, such behavior corresponds to a model of a selfish gene, as Dawkins describes it.

The fact that dove strategies can, even within model theories, withstand hawks is then a useful reflection of some of the findings from The Theory of Games. As has been shown in specific tournaments, the meeting of hawks and doves produces different results at different stages. With doves too dominated, hawkish strategies begin to prevail, making the overall balance intricately

graspable. However, the fact that cooperative strategies have a slight edge in the long run provides a starting point for considering that altruism is not only an ethical construct (it is right to help and cooperate), but that there is also a logical basis for it, and that cooperation can be seen as a rational form of behavior.

The HIIT method itself is only a tool and, like any tool, can be both useful and harmful. What we wanted to emphasize here is the fact that while combat activities have their sophisticated anchor in the philosophical ideas of some martial arts, we do not see with the HIIT method that it has been overwhelmingly realized from the very beginning with a certain vision. Improving physical parameters should be mentally based on self-improvement in terms of understanding and cooperation, rather than trying to dominate your surroundings and control someone by force.

Bearing in mind that in the case of HIIT, this is a training method that is primarily aimed at improving physical parameters, we consider it useful to look at the context of its use from other perspectives as well and to use approaches other than, for example, the field of sports training analysis. We believe that even such perspectives fall within the challenges of kinanthropology.

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Social Behavior in Children of Special Olympics and Non-sporty Children with Intellectual Disability

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ABSTRACT

Introduction: There is a lack of longitudinal research in the field of social behavior in children with intellectual disability (ID). The first goal of the research was to find out and compare the social behavior of children who regularly participate in Special Olympics (SO) competitions with non-sporty children. The second goal was to show the trend in the development of children's social behavior and to find out whether summer vacations have any effect on children's behavior.

Methods : The Reiss Screen Behavior questionnaire was used to determine social behavior. Participants were children with ID aged 6–20 years. A total of 4 measurements were performed over a two year period (the number of children in SO was n = 14, n = 18, n = 18, n = 13 and the number of non-sporty children was n = 42, n = 40, n = 39, n = 40).

Results: Children in SO have better social behavior by 10 % compared to non-sporty children. The trend of development in social behavior is unbalanced among children in SO, and summer vacations cause improvements in their behavior. Non-sporty children have a convex trend in social behavior and summer vacations have no effect on their behavior.

Conclusion: In children of SO, social behavior differs by 3 % from the norm of ideal social behavior. In non-sporty children, social behavior differs by 13 % from the norm. Sport in children with ID leads to fair play and improves social behavior. Overall, the behavior of children with ID is very good in the Czech Republic, as it differs very little from the norm of ideal social behavior.

Keywords: Questionnaire Reiss Screen Behavior, sport, physical activity, children, adolescents, Special Olympics, developmental trends

INTRODUCTION

Social behavior is the way we react to the social environment (to other people) and is influenced by stereotypes, attitudes, norms (Goleman, 2011, p. 43). One of the most important aspects of human life is interpersonal relationships, which are manifested in communication and mutual cooperation with other people. Relationships with our friends, co-workers, parents, children, etc. give our lives their main content and meaning (Nakonečný, 2011, p. 637). Social behavior can manifest in humans in different ways, such as prosocial behavior, antisocial behavior, altruism, aggression, etc. (Goleman, 2011, p. 44).

Research in Sweden, the United States and the United Kingdom agrees that children with intellectual disability (ID) have a high rate of behavioral problems with a prevalence of 22%–64% (Gillberg et al., 1986; Merrel & Holland, 1997; Totsika et al., 2011), and that behavioral problems are very common in children with ID (Kostikj-Ivanovikj, 2009; Lakhan, 2018).

Children with ID exhibit specific (repetitive) behavior that is not typical for children without ID due to its frequency and duration (Hodapp & Zigler, 1997). Typical behaviors include increased passivity (Linn, Goodman & Lender, 2000; McWilliam & Bailey, 1992), distracted attention, impulsivity (Kopp, 1990; Kopp, Krakow & Johnson, 1983), aggression, destructive behavior, and self-harm. At the same time, people who have highly problematic behaviors more often need more help from others, especially in looking after themselves (eating, dressing, washing), (Emerson et al., 2001). This behavior is often considered maladaptive and disruptive of their learning (Hodapp & Zigler, 1997). The degree and severity of behavioral problems is very individual (Iwata, 2006). Problem behavior is a risk factor for mainstream exclusion and social integration (Kishore et al., 2004).

Parents of children with ID perceive that the problematic behavior of their children is caused not only by ID, but also by social (difficulty understanding, limited attention) and environmental contexts (Jacobs, Woolfson & Hunter, 2015). Children with mild to moderate ID are not more likely to behave worse at school than children without disabilities, provided that their teaching is sensitive and appropriate (Bierbaum, Henrich & Zigler, 2005). Teachers rate children with ID as more disobedient than their peers with average intelligence (Zigler et al., 2002). Gender in children with ID does not show any significant correlation with any type of problem behavior (Lakhan & Kishore, 2018).

A two-year comparison of two groups of adolescents in the Czech Republic, namely participants in Special Olympics and non-sporty children, found better motor competences and social behavior among participants in SO. SO participants had a stabilized trend in motor skills and a growing trend in social behavior. On the contrary, non-sporty children had a declining trend in motor skills and a stabilized or slightly increasing trend in social behavior (Válková, 1998).

Many authors agree on the importance of physical activities on the psyche of people with ID (Winnick & Porretta, 2016, p. 5; Pitetti & Fernhall, 2004; Onyewadume, 2006). Involvement in physical activities also leads to improved coordination, visibility, recognition and thus a higher level of social status (Lahtinen, Rintala & Malin, 2007). Another benefit is the improvement of the aerobic capacity of the lungs, gross motor skills and especially the high level of satisfaction of participants in physical activity and sports (Johnson, 2009). Exercise also develops mental functions including perception, attention, memory, imagination, thinking, and speech (Kvapilík & Černá, 1990, p. 91).

There are also benefits of physical activities for people with ID in the social field. The individual comes into contact with society and develops social skills, i.e. togetherness, willingness, respect, discipline, order, and character are formed (Černá, 1985, p. 106). The integrative character of physical activities is also significant, especially gaining new friends (Svoboda, 1977). Sport has also been found to develop independence in individuals (Dlużewska-Martyniec, 2002).

In sporty children with ID, progress was found in everyday skills, i.e. in food, clothing, personal hygiene and communication. Skills improvement was greatest in younger children and was associated with a reduction in behavioral problems. However, these improvements were smaller with the sample of children without ID (Chadwick, Cuddy, Kussel & Taylor, 2005).

In developmental psychology, the assessment of development trends according to psychologist Švancara (1980, p. 20) and Válkova & Thaiszová (1989) is used to monitor children and adults, who list 6 basic development trends: positive, negative, unbalanced, stable, concave, convex. Thanks to the representation of the trend, we can find out if the child has made progress, is at the same level, or is getting worse.

The significance of the research lies in the longitudinal monitoring of children and adolescents with ID. Globally, there are few longitudinal studies dealing with the social behavior of children and adolescents with ID, and in the Czech Republic, where the research took place, no such study has yet been conducted.

The first goal of the research was to find out and compare the social behavior of children who regularly participate in Special Olympics (SO) competitions with non-sporty children. The second goal was to show the trend in the development of children's social behavior and to find out whether summer vacations have any effect on children's behavior.

METHODS

The research took place over 2 years at two primary schools in the Zlín Region in the Czech Republic. The research is longitudinal and was part of the nationwide Czech Healthy Community Project (Y2-17-600-11), which ran from 2017 to 2019. The research was funded by the US Golisano Foundation and was conducted in collaboration with the Czech Special Olympics Movement. This is a completely new study in indicators of behavior of children with ID, where the progress of the same sample of children is monitored over the long term.

Children' behavior was surveyed (interviewed) a total of 4 times in each school. The survey took place in June (2017 and 2018) before the summer vacations and in September (2017 and 2018) after the summer vacations.

Participants

The participants were children from the primary school in Zlín (classification ISCED 1 and ISCED 2) and the primary school in Otrokovice (classification ISCED 1 and ISCED 2). Both schools agreed to participate in the research and cooperation agreements were signed with them. All children from both schools were offered participation in the research. Half of the parents at each school agreed to their child's participation in the research. Consent was obtained from all participating

children from their parents. The research was also approved by the Ethics Committee of Faculty of Sports Studies of Masaryk University

The research participants were children aged 6-20 years. The age composition of the children was: 40% in school-age (6-11 years), 40% in puberty (12-15 years) and 20 % in adolescence (16-20 years). Children had mild ID or moderate ID. The most of children had a simple ID (without other associated disorder such as Down syndrome, epilepsy and autism). In the following table (Table 1) we see the characteristics of children in terms of sporty and non-sporty children and in terms of gender, so that the results can be compared with other research. A total of 56 children (June 2017), 58 children (September 2017), 57 children (June 2018) and 53 children (September 2018) participated in each survey.

The time period is also divided into the months of June (surveying children before the summer vacations) and September (surveying children after the summer vacations), in which the children were interviewed. (In the Czech Republic, all children have summer vacations in August and July, for that reason the time period before and after the vacations was chosen).

Sporty children regularly participate in the sports competitions of the Czech Special Olympics Movement, such as athletics, swimming, downhill skiing, cross-country skiing. Non-sporty children do not do any sports regularly. All children have regular physical education at their school, which ranges from 2 to 4 lessons per week. As a rule, children with a moderate degree of disability have a higher number of physical education lessons, i.e 3–4 hours per week and children with a mild degree of disability have 2-3 teaching hours per week.

Table 1. Characteristics of number children in research

	June 2017	**September 2017**	**June 2018**	**September 2018**
Children in SO – females	8	7	7	5
Children in SO – males	6	11	11	8
Non-sporty – females	18	17	17	16
Non-sporty – males	24	23	22	24
Total children in SO	**14**	**18**	**18**	**13**
Total non-sporty	**42**	**40**	**39**	**40**

Reiss Screen Behavior Questionnaire

Social behavior was assessed using the Reiss Screen Behavior questionnaire, which is directly designed for people with intellectual disabilities. The questionnaire evaluates adaptive - maladaptive social behavior and is designed for all levels of ID. A translated and verified version of the questionnaire according to Válková (2000, pp. 15–28) is used for the Czech environment.

The questionnaire contains a total of 38 items which show characteristics of human behavior, such as aggressive, anxious, addicted, inattentive, etc. For each item, 1 of the 3 categories offered, which best describes the behavior in a person with ID, is selected. The categories are:

- Behavior is not a problem – this answer is rated 1 point
- Behavior is a problem – this answer is rated 2 points
- Behavior is a big problem – this answer is rated 3 points

A gross score is obtained by evaluating the questionnaire. The minimum number of points that each person can get is 38 points, which means completely trouble-free behavior. On the contrary, a maximum of 114 points indicates major problems and behavioral disorders, where the person should visit a psychiatrist regularly and his or her behavior should be monitored.

For a better presentation of the score results from the Reiss Screen Behavior questionnaire, the gross median scores for each category are converted to percentages (Table 4, Table 6, Table 8). The resulting values were obtained in such a way that a minimum of 38 points (completely problem-free behavior) represents 100 %. And a maximum of 114 points (major behavioral problems) represents 300 %, or behavior 3 times worse than the norm.

The questionnaire was filled in for each child by their class teacher, who spends the most time with the childat school and therefore knows the manifestations of their behavior best. Behavior was assessed for each child a total of 4 times over two years.

The validity of the results was ensured by the researcher himself (leader of the volunteer team), who participated in all the measurements at the schools and supervised the team of volunteers. In addition, standard tests from the FUNFitness program, which is part of the global Special Olympics Healthy Athletes program, were used for measurements (Special Olympics, 2022).

Reliability is again ensured by using tests from the FUNFitness program, which is part of the global Special Olympics Healthy Athletes program. And then a longitudinal investigation took place at the same schools, with the participation of the same organizational team of trained volunteers.

The process of data collection and management of the research

The process of data collection and management of the research consisted of ensuring contractual cooperation with cooperating schools, arranging the dates of questioning at each school, and obtaining consent to participate in the research from the parents of the children. As this survey makes up only one third of the research within the project, it was undertaken by a team of 10 volunteers (with previously training), and their transport to the schools and uniform T-shirts within the project were also provided.

Furthermore, before each measurement, forms (empty questionnaires) were prepared to be filled in and other small things such as writing stationery. We also provided refreshments for all project participants, i.e. children, teachers and a team of volunteers. After collecting all the questionnaires, it was necessary to rewrite the data into a computer and evaluate it.

Data processing and analysis

The data were processed in Statistica and Microsoft Excel. Based on three normality tests (Kolmogorov-Smirnov, Liliefors, Shapiro-Wilks), it was found that these are nonparametric data that do not correspond to the Gaussian curve of the normal distribution. Therefore, the median is used instead of the arithmetic mean in the presentation of results.

Because this is a measurement on the same group of children, it is dependent data. Due to the fact that a total of 4 measurements were performed, we used analysis of variance, specifically Friedman's anova, to determine the statistics of significant differences at the 5% level of significance (for values $p \leq 0{,}05$). In the table (Table 2) we can see that in the analysis of variance no statistically significant differences were found for the given children in the individual categories.

Table 2. Analysis of variance - Friedman's anova

Behavior	p
Children in SO	0,07580
Non-sporty children	0,04229
Children in SO - females	0,15061
Children in SO - males	0,23845
Non-sporty - females	0,08838
Non-sporty - males	0,50955

With regard to longitudinal research, each area of research was evaluated in terms of development trends according to Švancara (1980, p. 20) and Válková & Thaiszová (1989), who state 6 basic trends: positive, negative, unbalanced, stable, concave, convex.

RESULTS

The results presented are by category: all children (females and males together), only females, only males. Due to non-parametric data, the median is used in descriptive statistics.

Children in SO and non-sporty children

Comparing the development of trends in behavior (Figure 1), we see that children in SO had better behavior throughout the measurements (lower values in the questionnaire) than non-sporty children. Only in June 2018 was the behavior of both groups of children the same (40 points).

We see an **unbalanced trend** in behavior among **children in SO**, where they always have completely problem-free behavior in September after the summer vacations (score 38 points) and always have increased values at the end of June (41,5 and 40 points), which indicates a deterioration in behavior. We can therefore say that **their behavior deteriorates during the school year, and conversely their behavior improves over the summer vacations**. This change is not statistically significant, see Table 2.

For **non-sporty children,** we see a **convex trend** in behavior, where they have a different point value in each measurement. They had the worst behavior at the beginning of the measurement in June 2017, namely 47,5 points. Gradually, their behavior improved until June 2018, where they had comparable behavior to the second group (40 points) and then their behavior deteriorated to 42 points in September 2018. Given the convex trend, we can say that **summer vacations have no influence over the behavior of non-sporty children**.

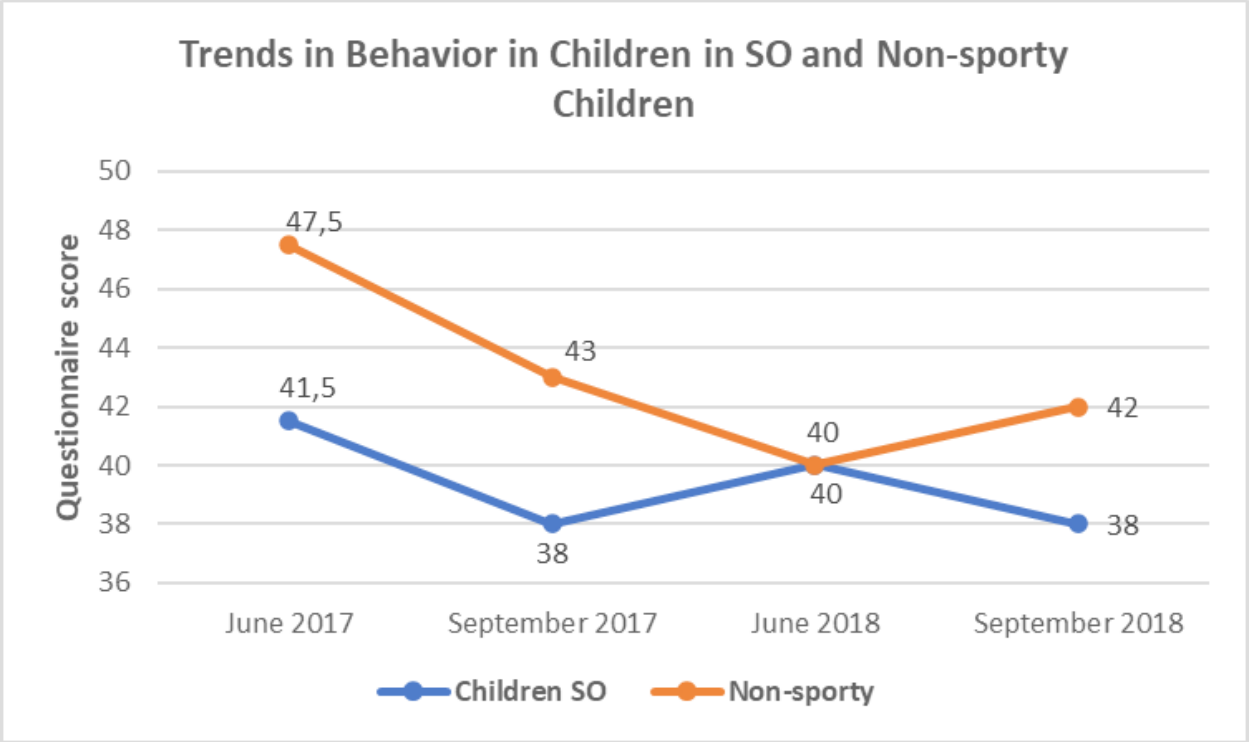

Figure 1. Graph of behavioral trends in sporty and non-sporty children

The following table (Table 3) shows descriptive statistics for the gross scores in the Behavior Questionnaire for children in SO and non-sporty children. Where, in addition to the median, the standard deviation and the minimum and maximum number of points that appeared among children in the given category are shown.

We can also notice that the maximum values for each measurement are higher for non-sporty children, i.e. they have worse social behavior.

Table 3. Gross scores in the Behavioral questionnaire for children in SO and non-sporty children

Behavior – gross score	Children in SO			Non-sporty children		
	Median ± SD	Min	Max	Median ± SD	Min	Max
June 2017	**41,50** ± 6,57	38	58	**47,50** ± 8,40	38	66
September 2017	**38,00** ± 7,64	38	62	**43,00** ± 10,27	38	89
June 2018	**40,00** ± 5,61	38	60	**40,00** ± 7,58	38	71
September 2018	**38,00** ± 1,52	38	42	**42,00** ± 7,16	38	68
Median of 4 measurements	**39,00 ± 6,63**	**38,00**	**59,00**	**42,50 ± 7,99**	**38,00**	**69,50**

Note: SD = standard deviation, Min = minimum value, Max = maximum value

Table 4 shows the median values converted to % for all measurements. We see that the behavior of children in SO differs from the norm (from 100 %) by 3 %. The behavior of non-sporting children differs from the norm by 13 %. Non-sporty children have worse social behavior by 10 % compared to sporty children in SO.

Table 4. Comparison of behavioral scores converted to % for children in SO and non-sporty children

Median v % normy	Behavior in % norm		
	Children in SO	**Non-sporty**	**Difference in non-sporty**
June 2017	109 %	125 %	**16 %**
September 2017	100 %	114 %	**14 %**
June 2018	105 %	105 %	**0 %**
September 2018	100 %	111 %	**11 %**
Median of 4 measurements	**103 %**	**113 %**	**10 %**

Females participating in SO and non-sporty females

When comparing the development of trends in females' behavior (Figure 2), we see that sporty females have better behavior than non-sporty females. Only in June 2017 and 2018 was the behavior of both groups the same (40 points).

For **sporty females** (participants in SO), we see a **negative asymptomatic trend** with the highest value (worst behavior) of 40 points in June 2017, followed by stabilization at 38 which represents ideal social behavior with no problems at all. **Summer vacations have no effect on the behavior** of sporty females.

In **non-sporty females**, we see an **unbalanced trend** which has a different value in each measurement. The value is always lower in June (40 and 38 points) and the value is always higher in September (41,5 and 43,5 points). **During the school year, their behavior improves slightly, and conversely, during the summer vacations, the social behavior deteriorates.** This change is not statistically significant, see Table 2.

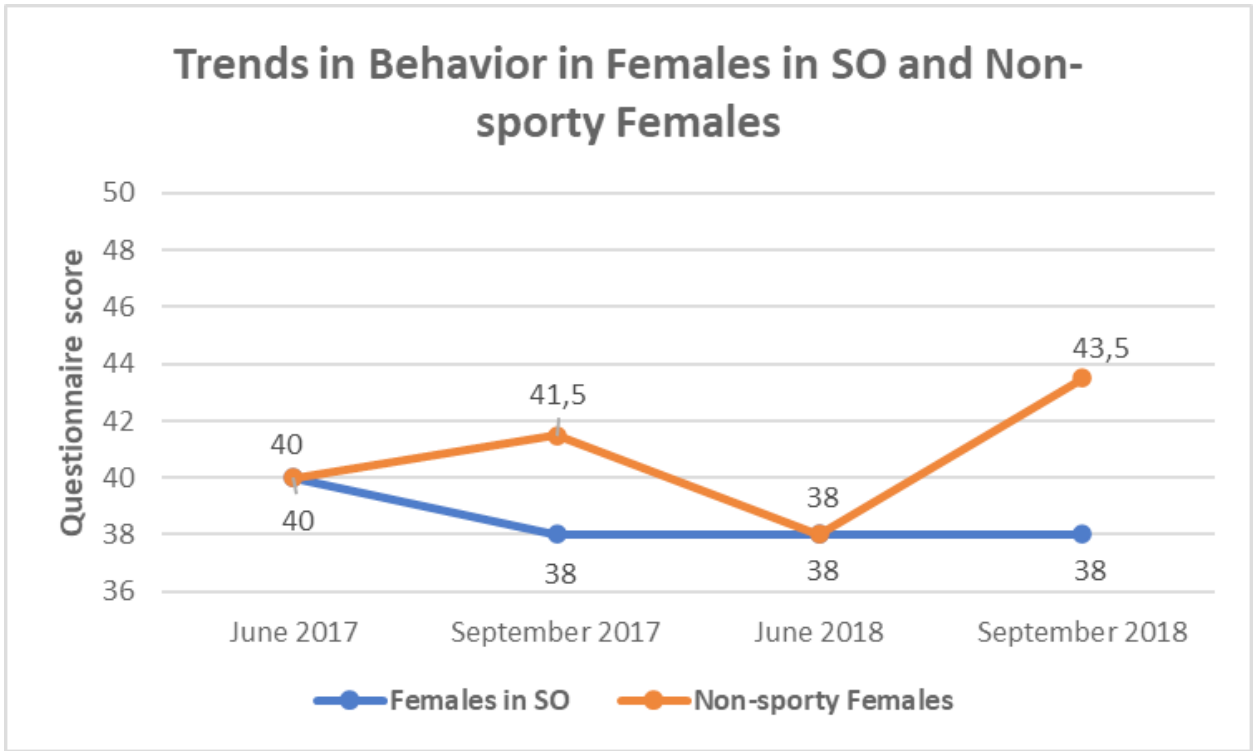

Figure 2. Graph of behavioral trends in sporty and non-sporty females

In the table (Table 5) we see descriptive statistics for gross scores in the behavioral questionnaire for sporty and non-sporty females. Also the maximum values in the questionnaire, i.e. the worst recorded behavior in non-sporty females, occurs in 3 of 4 measurements (June 2017, June 2018 and September 2018).

Table 5. Gross scores in the behavioral questionnaires for sporty and non-sporty females

Females – gross score	Females in SO			Non-sporty Females		
	Median ± SD	Min	Max	Median ± SD	Min	Max
June 2017	**40,00** ± 8,48	38	58	**40,00** ± 8,84	38	71
September 2017	**38,00** ± 9,06	38	62	**41,50** ± 5,44	38	59
June 2018	**38,00** ± 4,85	38	51	**38,00** ± 6,96	38	61
September 2018	**38,00** ± 0,89	38	40	**43,50** ± 7,75	38	64
Median of 4 measurements	**38,00 ± 6,67**	**38**	**54,5**	**40,75 ± 7,36**	**38**	**62,5**

Note: SD = standard deviation, Min = minimum value, Max = maximum value

Social behavior (Table 6) of sporty females does not differ from the norm (100 %) and for non-sporty females it differs from the norm by 7 %. **Non-sporty females have worse social behavior by 7 % compared to females who do sports.**

Table 6. Comparison of behavioral scores converted to % for females

Median score by gender in % of norm	Females in % norm		
	Females in SO	Non-sporty	Difference in non-sporty
June 2017	105 %	105 %	**0 %**
September 2017	100 %	109 %	**9 %**
June 2018	100 %	100 %	**0 %**
September 2018	100 %	115 %	**15 %**
Median of 4 measurements	**100 %**	**107 %**	7 %

Males participating in SO and non-sporty males

When comparing behavioral trends in males, we see (Figure 3) that non-sporty males have a higher value in the behavior questionnaire, it means worse social behavior throughout the measurement period.

Non-sporty males have a convex trend, where in each measurement they have a different value of points in the questionnaire and the summer vacations have no effect on their behavior.

Sporty males (participants in SO) have an unbalanced trend: they always have a lower value of points in September, i.e better social behavior (38 and 39 points), and conversely, their behavior always worsens in June (values of 42 and 41 points). The summer vacations cause improvement in the social behavior and their behavior deteriorates during the school year. This change is not statistically significant, see Table 2.

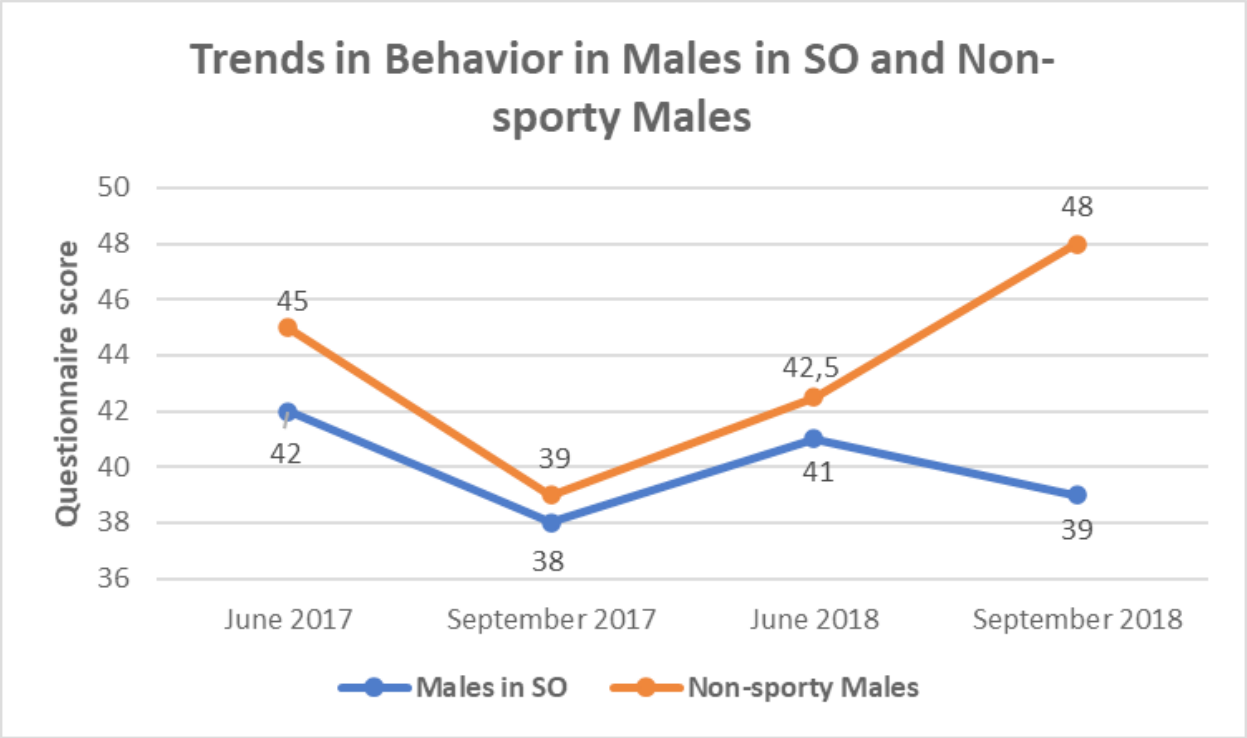

Figure 3. Graph of behavioral trends in sporty and non-sporty males

In the table (Table 7) we see descriptive statistics for the gross scores in the behavioral questionnaire for sporty and non-sporty males. The maximum values in the questionnaire or the worst manifestations of social behavior are higher throughout the research in non-sporty males (values 70, 62, 68 and 66 points).

Table 7. Gross scores in the behavioral questionnaires for sporty and non-sporty males

Males – gross score	Males in SO			Non-sporty Females		
	Median ± SD	Min	Max	Median ± SD	Min	Max
June 2017	**42,00** ± 2,16	38	44	**45,00** ± 8,07	38	70
September 2017	**38,00** ± 6,96	38	61	**39,00** ± 6,60	38	62
June 2018	**41,00** ± 6,20	38	60	**42,50** ± 8,11	38	68
September 2018	**39,00** ± 1,77	38	42	**48,00** ± 8,97	38	66
Median of 4 measurements	**40,00 ± 6,58**	**38**	**52**	**43,75 ± 8,09**	**38**	**67**

Note: SD = standard deviation, Min = minimum value, Max = maximum value

The social behavior of sporty males (Table 8) differs from the norm by 6 %, and that of non-sporty males differs from the norm by 15 %. **Non-sporty males have worse behavior by 9 % compared to males in SO.**

Table 8. Comparison of behavioral scores converted to % for males

Median score by gender in % of norm	Males in % norm		
	Males in SO	**Non-sporty**	**Difference in non-sporty**
June 2017	111 %	118 %	**7 %**
September 2017	100 %	103 %	**3 %**
June 2018	108 %	112 %	**4 %**
September 2018	103 %	126 %	**23 %**
Median of 4 measurements	**106 %**	**115 %**	**9 %**

DISCUSSION

The fact that all children in SO (males and females) have better social behavior than non-sporty children is likely to be due to the positive effects of physical activity and sport. A positive relationship between physical activity, improved behavior, reduced emotional problems, mental health and psychosocial well-being has already been demonstrated in children and adolescents with ID (Borland et al., 2022). Sport and physical activity lead to both the improvement of the physiological side of the individual, i.e. to increase muscle mass, strengthen bones, lower cholesterol, decrease heart rate, improve muscle coordination, and to improve the mental side of the individual, i.e. to increase self-confidence, stress compensation (Jančík, Závodná & Novotná, 2006), perception, attention, memory, thinking, speech development (Kvapilík & Černá, 1990, p. 91) and improve mood. Probably the main influence of sport is on fair play, discipline, and compliance with the rules. I think that sporty children are used to listening to a much greater extent (e.g. to a coach during training), and thus they have better behavior in all areas of their lives, including school.

Research on healthy adolescents has shown that adolescent athletes who participate in athletic disciplines and swimming also perform better at school than non-athletic classmates (Rees & Sabia, 2010). This is a suggestion for further future research on children with ID - to add another aspect of school success to social behavior and sport.

Furthermore, it is interesting that problem behaviors in children with ID abroad are 22 % - 64 % worse than the norm (Gillberg et al., 1986; Merrel & Holland, 1997; Totsika et al., 2011), while in the Czech Republic both sporty children (3 %) and non - sporty children (13 %) have a much lower incidence of problem behavior. The explanation may be that in the Czech Republic, compared to foreign research (where children with ID have 50% physical activity compared to the norm), children with ID have sufficient physical activity, i.e. reach 74 % - 122 % of the norm (the norm is 12 000 steps per day), (Kampasová & Válková, 2021), and thus even those children who do not participate in SO competitions probably have enough physical activity in their normal regime.

The fact that females have better social behavior than males could be explained by women having better relationships with others: they are more team-oriented and solve problems better (KarieraWeb, 2012). Men have higher testosterone levels, which makes them more prone to aggression (Psychology, 2014).

In the Czech Republic is a well-established education system for children with ID, where professional (graduated) teachers take care of the children. The school itself also provides a lot of voluntary activities for its children, such as outdoor school, swimming training, tourist course, floorball tournament, etc. Part of the regular teaching is, for example, structured learning, elements of art therapy, music therapy, speech therapy, self-sufficiency training in a training apartment, etc.

There was an unbalanced trend in children in SO, which causes a slight deterioration in their behavior during the school year, and, conversely, a slight improvement in behavior during the summer vacations. The composition of the children may play a role, with 40 % of children being of school age, 40 % of children being in pubescence and only 20 % of children being in adolescence. It is possible that prepuberty and puberty play a major role in their behavior at school. During this period, emotional instability increases, first loves arise, and mood swings are frequent (Nakonečný, 2011, pp. 679-680). Children may, for example, perform in front of each other in the school year, want to be the center of attention, etc. Children with ID develop a disparity between mental and biological maturity during puberty, which deepens during their further development, while in children without ID it equalizes (Lečbych, 2008, pp. 43-44).

CONCLUSIONS

Children in SO (females and males together) have an unbalanced trend in social behavior, and summer vacations cause an improvement in their behavior. Non-sporty children (females and males together) have a convex trend in social behavior and summer vacations have no effect on their behavior. Children in SO have better social behavior by 10 % compared to non-sporty children.

Females participating in SO have a negative asymptomatic trend in social behavior and summer vacations have no effect on their behavior. In non-sporty females, there is an unbalanced trend in social behavior, and summer vacations cause a deterioration in their behavior (and vice versa, there is an improvement in behavior during the school year). Females participating in SO have better social behavior by 7 % compared to non-sporty females.

Males participating in SO have an unbalanced trend in social behavior, and summer vacations cause an improvement in their social behavior (and vice versa, there is a deterioration in their behavior during the school year). There is a convex trend in social behavior for non-sporty males, and summer vacations have no effect on their behavior. Males participating in SO have better social behavior by 9 % compared to non-sporty males.

The behavior of children with ID in the Czech Republic is very good, as they differ very little from the norm of ideal social behavior. The results showed that sport in children with ID leads to fair play, to improve their social behavior, and therefore sport should be supported nationwide for children with ID.

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Error Rate in the Decisions of Elite Futsal Referees in the Context of their Position on the Pitch

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ABSTRACT

One of the primary requirements for a futsal referee is the minimum of incorrect decisions in a match. An important starting point for the possibility of the correct decision of the referee is his position on the court when deciding. The aim of the thesis is to find out whether the error rate of the futsal referee changes when assessing game situations (leading to a direct free kick) in connection with his position. The research group consisted of referees of the 1st futsal league in the Czech Republic (n = 15); average age 39.4 (SD = 6.2). A total of 685 game situations were assessed from 42 matches in the 2020/21 and 2021/22 seasons. The methods of work were: indirect observation of video recordings, notation analysis, expert assessment of game situations by an expert group (n = 5). Results: the error rate in the decisions of referees is 7%; inadequate positions detected 3%; A statistically significant relationship was found between the degree of error rate in the referees' decisions and the quality of the position ($r_s = .32$, $p < .001$) but no material significance was found. We recommend a more detailed research solution to this issue.

Keywords: futsal, referee, error, decision-making, positioning

INTRODUCTION

The match of sports games requires very precise and, if possible, maximum performance of all participants of these games – if it is a top or professional competition. Player characteristics have been described in terms of performance for many years. The performance characteristics of the referees of these games are no less important - for the performance of the referees themselves, and thus for the overall quality of the match.

The activity of referees of invasive sports games in a match is referred to in the scientific field as the expert performance (Gilis, 2008; Helsen & Bultynck, 2004). The starting point is the so-called theory of deliberate practice, which emphasizes the length and quality of preparation for the activity - from which the acquired skills and abilities will emerge (Ericsson & Lehman, 1996).

One of the primary requirements for referees is the minimum of erroneous decisions. According to Bompa, expert performance in the perceptual-cognitive area is crucial for the referees, in terms of their decision on the game situation (1999). From a psychological point of view, the decision-making process in sport is a process of using the perceptions of the information obtained to determine whether an answer should be made, or what the answer should be (Elliott, 1999) – in our case, the answer is the referee's decision. The referee therefore interprets the perceived game information for the final, most appropriate answer. The quality of this decision depends on: 1. the quality of the perceived information obtained; 2. experience of the decision-maker (Abernethy, 1986). Bless et al. (2004) describes the individual steps of the referee's decision-making process in sports games in the following way: the primary is the stimulus (e.g., tripping an opponent), stimulus perception by the referee (referee saw the fault), categorization as a fault and subsequent integration of information with severity assessment (here the judge uses his memory and skills). The last step is a behavioral response (e.g., a direct free kick and a red card). If the above scenario is violated, a wrong decision may be made (Balkó et al., 2016; Plessner & Haar, 2006).

For several years now, there has been a targeted focus on the training of perceptual-cognitive abilities in the referees of the relevant sports game (Catteeuw, 2010; Kresta, 2015). In the world of popular games like football (Catteeuw et al., 2010), basketball (MacMahon et al., 2007), handball (Souchon et al., 2004) or American football a relatively large amount of knowledge has already been researched - regarding the referees´ decisions and their error rate. Less popular games lag somewhat in this respect - one of these sports games is futsal, which is the subject of our research plan.

Kresta (2018) comprehensively analyzes the current state of knowledge about the performance of futsal referees. He states that there are only a limited number of studies that deal with their physical activity during matches (Ahmed et al., 2017; Rebelo et al., 2007, 2009, 2011), and stress of the referees is analyzed by (Ferreira et al., 2009). New knowledge about the movement intensity of the match is brought by Serrano et al. (2021) and Bolotin & Bakayev report on the possibilities of individual fitness training (2017). Shared mental models are researched by Sinval et al. (2020) and Aragao e Pina et al. (2021). Burnout syndrome is researched by Ribeiro & Alvarez (2019). The overview futsal study is presented by Sanmiguel-Rodríguez & Giráldez (2021), but only limited to children's futsal play. The error rate of the elite futsal referees was solved minimally. Kresta (2018) found the elite referees´ error rate of 7% for the whole match. He found a statistically significant relationship between the degree of error rate in the referees' decisions and the quality of their position (Kresta, 2018).

The referee's performance in a futsal match is conditioned by a certain technique and mechanics of decision-making, which is determined by futsal standards, especially the recommendations and obligations (for the referee and the second referee) arising from the futsal rules. In terms of position on the vicinity of pitch, it is a so-called diagonal control system (Ahmed et al., 2017; FIFA, 2021; Rebelo et al., 2011). The best position of the referee on the vicinity of pitch is considered to be the one from

which the referee can: make the right decision, control the whole game situation, have the maximum view (FIFA, 2021). These positions of referees also take into account sports and game variability – i.e., it is not always possible to dogmatically determine the exact position of the referee (e.g., the exact distance), because he must respond to the development of the game situation (FIFA, 2021; Mallo et al., 2010). When it comes to responsibility for offenses against rule XII (offenses and offenses leading to free kicks), the responsibility of both referees is divided into the so-called space around the ball, i.e., within the action area and space within the influence area). The referee makes most of the decision related to breaking Rule XII in the action area – which is a game situation that is the subject of our interest, both in terms of the referee's decision and his position. The aim of our work is to describe and explain the decisions (correct vs. wrong) of futsal referees in connection with their position on the vicinity of pitch. Hypothesis: the error rate in the referee's decisions increases depending on the declining quality of his position on the vicinity of pitch. The aspect of futsal decision making error rate, which is a key aspect of the proper conduct of the match, has not yet been sufficiently researched.

MATERIALS AND METHODS

Research group, expert group

The research group consisted of all 15 referees with the highest A license authorizing refereeing of the futsal 1st league (so-called group intended only for the 1st league), average age = 39.4 years (*SD* = 6.2); professional experience in refereeing futsal 1st league matches was on average 13.8 years (*SD* = 5.2). The height and weight of the referees were on average 178.8 cm (*SD* = 2.3), respectively 82.2 kg (*SD* = 7.2). We obtained personal data from the referees by personal anamnesis and somatometry; the somatic measurement tool was a medical scale with an integrated height meter (Tanita WB-3000, Tanita, Japan).

The evaluation expert group set up from leading Czech experts consisted of 5 people with an average age 51.8 years (*SD* = 12.5) and their professional experience was 22.6 years (*SD* = 7.8).

Methods, tools

We collected data on the referees' activities in the match by indirectly observing video recordings (ex post) according to Hendl (2005). We used expert assessment of selected game situations used in sports games (Helsen et al., 2006; Knudson & Morrison, 2013). The tool was a Samsung TV – UE40F6740 (Samsung Electronics, South Korea).

We used notation analysis to analyze the error rate in the referees' decisions (D´Ottavio & Castangna, 2001; Hughes & Barlett, 2002). We quantified the position on the vicinity of pitch by categorical systems according to Gavora (2000), which were already used directly for these purposes by Kresta (2018).

Research design

This is a non-experimental research, specifically an observational study. Data were obtained from the Czech 1st League matches of futsal in the competition years 2020/2021 and 2021/2022. The research sample consisted of referees from the population of elite referees in the Czech Republic. For these referees, we had the expert group assessing the error rate and the position of the referees on

the vicinity of pitch while assessing these game situations. The study was performed: anonymously; in accordance with the Declaration of Helsinki; the ethical standards of the university have been respected; it was carried out with the consent of the jury of the Futsal Association of the Football Association of the Czech Republic.

In the video recordings of the matches (n = 42), taken by the sports television station, which is the official broadcaster (Czech Television, 2022), we used notational analysis to identify offenses against rule XII of the futsal rules (FIFA, 2021); specifically, these were offenses leading to a direct free kick, or penalty kick. The subject of our research was only those game situations which the referee classified in the match as offenses, i.e., he interrupted the game with a whistle and ordered a direct free kick (or penalty kick) or signaled an advantage in the game. In accordance with the previous work (Helsen et al., 2006; Mallo et al., 2010), other game situations were not taken into account, if the referees did not evaluate the game situation as a violation of the rule. Both referees who manage a futsal match on the vicinity of pitch have the same powers on the assessment of these offenses in the match, therefore offenses were assessed throughout the match by both referees (i.e., the referee and the second referee). Their mandatory and recommended responsibilities and position on the vicinity of pitch were taken into account in the assessment (FIFA, 2021).

Analogous to the Kresta research (2018), we used an expert group, in which the training of assessors and verification of qualitative indicators of expert assessment was carried out (see chapter Results).

We used a proven categorical observation system to assess the error rate and position of futsal referees (Kresta et al., 2015; Kresta, 2018). The expert consensus of our expert group was quantified using two scales: 1. three-level categorical scales for assessing the decision-making position, where the criterion for inclusion into one of the categories was whether the realized position of the referee in the game situation corresponded to the futsal standards in the context of the game situation, or to what extent; this scale took values from 1–3 (see Table 1). 2. dichotomous categorical scales for assessing the correctness of decisions, where the criterion for inclusion into one of the categories (correct vs. wrong decision) was whether the decision made by the referee was in accordance with rule XII of the futsal rules of the game; each judge made a verdict on the decision of the referee on the relevant game situation (correctly or incorrectly, value 1 or 0); Based on the ratio of the judges' verdicts, a consensus of the expert group was made, i.e., whether the referee decided the game situation correctly or incorrectly (see Table 2). The design validity of both scales was positively verified (Kresta et al., 2015; Kresta, 2018).

Table 1. Referee´s positioning assessment scale with calculation record

Position	Points	Consensus value
Adequate	3	1–3
Acceptable	2	
Inadequate	1	

Note: adequate positioning as consensus of the expert group is to be found within the interval 2.8 – 3; acceptable within the interval 2 – 2.6; inadequate within the interval 1 – 1.8. E.g. 4 evaluators set adequate positioning (value 3) and one evaluator inadequate (value 1), that is $(4 \cdot 3 + 1 \cdot 1) : 5 = 2.6$ (consensus of the expert group).

Table 2. Scale to assess a referee´s decision with calculation record

Decisions	Ratio of verdicts (correct : erroneous)	Consensus value
Correct	5:0	1
	4:1	0.8
	3:2	0.6
Erroneous	2:3	0.4
	1:4	0.2
	0:5	0

Note: according to the ratio of verdicts in individual evaluators (the average of correct decisions) was the consensus value 0 – 1 (one decimal). The closer the value was to 1, the more agreement the expert group showed in assessing a referee´s decision.

The examined game situations (685 video clips from 42 matches) were presented on a TV connected to a computer to each judge separately. It was also possible to play repeatedly, slow down, or with the possibility of stepping or stopping the recording. The assessor first solely assessed the position of the referee (regardless of the correctness of the decision). He then assessed the correctness of the decision - his task was not to take into account the position of the referee. We used a code system and a record sheet verified by Kresta to record the data of the expert group (2018). The above procedures allowed us to record and subsequently quantify the opinion of the expert group on the referee' decisions and their position on the vicinity of pitch in these decisions.

Statistical data processing

Due to assessing data normality by Shapiro-Wilk W test we can state that the monitored quantities (decision $p < .001$ and position $p < .001$) have different than normal distribution. We analyzed the relationship between position and decision by Spearman's Rank Order Correlations. The tools used: software Microsoft Excel 2020 (Microsoft Corporation, USA) a Statistica PRO trial version (StatSoft, ČR).

RESULTS

Below we will first present information about the assessed game situations and the expert group. Subsequently, we will describe the degree of error rate in the decisions of the referees and the quality of the position in these decisions. Finally, we will present the relationship between the error rate in decisions and the quality of the position.

Assessed game situations

A total of 685 game situations leading to a direct free kick were judged. Season 2020/21 (season No. 1) in 22 matches, season 2021/22 (season No. 2) in 20 matches. Details in Table 3.

Table 3. Investigated game situations - descriptive characteristics

Season No.	n	M	SD
1	358	16.2	3.6
2	327	16.3	2.8
1+2	685	16.3	3.2

Note: M = Mean, SD = Standard Deviation

Expert group

The expert group established by us was subjected to training, after which the qualitative indicators were verified. Criteria validity of our expert assessment, verified on the selected game situation (criterion), reached 93 % compliance with this criterion. The inter-subject reliability, assessed among observers, was 88 % for error and 85% for correctness of position. Intra-subject reliability in terms of stability of observations over time (repeatability) was 91 % for error rate and 83 % for position accuracy. The stability of the group's expert consensus over time was 85 %.

Error rate in decisions

The referees, in the 685 game situations we examined, decided almost 93 % correctly (637 decisions with a value of 0.6 or 0.8 or 1, according to Table 2). The error rate in decisions is therefore 7 % (48 wrong decisions with value of 0 or 0.2 or 0.4). Details are given below (Table 4).

Table 4. Frequency of decisions assessed by the expert group

Decision	Value of decision	Frequency			
		Absolute (n)	Relative absolute (%)	Cumulative absolute (n)	Relative cumulative (%)
Erroneous	0	7	1	7	1
	0.2	21	3	28	4
	0.4	20	3	48	7
Correct	0.6	61	9	109	16
	0.8	146	21	255	37
	1	430	63	685	100
Total		685	100	685	100

The stated values are the consensus of the evaluation of the expert group as a whole according to the mentioned methodology. The consensus of the expert group on the referees' decisions was on average close to 0.9 (SD = 0.21) out of the maximum possible value of 1, which would mean 100 % agreement of all the judges. It is therefore possible to state 90% agreement of the judges in this variable.

Quality of position in decision making

The referees took an adequate position in approximately 63 % of cases. The position categorized as still bordering adequate was found in almost 34 % of cases. Inadequate position was detected in only 3 % of cases. See Table 5 for details.

Table 5. Frequency of values in referee´s positioning while making decisions on game situations

Positioning	Value of positioning	Frequency			
		Absolute (n)	Relative absolute (%)	Cumulative absolute (n)	Relative cumulative (%)
Inadequate	1.0	3	0	3	0
	1.8	18	3	21	3
Bordering adequate	2.0	20	3	41	6
	2.2	65	10	106	15
	2.4	36	5	142	21
	2.6	111	16	253	37
Adequate	2.8	197	29	450	66
	3.0	235	34	685	100
Total		685	100	685	100

Relationship between error rate and quality of position

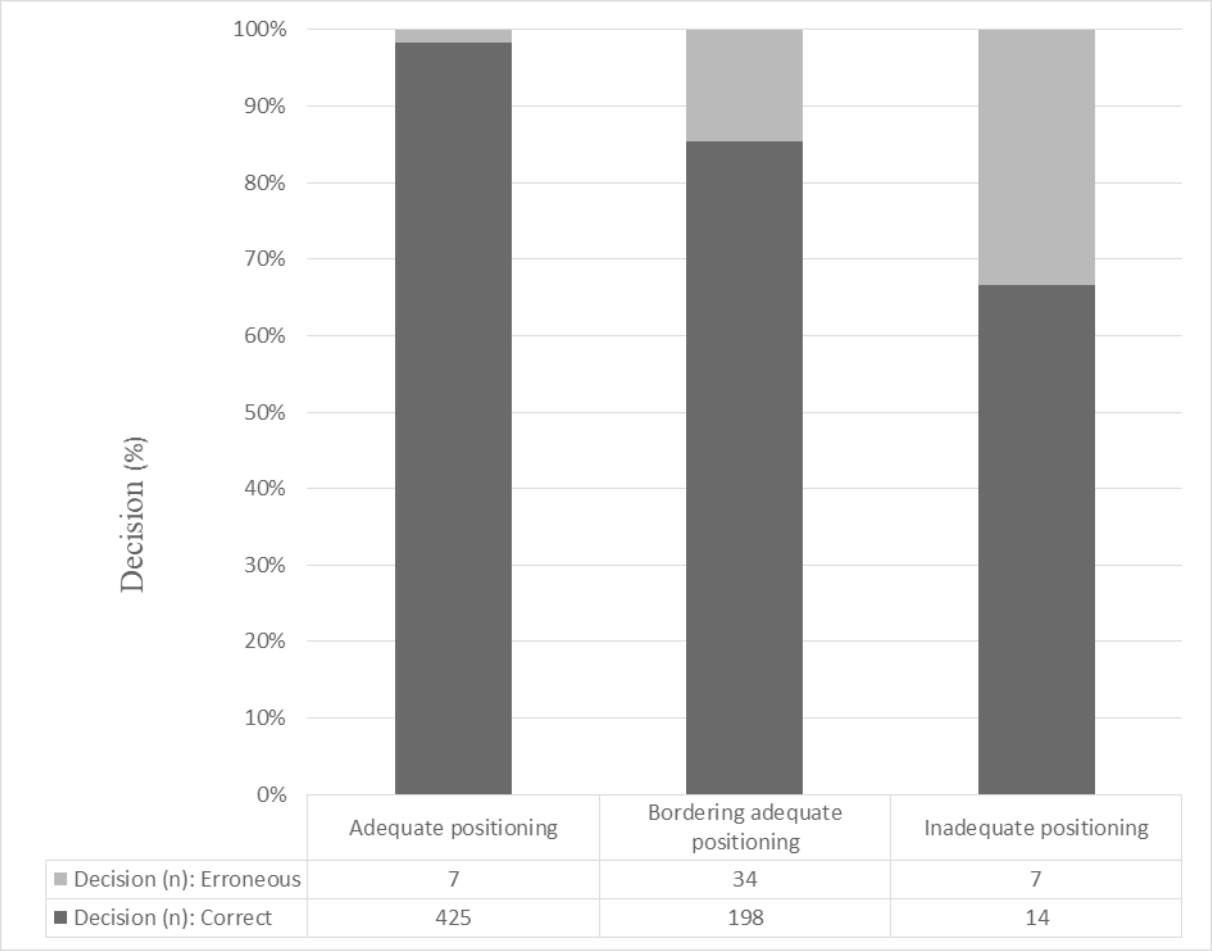
The relationship between error rate and quality of position is comprehensively presented in Figure 1. The total percentage of errors in the decisions of referees standing in adequate positions (positions are defined in Table 1), without distinguishing the value of the consensus of the expert group, is less than 2%. With a deteriorating position, the error rate of the referees also increases. A still adequate position corresponds to almost 15% error rate and an inadequate position to 34 % error rate.

If the referee took an adequate position, he decided the game situation mostly correctly, however, within the adequate positions, evaluated by the consensus of the expert group only 3.0, a total of 235 decisions were made – out of this 97 % correct and 3 % wrong, which shows a higher error rate than adequate positions overall.

Paradoxically, there is a list of inadequate positions for which the expert group unanimously agreed (n = 3, consensus 1.0) – in these judges they always decided correctly (the consensus of the expert group on the correctness of the decision with the values was always 0.8; see Table 2). For inadequate positions with a consensus value of 1.8 (n = 18), both right and wrong decisions are already appearing, see Figure 1.

Based on the results of Spearman Rank Order Correlations, we can state that the correlation between the two variables was proven, $r_s = .32$, $p < .001$, that is, the position of the referee influences his decision.

Figure 1. Referees´ decisions in context to their positioning



DISCUSSION

We chose elite futsal referees for our work, with whom we focused mainly on their error rate in decisions during the two seasons of the Czech highest competition. We consider this aspect of error rate to be crucial for the referees' activities in the match. The informative values of the submitted research may be qualified by certain limitations (research sample, the problem of subjectivity of assessment by referees and expert group). We will discuss the results analogously to the results section.

Assessed game situations

In accordance with Helsen & Bultynck (2004), we placed 685 game situations into our assessment, into the category of observable referee decisions i.e., when the referee whistles a direct free kick and interrupts the game or signals an advantage in the game and does not interrupt the game. According to our experience, these decisions are easily identifiable.

Our results show that the average number of decisions per match (M = 16.3, SD = 3.1) is approximately 2 such decisions in five minutes of play. Comparisons are made possible by official statistics of international competitions, which report an average of 11 accumulated fouls per match, however, with a large range of variation (FIFA, 2021), indicating 1–2 decisions in five minutes of play. Here, however, it is necessary to point out the different competitions (national

versus international), where our own experience shows us substantial differences in this parameter. A relevant comparison with the previous futsal study by Kresta (2018) is not possible, because there were also assessed indirect free kicks and it was not primarily an analysis of frequencies. Comparison with other invasive sports games does not seem appropriate with regard to other pitches, number of players, referees, etc.

It should be noted that this is not the total number of these referee's decisions in the match, because there are typologically identical game situations, which the referee does not evaluate as an offense, does not interrupt the game, or does not signal an advantage in the game. Consistently with Helsen & Bultynck (2004), we argue that the quantification of unobservable decisions causes methodological difficulties. This is especially the data collection when categorizing the game situation, when it is necessary to analyze this with the referee.

Expert group

Our expert group showed similar qualitative indicators as the group used by Kresta, also in futsal (2018). Our values and Kresta´s are relatively close to most indicators: criterion validity (93 % let us say 92 %) compliance with this criterion; inter-subject reliability, assessed among observers (88 % let us say 89 %) for error rate and for position (85 % let us say 81 %); intra-subject reliability in terms of stability of observations over time (repeatability) 91 % let us say 90 % for error rate and 83 % let us say 81 % for position; stability of the expert consensus of the whole group in time (85 % let us say 81 %).

The consensus values of the expert group on the decisions of the referees found by us were close to the average value 0.9 (SD = 0.21), therefore, we find 90% assessor agreement for this key variable. They unanimously agreed in 63% of the game situations, i.e., all 5 judges confirmed the referee's decision. This is a minimal difference compared to the previous futsal research of similar parameters, where 59% agreement was calculated.

The agreement of the expert panel, according to Button et al. (2009), which examined the decision-making of referees in football is 88%. He states that this is approximately 25 % higher than the correctness of the assessment of game situations in the match by the referee, i.e., we can conclude that the expert panel is more suitable for the evaluation of these situations than the individual. It should be noted here that the referee in a match does not always have the opportunity to reassess the game situation from the video. Football Video Assistant Referee (VAR) protocol allows this only in certain situations, similar to the futsal tool Video Support (hereinafter VS), which is intended for review only by the referee in the match (FIFA, 2021). Other sports games such as rugby, basketball, etc. do not have the same approach to the issue, see below.

From our data it is possible to detect inconsistency of assessors in certain situations. Gaming situations that can be described as borderline are 12 %. These are situations where the consensus of the expert group had values of 0.4 and 0.6 (according to the Table). We believe that this is a so-called difficult game situation, and we see a strong relationship between this difficulty of the game situation and the correctness of the decisions of the members of the expert group. This is less than 16%, according to Kresta (2018). It can therefore be assumed that our expert group looks better in this respect. We see the reasons mainly in the higher number of researched situations, better video recordings and a more experienced expert group in our case.

Expert assessment, used in the work to detect the qualities of decisions and position, will always be associated with a certain degree of subjectivity of the assessor (Gilis, 2008; Helsen & Bultynck, 2004; Starkes & Ericsson, 2003). In this statement, based on our many years of experience and experience directly from elite referees and match delegates, we agree with the above sources.

Directly here we can see the possibilities in improving the agreement of the judges, especially in the area of unifying the interpretation of the rules of the given sports game in typologically similar game situations, which we examined.

Error rate in decisions

The error rate detected by us in the decisions is therefore 7 % (decisions with a value of 0 or 0.2 or 0.4). Here we approach the results of Kresta, which presents a value 0.5 % lower (2018). There can be many reasons for a wrong decision. However, based on our experience, most errors arise when violating the referee's decision-making process scenario (from stimulus to behavioral response), which we presented in the introduction. The disturbing variables are the stress of the referee, fatigue, reluctance to make unpopular decisions and, last but not least, the wrong position, which makes it impossible to perceive the situation adequately (see below).

However, other scientifically published data on futsal error rates are missing. One of the ways could be to make the referee observer reports in UEFA matches available. However, they are not currently freely accessible and represent a one-person evaluation, albeit using the possibility of video recording.

Comparing our results with other sports games is difficult due to the absence of scientifically published information or due to the differences between these games or the methodology used. However, it is possible to try this in football, where rule XII is analogous to the rules of futsal (i.e., the decision on free kicks). Data on error rates are presented by Catteeuw et al., who reports higher relative values for the main referees when judging a prohibited game when compared to the referee's assistants. (2010). Football referees made 17 % of wrong decisions at the 1986 World Cup (Van Meerbeek et al., 1987).

In the past, research findings applied to practice had made progress in reducing error rates for football referees. The error rate in deciding on offside situations has decreased after the application of the theory of intentional gain of experience - in comparison with world championships 2002 and 2006, error rate 26.1 % versus 10 % (Catteeuw et al., 2010). At present, this error rate in elite competitions is reduced, especially with the use of modern technologies. We believe that, for example, measuring the offside using a calibrated "offside line" in football is technically feasible and with a minimum of errors. However, it still does not seem to be fully and positively received by players.

An extensive study is presented by Spitz et al., where VAR was used in more than two thousand football matches to revise the referee's previous decision on the vicinity of pitch. The predicted probability of increasing the correctness of the decision increases from 92 % to 98 % after the use of VAR. Decision review is relatively fast, averaging 15 seconds for decisions made directly by VAR. In the case of a referee review on the vicinity of pitch at the monitor after a VAR alert, the average review time is around 60 seconds (2021).

Similar systems of "video referee" are also seen at elite matches of basketball, American football, rugby, etc. This is probably one of the future ways of making decisions in sports games, where more and more decisions will be made by some instrument alone (e.g., measuring the offside in football, or the ball outside the playing field in handball) or it will be technical assistance to the referee by video recording, etc. – where, however, the decision is made by the referee himself, but with this support.

However, in our experience, a key issue arises, namely decision-making about human behavior using tools (video) - in our case about the player's activities (e.g., the player fouled). Is it possible to quantify qualitative data such as a player´s foul this way? How can the tool itself implicate, for example, the intensity of contact between two players? In football, this problem is already suggested by Spitz et al., (2021) discussing the negative aspects of VAR. These are delays in the game, return in the game storyline, etc. There is also the problem of real assessment of the game situation in three-dimensional presentation (3D) versus assessment in two-dimensional 2D presentation on the monitor (Put et al., 2014).

Quality of position on decision

The referees took an adequate position in 63 %, bordering adequate position was found in 34%, inadequate position in 3 %. These values are close to the values of similar futsal research where the values are 66 %, 30 % and 4 %, respectively (Kresta, 2018). We are no longer surprised as our predecessors that the value of adequate positions is between 63–66 %, because if we add the values of bordering adequate positions, we get to the values of 96–97 %. We justify it by: certain subjectivity of the assessors of the expert group; not completely strictly defined position according to standards in all game situations; game variability of futsal. Our expectation of a minimum of inadequate positions has been confirmed.

Comparisons with other sports games are not entirely relevant for analogous reasons discussed for error rate. Although this issue has been solved, for example, by football assistant referees, where the position on the offside line is considered to be crucial (Baldo et al., 2002), although there are studies that refute this and place more emphasis on the assistant's experience (Catteeuw et al., 2010). However, modern technology (VAR) shift this aside to the background. Mallo et al. advert to an average 20m distance of the football referee from the ball when judging fouls (2010). We cannot paraphrase futsal, but we can learn from the fact that this distance extends towards the end of the match.

Categorization of positions may seem problematic. The evaluation of futsal referees in the practice of the parties on the vicinity of pitch usually takes place dichotomously - adequately versus inadequately. However, only the bipolar scale did not fully take into account the practical possibility of taking a position. That was one of the reasons why we finally chose the three-point scale. Experience shows that it is not always possible to take an adequate position (e.g., in a rapid counterattack), and this is not usually blamed on the referee, because it was not within his means (in terms of human motor skills). In this case, it is crucial whether the referee decided correctly - here again we come across the experience of the referee, which will help him anticipate, decide (Catteeuw et al., 2009). It is possible to agree with methodological materials (FIFA, 2021) that it is not appropriate to define the position of referees more strictly than the case currently is. Experience shows that it is necessary to take into account the variability of game situations about the position

to decide in connection with them - all this is exacerbated by the need to cooperate with the second referee within the diagonal principle of management.

Relationship between error rate and quality of position

Between the error rate and the quality of the position, the results visually show a trend (see Figure 1) that the error rate decreases with increasing quality of the position. The proven correlation between the two variables shows the interdependence, namely that the position of the referee affects his decision. The total percentage of errors in the decisions of referees standing in adequate positions is less than 2 % - compared to 34 % of the error rate in inadequate positions.

Our results confirm previous futsal research (Kresta, 2018; Kresta et al., 2015), which verify the relationship between the error rate and position with a statistically significant dependence and 99% of correct decisions in adequate positions.

In conjunction with the trend seen in the graph above (Figure 1) and the previous two surveys, these findings can be agreed. We know from our own experience that in the case of inadequate positions, the error rate increases (large or small distance from the game situation; wrong view of the game situation, etc.).

With the absolute agreement of the expert group (5 members rated the position as adequate) on adequate position (n = 235), there were 1% fewer correct decisions, i.e., higher error rate than adequate positions overall. The situation is also paradoxical for inadequate positions (n = 3), for which the expert group unanimously agreed (5 members assessed the position as inadequate). In these referees always decided correctly. These cases can be attributed to the disproportion between the real decision on the pitch in the case of the referee and the assessor in the expert group assessing at the monitor, as well as the complexity of the decision and other influences (even unknown).

Based on the above facts, we state that the correlation between the two variables shows the interdependence $rs = .32$, $p < .001$, that the better position of the referee affects his better decision. Practice and similar research confirm this assumption of a positive relationship between decision and position as correct, but not the only one.

CONCLUSION

From the point of view of the description and explanation of the referees' decisions in connection with their position on the vicinity of pitch and movement activity, it can be stated: that the better position of the referee affects his better decision. We see the assumption of a positive relationship between decision and position as correct, but not the only one.

We recommend for practice: to unify the interpretation of the rules of a given sports game in typologically similar game situations that we have investigated; to focus on the position of a referee on the pitch. We recommend that the issue be further scientifically researched in the areas: gathering data on the referee's error rate; quantification of unobservable decisions; difficult game situations for referees; subjectivity of judges and referees; the problem of real assessment of the game situation in 3D versus 2D.

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Olympic Versus Sokol Movement

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ABSTRACT

Contemporary sport in all its many-sided forms and levels is in the first line determined by global dynamic development of consumerist society oriented to economic prosperity, top performance, personal success, social admiration and unique incomparable experience. The many-sided world of sport strongly reflects the prevailing ethos of global drift, as well the local cultural development of given society. An essayistic comparison of the Olympics as the reflection of top level of global sport on one side and the value-oriented ethos of Sokol movement of the other side, is a specific contribution to a better understanding of different value roots, sense and objectives of sports in our cultural context. In the contemporary time of postmodern society, the Olympic Games are the most unique and most watched two-week sporting event of the best athletes in an ever-expanding range of traditional and new sports in the world. In the context of the growing commercialization and scientification of sport, it is worthwhile to confront the ideological emphases and ethos of both the founders of the initiators of the modern Olympic Games, as well as the founders of the unique physical education Sokol movement. Miroslav Tyrš and his followers at the time (Kožíšek) rejected competitive sports. Competitive performance sports and participation in the Olympic Games were not in the spectrum of Sokol's interest. The Sokol values principles rejected the one-sidedness of the sports specialization with the pursuit of performances and victories. However, the later development of Sokol agreed with Coubertin's principle that Olympism is not a formal system, but a state of mind, a certain conception of life, a unique philosophy of life, a balance of physical fitness, will and spirit. Thus, in the development of Sokol and Olympism, there were culturally different emphasis on values, which today took the position of discussions about the meaning and mission of the top media-attractive elite sport, embodied primarily by the Olympic Games on one hand, and the movement for a higher mass of sport in the sense of the sports for all principle on the other hand.

Keywords: Olympics, the Sokol movement; performance; mass culture, Sport

INTRODUCTION

Sport in the context of contemporary society

The dynamics of the development of modern and especially postmodern information mass consumer society, starting from the revolutionary changes of the industrial stage of humanity, brings immense and previously unsuspected cultural changes in the history of not only our civilization, with many dramatical effects on the genesis of social and interpersonal relations, value group and individual preferences, the concept of authority and prestige, the possibilities and limits of social and economic progress, the changing understanding of the institution of elites and celebrities. The stormy sea of the performance society in which we currently and often unprepared find ourselves, then rather relativizes the difficulty to objectively measure performance by relativizing the paths to their achievement. On the path of often convoluted and incommensurable "career paths" of our world, mainly economic goals and sports performances adored by the mass consumer society are increasingly applied more and more visibly. At the level of high-performance sports, it brings the uniqueness of physical performance, the indisputability of record results, the unrepeatability of unique victories, and the peak of social recognition.

Admiration, which is usually caused by the unattainability of the performance, only suspected individual training devotion on the way to victory, the desire for material pleasures and social recognition and admiration. Admiration, which does not stem from the appreciation of practical social usefulness, but relates to a performance that is not only completely unique, beyond the "boundary of human possibilities", but which is essential, clear, measurable and indisputable in our world of relativization of values. That is, worthy of admiration, adoration. Sports adoration is incomparable to other areas of social life. Unlike the relativization of the "performances" of politicians, businessmen, and artists, this category is of a rather unstable interest or variable value perception of mass attention (Sekot, 2015).

The aim of the paper is to compare the relationship of the Sokol movement with the modern Olympic Games, based on the development and the current state, and at the same time to outline the relationship with the different levels of contemporary sport.

METHODS

This is a purely theoretical article. The methodological approach to solving the research problem is based on the study of relevant literature. Basic methods of analysis and synthesis were used when working with the text. Standard methods were used as working methods, mainly direct and indirect, partly also biographical.

RESULTS

Olympics – top level of performance elite sport

Sports is one of the most popular forms of play. By its nature, it represents a typical and symbolic manifestation of modern times (Pelc, 2018, p.44). Performance sport, attractive to spectators, thus

becomes an integral, irreplaceable part of the interest of individuals and social groups and enters the everyday image of the information society. Today thanks to the mass media, it is undoubtedly the most attractive form of mass culture. Its reach for the widest possible circle of consumers, the clear "readability" of its message, the simplicity or undemandingness of the assumptions of spectator "consumption", the imaginability of identification with the value potential of sports actors is obvious along with the ability to generate sports stars, icons or even heroes unimaginable elsewhere.

In this way, the mass media can mediate the most popular sporting events immediately, truly naturally and dramatically, mobilize sports fandom, present the irresistible performance of sports idols to the masses (Sekot, 2010).

To discuss our topic means to distinguish concept Olympic movement and Olympic (synonym for Olympic Games). Olympic movement is, with accordance of Olympic Charter to contribute to building peaceful and better world by educating youth trough sport practised with accordance with Olympism and its values. Olympic Games or Olympics are the leading international sporting events featuring summer and winter sports competitions in which thousands of athletes from around the world participate in a variety of competitions. The Olympic Games are considered the world's foremost sports competition with more than 200 nations participating (Encyclopedia Britanica, 2008, International Olympic Committee, 2020).

The Olympic Games have been, and undoubtedly will be, the ultimate, unique and most watched sporting event. A two-week sports competition of the best athletes in an ever-expanding range of traditional and newly emerging sports, attracting to the television screens the largest mass that this medium can mobilize as an audience.

Kinanthropology thus keeps returning and updating the need to at least trying to give an answer to the key question: Are the Olympics the pinnacle of the movement of an individual, a parade of following worthy models of success, prestige and admiration? Or are they rather a form of the audience's growing desire for extraordinary performances and "stories" that ordinary reality does not offer? (Lipiec, 1999). As in many social, cultural or economical phenomenons or events, the nature and consequences of them are reflectig value roots of given culturte: In the context of our consumerist society where the social admiration is on the peak of value levels, the top performance is to be stimulation for personal utmost activity in the field of top sport offering popularity, status and stardom behind and outside the limits of ordinary life standarts.

Sokol versus sport

In our national context, it is undeniably the Sokol movement, which with its time-varying value message carries the permanent idea that movement, as an elementary manifestation of human nature, is increasingly clearly understood as an integral part of the versatile and valuable development of a healthy, active, vital and responsible individual Olympism, in its diversity of views on sport in the broadest sense, offers a unique view of the contemporary changes in the organizational form of the top manifestations of movement with all the colorful impacts on the value changes of modern times (Sekot, 2006, pp. 279–282).

In general, is elite sport more of a platform for mass audience interest or an effective and irresistible impulse for proactive leisure fitness sports? In other words, the sum of problems that,

by thinking through them, can be a source of acquiring new knowledge, but also an impetus for the regular cultivation of sports skills, the joy of regular exercise, and a responsible approach to health. They can also be the activation of positive life impulses and stimuli, which are particularly beneficial for its health and fitness benefits and also bring undeniable social positives: Life attitudes or daily rituals that should be a self-evident and integral part of every person. And even here, Sokol's value platform offers a unique perspective on sports and physical activities. At the same time, it is good to remember in particular the historical maturation of this unique physical education organization which, despite the adversity of the times, maintains a unique attitude towards the meaning of movement as an integral part of the life cycle of every individual. Sokol is an important, typically Czech phenomenon, which made a significant mark in the history of the Czech and Slovak nation and, in a certain sense, foreshadowed and marked its spiritual development. It is connected with the peak of the revival period, with the emancipation of Czech culture and the entire Czech element, with the struggle for the independence of the state. This civically extremely stimulating effort combined physical education, education and general cultural activities.

Literary historian Arne Novák defined three main pillars on which Miroslav Tyrš, the originator and founder of Sokol, supported the Sokol idea: the national romance of German gymnastics, the proportionate and harmonious ideal of Greek kalokagathia and patriotic liberalism. The template of Sokol thus became the Turner movement, which was considered to be the bearer of democracy (Sak, 2012, p. 64).

Health — strength — beauty! Defend the truth! Just a quick look at these slogans, no matter how period-tinged, but permanently targeting values, undoubtedly belong to the ideological equipment of the oldest Czech physical education organization, Sokol. Especially thanks to her, Czech physical education is known in the world for the uniqueness of mass performances. It was in this regard that the principle was used that physical exercises, due to their movement character, are the activities that are essentially closest to man. All the more so because they are comprehensible, currently applicable and modifiable and, moreover, strongly emotional. Miroslav Tyrš was also the author of his own gym system with the original Czech nomenclature, perfect for the time. Tyrš correctly understood that a nation can develop to the highest level of freedom and education, if all its members know how to take good care of their physical health, if they fill their insides with the wealth of the spirit and base their mutual relations and relations with other nations on morality.

From the point of view of mass physical education, the importance of Sokol since its foundation in 1862 lies mainly in its All-Sokol rallies. The first in 1882 was the culmination of Tyrš's organizational work. The gatherings, which took place after about six years, apart from the period when Sokol could not officially function, laid the foundations of the tradition of mass physical education performances, which brought large masses of people to active exercise and physical education activities (Strachová, 2020).

The phenomenon of sport as a competitive activity was perceived as incompatible with the ideological mission of physical education. In 1882, František Kožíšek wrote in the magazine Sokol: „Sport is only for one to excel over the other, so that the winner wins the bet, even at the expense of health." (Perútka, 1985, p. 113). As an uncompromising promoter of the gym movement, he also

criticizes sports clubs: „The members of these exercise, only the arms, or only the legs, to satisfy selfish ambition, won a bet or a shiny decoration. On the other hand, the members of the Sokol practice all-round, they are concerned with the all-round symmetrical development of the body in the ancient sense, and their stimuli are health and strength, a reality for civic life, for the service of the country..." (Perútka, 1985, pp. 113–114).

Sokol as the main representative of the Czech movement culture tradition and logically the most important partner and opponent of the penetrating "Anglo-Saxon" of sports until the end of 1939, he expressed his reservations about elite sports. At the same time, the founder of Sokol had a completely positive attitude towards sports (Pelc, 2018, p. 44).

Sokol's negative attitude towards sport (understood as synonymous with a commercially oriented desire for victory) was also manifested in his negative attitude towards participation in the Olympic Games.[1] The spirit of the times and the mission of Sokol is even characterized by a preference for trips over organized tourism. Already from this point of view, one can imagine what attitude such an opinion front would take towards today's forms of professional, commercially-media-used elite sport. However, one thing is certain: for the then understanding of movement activities, today's concept of sport would remain - understandably for a number of reasons - probably beyond the horizon of common imagination.

Sokol represented a distinctly democratic system of the time based on respect for the universal values of physical exercises with an emphasis on ethics, aesthetics, health and physical fitness. At the same time, Sokol's main goal was the effort to unify and raise the level of the Czech nation, including its military preparedness, patriotism and contemporary "all-Slavism". Physical exercises combined with educational and artistic activities as well as civic engagement were the means for this. Tyrš emphasized work for the nation, advocated progress, Slavic reciprocity and democracy. He drew on the ancient ideal of kalokaghatia, the harmony of beauty and goodness. In it, the results of physical education, cultivating a beautiful body (kalos), and the education of a good spirit (agathos), whose principle is virtue, justice and bravery, are mutually reconciled (Tyrš, 1969). As a such, Sokol accents for regular sportive activity, for civic activity in broad sense, for active attitude to life challenges, is steadily constantly cultivated with acccordance of contemporary drift Sport for all movement, but as well as fruitful base for heading towards top Olympic sport.

This principle is an expression of the harmony between "inner" and "outer", which is considered by Greek pedagogy and aesthetics to be a condition of beauty directed towards order, harmony, balance and noble moderation. Sokol's gym system was also conceived in the spirit of such ideas. At the same time, he considers the element of competition to be an important stimulator of human activity and a prerequisite for progress, as a manifestation of an effort to match the better and possibly surpass them. However, in accordance with the ancient thought, he condemns competition associated with rivalry and intolerance. Moreover, one-sidedness is rejected, i.e. the principle from which grew Sokol's opposition to sports specialization and the pursuit of performances.

The ideological base of Sokol movement, with its democratic accents, was incompatible with totalitarian communist ideology, which is why Sokol was gradually liquidated at the turn of the forties and fifties. Its organizational renewal in the 1990s also meant a revival of emphasis on

1 The first three Olympic Games passed without the interest of Sokol.

one's own national traditions and values. However, this, in the context of the growing influence of globalization and its internationalized values, also means for Sokol himself the necessity to improve the versatility of physical education activities in a general social climate focused more on specialization, performance and victory.

At present, it is in the confrontation with the rather "idealess" elite sport that we become more and more acutely aware of the pros and cons of Sokol in general. His emphasis on a healthy way of life, the cultivation of a sense of belonging and the development of a harmonious personality, the introduction of mass sports and financial availability for all can be positively evaluated. Conversely, the negatives are in lack of trainers and attractivity for young generation growing up in consumerist and sedentary society.

Sokol versus Olympics

The relationship of Sokol to Olympism and its organizational aspects is based on Tyrš's writing "Olympic throw", which reflects on the meaning of physical exercises and their individual and social application. At the same time, the best way to compare "Olympism" and "Sokol" is to compare the ideological emphases of Tyrš and Coubertin. In addition, one-sidedness is rejected, i.e. the principle from which Sokol's opposition to sports specialization and the pursuit of achievements grew. Coubertine, on the contrary, combined Olympism with education for international belonging (Tyrš, 1969, 117–149). Tyrš, with his fascination with ancient Greece and the Greek ideal of man, understood the Olympic Games as the greatest holiday in the celebration of humanity in history. From Plato he draws the idea that the state is strong and secure when all its members are strong and secure: A healthy, strong and educated nation is a condition for a strong and successful state. Hence the emphasis on all-round physical fitness and a restrained attitude towards performance sports. The idea of olympism appealed strongly to Sokol, but they did not aspire to the Olympic Games as a display of peak individual performances. Sokol's activity was not focused on performance and victory, but on human perfection in the sense of kalokagathia (Tyrš, 1969). The fascination with the ancient Greek Olympic Games was connected with Tyrš's fascination with the landscape in which they were held. Tyrš's Sokol, foreshadowing Sokol's further intellectual development, is socially and culturally oriented towards a specific society, without Coubertin's later international emphases. At the same time, Sokol's later development agreed with Coubertin's principle that Olympism is not a formal system, but rather a state of mind, a certain concept of life, a unique life philosophy, a balance of physical fitness, will and spirit.

In general, we can summarize that while Tyrš devoted his intellectual and organizational potential to a purposefully specific society, Coubertin's significant contribution — to restore the Olympic Games on an international scale — is the basis of the idea of modern Olympism.

Next to the focus on the Olympic Games, there is the Sokol idea of Olympism as an everyday process. Hence the diversity of emphasis in the field of education. For Coubertin, education was understood as a reflection of sports activities aimed at participating in the Olympic Games. In contrast, Tyrš built a clear educational system based on an understanding of physical culture in the broadest sense of the word i.e. physical education, educational and cultural activities. In terms of value, however, these emphases have a universal character (Dovalil, 2004). At the time being, in

the context of complicated war situation in Europe, Phylisophical heritage of Tyrš is still topical and inspirative: The founder of the Sokol understood that „ the question of freedom is, above all, the question of education, the question of the education of body and spirit t the question of the cultivation of the (Czech) nation. This idea is equally desirable today.It will always be the case that only a society of "good" people (personas) allows the way to progress, democracy and freedom" (Bábela, Oborný, 2018, p. 325)

Olympism is generally defined as a philosophy of life, the ideas of which are instilled especially in the youth and are usually reduced to the principles of fair play. Sokol orients these principles to the national population through a systematic educational system. Olympism works with the concept of sport and, given the meaning and meaning of the Olympic Games, emphasizes — unlike Sokol - performance. On the other hand, Sokol works with the term physical exercise, "physical exercise", as an important element of culture aimed at educating a well-rounded person. Here it should be remembered that Sokol emphasizes not the one-time importance of the competitive Olympic Games, but Olympism as a peaceful idea of the union of physical fitness, will and spirit. At the same time, Sokol is not in opposition to sport, but looks with concern at some of its negative phenomena related to top elite professionalism focused unilaterally and purposefully on performance, victory and reward.

The Sokol movement showed its performance and representative ambitions only in the period of the nationally emancipated independent Czechoslovak Republic. Sokol gymnasts in particular won medals at the Olympic Games. The first Czechoslovak Olympic champion – Bedřich Šupčík [2], Ladislav Vácha, Emanuel Löffler[3], Jan Gajdoš, Alois Hudec[4], Vlasta Děkanová, Zdeněk Růžička, Věra Růžičková etc.

CONCLUSION

Thus, in the development of Sokol and Olympism, there were culturally different value emphases. which today have matured into the position of discussions about the meaning and mission of top media-attractive elite sports, embodied primarily by the Olympic Games on the one hand, and the movement for higher mass sports in the sense of the principle of "sport for all" on the other. It is a topic that is constantly updated by the dynamics of the development of a performance-based society, and thus in a wider context it also concerns the future development of the relationship between recreational and performance sports. However, it cannot be overlooked that it is a complex of topics strongly distant from the world of values of the founders of the Sokol movement.

To discuss properly topic of relation of Sokol movement to contemporary Olympics means to outline its pure relation to different levels of contemporary sport we have respect the fact of *various impacts* of given different sports on different experiences and consequences (power and performance sports versus pleasure and participation recreational sports) including the importance value of sportive activity in everyday leisure. As it is evident the phenomenon of sport has been strongly transformed during past two or three decades: The process of commercialization and

2 Bedřich Šupčík – Paris – Games VIII. Olympics 1924.

3 Löffler – together with Jan Gajdoš, he was one of the biggest constants of interwar Czechoslovak gymnastics.

4 Jan Gajdoš, Alois Hudec – gold medal in the rings of the Games of the XI Olympiad in 1936 in Berlin.

medialization of elite professional sports. In such perspective we could find relevant levels of sport: Power and performance models of sports are highly organized and competitive and emphasize strength, speed, and power, competitive success, setting records, selection systems, hierarchical authority structures, antagonism.

The pleasure and participation model of sports is characterized with the primary emphasis in on the con¬nection between people enjoyment, good health, pleasure and well-being differences in physical skills, interpersonal support. Alternative sports encom¬pass an infinite array of physical activities done individually or with groups. Their popularity is based, in part, on children's reactions against the highly structured character of adult-controlled, organized sports. With respect to discussed nature of Sokol we could conclude this movement and organization is rooted in sport values of pleasure and participation and alternative sports.

From the perspective of the orientation associated with many spectator sports today including Olympic sports have shifted from aesthetic to the heroic. Aesthetic orientation emphasis on beauty and pleasure of movement, mastery of technical skills, willingness to explore limits, commitment to staying active and involved as a participant. Heroic orientation emphasis on dan¬ger and excitement of movement, style or mastery of dramatic expression, wil¬ling¬ness to go beyond limits a commitment to victory and success of the team or sponsor. As a dominant form of sport, it emphasizes strength, speed, dominating the opponent, pushing the limits of human possibilities, victories, records, titles. Admirable hard sports training, willingness to pain, sacrifice, emphasis on breaking records are undoubtedly an essential part of it (Coakley, 2001). At the same time, this level is gradually moving away from the Sokol value, which sees the human body in sport not as a goal, but as a means of sporting activity. In this context, we can summarize that the development of Olympism is more and more oriented precisely to the exclusivity of the commercial and political goals of the Olympic Games, which are characterized today in the context of top sport by a permanent spectator appeal (will e-sports become part of the Olympic Games?). They are also characterized by globalization controlled by developed powerful countries and organizations, interest in the commercialization of alternative sports, the tendency to expand the spectrum of so-called Olympic sports, global management and coordination of regional, international and world sports competitions (Payne, 2006).

At the same time, countries such as Norway, Finland, Iceland, Germany, Australia and Canada will continue to be model countries for the harmonization of sport for all and top sport. It is Sokol, even in this context, that does not lose sight of the increasingly urgent challenges of focusing on the support of sports activities and leisure sports, considering the specific conditions of place, time and specific situation. As an integral part of an active life and all-round development of an individual (Dovalil et al, 2005, p. 45-60).

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The Role of a Forensic Expert in the Field of Self-Defense Under Current Legislation and Beyond

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ABSTRACT

A forensic expert in the field of self-defense is a specialist with extensive knowledge in defence methods, close combat, defensive means, or coercive means. The core of the forensic expert's work in this field is the assessment of the facts of conflict situations in which physical violence between two or more persons has been used. The role of a forensic expert is to answer questions related to the parties' roles in the conflict, factors that influenced the conduct of the fight, the course of the fight and the possibility of resolving the conflict situation. Self-defense expertise is sometimes associated or confused with martial arts or combat sports expertise. This judgment is based on the assumption that most forensic experts in the field of self-defense also have experience or expertise in martial arts and combat sports. Such knowledge is an advantage for the profession of forensic expert in the field of self-defense, similar to knowledge in the field of weapons and ammunition, but it is not the same area as expertise in the field of self-defense or a condition for performing this profession. The new Act No. 254/2019 Coll., on forensic experts, expert offices and expert institutes, faces professional criticism in several areas (expert duties, sanctions, division of specializations, etc.) and is likely to lead to pressure for further amendments. The article deals with these changes and the perspective in the coming years with the expert opinion of current forensic experts in the field of self-defense on the appropriate inclusion of this specialization in the future categorization of specializations.

Keywords: forensic expert, self-defense, necessary defense, combat, martial arts, combat sports, weapons, legislation

INTRODUCTION

A forensic expert is a profession that provides expertise in the form of an expert opinion to law enforcement authorities and thereby helps to clarify questions of fact (questio facti). The court compares the factual situation with legal regulations (questio iuris) of substantive law. The activity of an expert is part of procedural and public law with private law elements (Křístek, 2013).

Forensic expertise in the specialization of self-defense is unique and can be acquired through many years of practice and theoretical studies. Self-defense is a multifactorial field that requires knowledge from many fields. Probably due to the motor component of conflict situations (physical combat), the specialization of self-defense is currently included in the field of Sport, the branch Sport – prosecution. Although this classification has some justification, it is far from accurate and leads to frequent mistakes in understanding self-defense as a field of human activity. Common mistakes include, for example, equating self-defense with martial arts or combat sports. The article aims to define the subject of investigation of self-defense specialization, to characterize the difference from martial arts and combat sports, and subsequently to recommend the inclusion of self-defense specialization in the system of forensic expertise in the Czech Republic.

METHODS

The material was processed using the focus group method. The expert group was composed of n=5 experts specializing in self-defense. All experts have a university degree and many years of experience in self-defense. Four experts are currently appointed forensic experts specializing in self-defense and practice this profession (while the total number of experts in the specialization of self-defense appointed in the Czech Republic is five). The last member of focus group provided expert opinion in the fields of self-defense, law and sport science (kinanthropology). The focus group was managed by the moderator. The moderator was an expert and researcher in the field of self-defense, sports science, and androdidactics. The group was managed with a low level of moderator involvement (Morgan, 2001). According to Morgan (Morgan and Krueger, 1993, cited in Morgan 2001) the focus groups don't have to be made up of people who do not know each other. In our focus group, some of the participants knew each other, and some did not. The focus group had less structure (Morgan, 2001). Following issues were discussed:

1. What is the delineation, structure, and mutual differentiation between self-defense, martial arts, and combat sports?
2. How should be the self-defense expertise included in the future experts system?
3. What are the reasons why self-defense should be included as a separate specialization within forensic science?
4. What is the typical role of a self-defense forensic expert and what are the typical challenges they face?
5. Which competences and qualification should be requested from a forensic expert?

We consider the results of the focus group analysis to be the professional consensus of a expert group which represents the majority of the professional community in the given specialization in the Czech Republic.

RESULTS

In order to describe the role of a forensic expert in the specialization of self-defense, it is first necessary to define self-defense as a field of human activity and its relationship to martial arts and combat sports.

Self-defense

Self-defense is an open system of all measures and activities used to prevent victimization, avert an acute threat by using tactical, psychological, verbal or physical means, including adequate force in accordance with the law in the conditions of necessary defense and mitigating the negative consequences of an attack (Vít, 2016). In terms of focus, self-defense can be further divided into personal and professional. While personal self-defense is for the lay public, professional self-defense is for employees whose occupations require specific self-defense skills (police, municipal police, military police, judicial guard, etc.).

Qualified self-defense training includes methods and means for acquiring the individual's tactical skills to prevent the emergence of self-defense situations, communication skills (verbal self-defense), motor skills to avert an acute physical attack, fitness skills to increase capacities to face the difficulty of the situation, and psychological methods for coping with stressful situations (coping strategies). The goal of self-defense training is to develop the necessary competencies to the maximum extent possible, optimally in the shortest possible time. Also other competencies may be useful to develop for each individual due to their natural equipment such as personality, upbringing, somatotype, fitness, mental possibilities, etc.

Many professionals provide qualified self-defense training based on their experience, often without creating their own system that had its own name and marketing. On the other hand, some systems have established themselves as globally known with an extended network of training centers and a team of instructors (e.g. Krav maga, SPEAR system, FAST Defense, Sambo, etc.).

Martial arts

Diverse ways of fighting are as old as mankind itself. The origins of some martial arts that have survived to this day are thousands of years old (e.g. kalaripayattu – India). Although their original purpose was purely utilitarian (self-defense, warfare, etc.), through gradual cultivation, they developed into complex systems enabling the development of trainees not only for combat purposes. Today, martial arts are practiced all over the world with the goal of personal development of practitioners in various spheres: biosphere (physical), psychosphere (mental), sociosphere (social), noosphere (spiritual).

Therefore, martial arts can be defined as mainly movement systems that have evolved from old ways of fighting, which are used today as part of life's journey, for sport, self-defense, or their goal is to preserve tradition and cultural heritage (Reguli, 2005).

An example of the protection of these ancient martial arts is inclusion of some of them in the list of Intangible Cultural Heritage by UNESCO (Pencak Silat - Indonesia, Chidaoba - Georgia, Tahteeb - Egypt, Taekkyeon - Korea, Pahlevani - Iran) (UNESCO, 2022).

Combat sports

Combat sports form a large group, the common feature of which is overcoming the opponent through physical contact. The intensity of contact varies according to the rules of individual sports or their disciplines. The distinction between full-contact, semi-contact, etc. is often used. Some

sports use only parts of the body for contact fighting (e.g. boxing, karate, judo, etc.), others focus on the contact created by weapons (fencing, kendo, etc.).

Combat sports are characterized by their name, development, technical means, membership and hierarchy, umbrella sports organization, training methods, competition system and rules. Among the most famous of them are the sports included in the program of the Summer Olympic Games (boxing, judo, karate, taekwondo, fencing, wrestling).

Differences and relationships between self-defense systems, martial arts and combat sports

Self-defense systems, martial arts and combat sports together make up combative systems. All three groups of combative systems are united by a unifying element, which is contact combat between two or more people. At the beginning of their creation, all martial arts performed, among other things, the function of self-defense. Martial arts were created for the purposes of warfare and self-defense. However, this function gradually receded into the background with the development of new technologies for conducting combat (typically firearms) and also with the development of modern training methods.

The relationship between martial arts and self-defense remains, however, in the sense that a number of self-defense systems to some extent draw technical repertoire from martial arts, or are partly inspired by them. However, the difference in self-defense and martial arts training today is significant. Martial arts teach trainees technically perfect movement, a higher level of coordination, mental development, spiritual development, development of social relationships and mastery in the broadest sense of the word. However, most martial arts teachers and practitioners do not make it their primary goal to learn self-defense. The path through martial arts would take longer to reach this goal than the security situation requires. Also, martial arts are trained mainly through the method of formation into patterns or a specific form of sparring. However, these methods do not sufficiently induce stressful conditions typical for self-defense situations. Martial arts practitioners may therefore be at a high technical level in their specific movement, without sufficient self-defence skills. In the conditions of real interpersonal violence, the martial arts skills are often insufficient for resolving conflicts.

Combat sports are combat systems that often arose from martial arts through narrowing the technical repertoire into the rules of the sport so that it can be safely competed in. Some of these combat systems are both martial arts and combat sports (e.g. judo, karate, muay thai, etc.). Practitioners of combat sports can have a high performance level in a given system, they can be adapted to the psychological pressure of a sports competition. However, like martial arts practitioners, they are often not adapted to face the stress of real interpersonal conflicts, as their training has other goals.

In summary, martial arts teach practitioners perfection and mastery in their combat style and have higher goals of personal development.

Combat sports teach player to apply combative movements in the conditions of a sports competition with the aim of achieving the highest possible performance within the rules of the given sport and the competition system.

Self-defense teaches trainees to achieve the highest possible competences for solving real interpersonal conflicts in the shortest possible time according to the individual capabilities. The goal

is not to achieve mastery in the long term, but to compromise between the individual personality possibilities and the requirements of practice (security situation).

Classification of forensic experts specializing in self-defense according to current legislation

The current classification of forensic experts specializing in self-defense shows Table 1.

Table 1. Classification of forensic experts specializing in self-defense

Field	Branch	Specialization	Number of experts
Sport	Sport - prosecution	Self-defense	4
Criminalistics	Criminalistics	Self-defense	1

From the above, there is a discrepancy in the inclusion of the self-defense specialization. Four of the five forensic experts are appointed in the field of Sport and Branches of Sport prosecution, while the fifth expert is appointed in the field of Criminalistics. There is also terminological discrepancy in the definition of other specializations listed by forensic experts (combative sports, fighting sports, conducting of close combat).

We can only speculate how this discrepancy arose. Our expert group believes that the inclusion of the specialization of self-defense in the field of Sport results from a traditional and inaccurate understanding of this expertise, which in the Czech Republic is often mistakenly confused with combat sports and martial arts. The difference between these areas has been explained in detail above. We also consider the inclusion of one of the experts in the field of Criminalistics inappropriate, as this field could answer partial questions in relation to self-defense (e.g. forensic biomechanics), but does not cover the entire field of self-defense specialization.

Subject of assessment of forensic expertise in the specialization of self-defense

The subject of assessment by a forensic expert specializing in self-defense is the factual nature of conflict situations between two or more persons. In the expert opinion, the forensic expert answers questions of fact (questio facti) he was asked. It is not up to the forensic expert to evaluate legal questions (questio iuris). The materials for preparing an expert opinion are for the court expert the submission of explanations, camera recordings, photo documentation, other expert opinions, etc. On the basis of the submitted material, the forensic expert assesses the conditions of occurrence, course and result of conflict situations in which physical violence by means of the body or a weapon was used etc. The complexity of judgment arises from the multifactorial nature of interpersonal conflicts. Factors influencing the emergence, development and outcome of self-defense situations include psychological, tactical, technical and fitness factors.

Aspects assessed by a forensic expert specializing in self-defense include in particular:

- circumstances preceding the emergence of the conflict
- the initial distance between the parties to the conflict and the resulting tactical options for resolving the conflict
- verbal and non-verbal communication and their relationship to the initiation and development of conflict
- a way of establishing contact between the parties to the conflict

- way to launch an attack
- way to start a defense
- the use of technical fighting means (punches, kicks, covers, dodges, etc.) during the development of the conflict
- use of weapons (cold, firearms, non-lethal, improvised, etc.)
- intensity of force used on both sides of the conflict
- tactical circumstances and conflict resolution options
- way to end the conflict

A forensic expert specializing in self-defense describes conflict situations in such a way that it is clear how the incident took place, what factors had an influence on its origin, development and termination. The core of the assessment are the circumstances of the technical course of the collision between persons, i.e. what technical means were used, with what intensity and with what result. Knowledge of combat techniques, defenses and how to use them is essential here. This expertise helps the authorities in criminal proceedings to assess whether and in what way legal norms have been violated and to determine the legal qualification of the actions of the persons involved.

Examples of questions asked by experts specializing in self-defense

For a clear explanation of what questions a forensic expert specializing in self-defense answers, we present several examples from practice. These specific questions have been asked in previous years:

- Assess how the whole situation occurred and, if applicable, how the incident developed, including its conclusion.
- Describe and define the course of the incident between the suspect and the victim, according to the available camera footage.
- Assess the individual roles of everyone involved (e.g. whether they changed during the incident).
- Assess whether it is possible to establish who was the defender and who the attacker during the incident (or assess this as part of self-defense).
- Describe and assess the self-defense techniques used in the given situation.
- Assess what methods (forms, factors, aspects) he used to solve the situation from the point of view of the victim.
- Assess what methods (forms, factors, aspects) the attacker used to solve the situation.
- State whether the victim had the opportunity to defend himself and react to the accused's attack.
- Determine the degree of aggressiveness and brutality of the attack by the examinee, if this can be determined from the available documents.
- Comment on the victim's grip, which he used to hold the suspect's right hand in the wrist area with his left hand.
- Assess whether the accused averted an imminent or ongoing attack on an interest protected by law.
- Provide additional information and facts that he considers important to include in the matter. Further expert findings.

Considering the above-mentioned questions, one can imagine how broad a scope and knowledge an expert with this specialization should have. It is also clear from the questions that the court should not make legal conclusions if these questions of fact have not been answered by the forensic expert specializing in self-defense.

Qualifications of a forensic expert in the field of self-defense

Gaining knowledge and experience for the profession of forensic expert specializing in self-defense requires many years of experience, professional study and personal training. We consider the combination of practical skills and theoretical knowledge to be essential. Without own practice and training of combative skills, handling defensive and offensive means, no person can fully penetrate the essence of self-defense. For this reason, as a group of forensic experts, we believe that for a given profession, a forensic expert should meet the following criteria.

An expert specializing in self-defense should have a broad overview of the possibilities, procedures and means of self-defense and their use in the event of a physical conflict between two or more people. Knowledge of martial arts techniques, combat sports and self-defense systems is important for assessing the combat equipment used in self-defense situations. The expert should be able to evaluate the movement of the persons involved, assess their possibilities of defense from the point of view of motor level.

Broader knowledge of used weapons (e.g. firearms license) is also beneficial for the profession of forensic expert. Furthermore, the expert must have interdisciplinary overlap in the legal field (circumstances excluding illegality, authorized use of a weapon, provision of first aid, etc.). The expert also often works with other assessments, e.g. from the field of healthcare, the field of forensic medicine, which he must understand and work from their conclusions. The specialization of self-defense is therefore very broad, and the professional level of the expert should correspond to this.

The professional competence of an expert is regulated in § 8 of Act No. 254/2019 Coll., on experts, expert offices and expert institutes and further by Decree No. 505/2020 Coll., which establishes the list of expert branches of individual expert fields, other certificates of professional competence, certificates issued by professional chambers and specialized studies for fields and branches.

Currently, the specialization of self-defense is classified under the field of sports, so it is a logical prerequisite for a university education of at least a master's degree program in the field of sports, e.g. Physical Education and Sports. We believe that the condition of secondary higher education in the field should be maintained in the future. As an optimal qualification in the Czech Republic, one can recommend fields of study that include both theoretical and practical education in self-defense, such as Applied Sports Education for Security Bodies at Masaryk University, Police Academy of the Czech Republic in Prague or University of Defense.

We consider the length of professional experience of 10 years of professional experience to be sufficient for gaining knowledge, experience and also life perspective for assessing such complex phenomena as self-defense situations. This kind of practice can be defined as the active pursuit of a security profession (e.g. police officer, constable, etc.) or pedagogical activity (e.g. head of training of a security force, teacher at a specialized school with a study field of security, etc.). In addition, the

applicant for this profession should document his qualifications in self-defense (e.g. a certificate of completion of long-term training, obtaining a technical degree or a training class in one of the combat systems, etc.).

As secondary criteria for appointment as a forensic expert in self-defense could be own scientific research activity, publishing, lecturing and teaching activities in the field.

Recommendations for the future inclusion of self-defense in the system of forensic experts

We believe that we have managed to define the main differences between self-defense and sports. These are, in particular, the multifactoriality of self-defense situations with interdisciplinary overlap and the essence of assessing conflict situations in cases of the use of physical violence. A forensic expert assessing a self-defense situation must look in a different way than an expert in the field of sports, assessing the circumstances established by the sports rules. In addition, broader knowledge and experience gained through own practice and study is needed. From this point of view, we recommend considering the inclusion of self-defense as a separate field.

Beyond the scope of expert issues, a polemic is offered as to how far the question of assessing the legality of self-defense is a purely legal issue (Sangero, 2006, Kuchta, 1999, Explanatory report to Act No. 40/2009 Coll) and how far it is a non-legal – expert one. It follows from the legislator's intention that the assessment of the necessary defense is the responsibility of law enforcement authorities. Act No. 40/2009 Coll., Criminal Code, as amended, and Act No. 141/1961 Coll., Criminal Process, as amended (hereinafter only the Criminal Code), do not combine the assessment of the necessary defense with another mandatory condition for assessment of the professional nature of the matter. Therefore, the court or law enforcement authorities can only follow their own considerations and do not have to use expert statements or expert opinions in cases of necessary defense, unless they consider it important with regard to 105 paragraph 1 of the Criminal Code:

"If expert knowledge is needed to clarify a fact important for criminal proceedings, the criminal enforcement authority will request an expert statement. If such a procedure is not sufficient due to the complexity of the question under consideration, the law enforcement authority will appoint an expert."

We believe that the issue of personal self-defense, the legal legitimacy of which is determined by the Institute of Necessary Defense, is such a specialized and complex area that it should be customary to invite a relevant expert, not only from the field of self-defense. Self-defense is, as already mentioned, an interdisciplinary phenomenon; It is not primarily a legal issue, but much more technical or biomechanical, psychological and tactical. However, inviting an expert is not a usual act, as can be seen from the research that the author conducted in 2017-2018 (Novák, 2019).

In this case, it was not assessed how many cases an expert with self-defense expertise was invited, but in how many cases the court dealt with the claim of the attacked person that he faced acute anxiety, which affected his actions (these were cases where the attacked person defended his actions just lack of clarity of the situation, fear, etc.). Again, this was an expert question, and, due to the nature of the matter, the court cannot and cannot make an expert assessment. In 89% of cases, the court somehow dealt with this issue, but only in 53% of cases was an expert called in to assess the state of acute anxiety of the attacked person and other decisive psychological facts. The

research was carried out based on the analysis of court decisions regarding the necessary defense, which was found according to the key in the ASPi legal system (Novák, 2019).

On the basis of the above, it can be similarly stated by analogy that if law enforcement authorities do not need to require an expert opinion or an expert opinion in issues such as the issue of psychology, psychiatry, and forensic psychopathology, it can be expected that the situation in self-defense expertise will be similar, as follows from the partial analysis of the aforementioned research. We believe that this may also be one of the important reasons why individual judicial instances assess a given case of necessary defense differently (Kuchta, 1999), and it is quite common that the rejection of the application of the institute of necessary defense in a given case is subsequently corrected by the Supreme Court of the Czech Republic.

We believe that a suitable solution would be for the defense to request a professional opinion or an expert opinion in almost the majority of cases, in which questions of a professional nature would be settled (time and factual course of the encounter, intensity of the technical means used, etc.). We believe that only on the basis of the settlement of these professional questions are the law enforcement authorities able to assess the legitimacy of self-defense or the necessary defense as a matter of law.

DISCUSSION

In this article, we tried to describe the basic principles and the subject of the profession of a forensic expert specializing in self-defense. Although we believe that most of the information has been comprehensively summarized, there remain a number of unanswered questions for discussion.

First of all, it is about the appropriate inclusion of the specialization of self-defense in the systematics of branches, branches and specializations. Our expert opinion is the creation of a separate field of self-defense. By creating a specific group of experts for this field, it would be possible to establish more appropriately and concretely the qualification criteria, areas and methods of further training of forensic experts in the field of self-defense.

Another question for professional debate remains whether it is appropriate to distinguish between personal and professional self-defense. We understand that, for example, a police officer with ten years of experience, who is fully versed in the field of official interventions and the use of coercive means within the security forces, could provide the state with valuable expertise in this area as a forensic expert when assessing the intervention of police officers, etc. However, at the same time, he does not have to be equally educated to judge personal self-defense cases. On the contrary, not every expert and personal self-defense must have a sufficient overview of the specific procedures of official interventions in the security forces. The last question is the determination of qualification criteria for a given profession, which is an illustrative example of a field that, due to its specificity and size, creates a small group of experts whose qualifications should be assessed hypothetically by another group of "super-experts". However, no such group is available. We raise these professional questions for further consideration by the relevant authorities and submit this article as a contribution to further discussion.

CONCLUSION

We described the theoretical foundations for assessing conflict situations with the use of violence, defined the subject of assessment of a forensic expert in the specialization of self-defense and depicted the inclusion of forensic experts in the current legal categorization. Our effort was primarily to define the difference between self-defense and combat sports, or martial arts. We consider the inclusion of self-defense in the field of sport to be outdated and inconsistent with the current state of knowledge. As a professional group in a given field, we offer our knowledge for the purposes of forensic expertise and at the same time we feel the need to update and better define the given field. Based on the assessment of our focus group, we recommend the creation of a separate field of self-defense and further discussion on the setting of qualification criteria for this profession and the system of training forensic experts in the field of self-defense.

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Vyhláška, kterou se stanoví seznam znaleckých odvětví jednotlivých znaleckých oborů, jiná odvědčení o odborné způsobilosti, osvědčení vydaná profesními komorami a specializační studia pro obory a odvětví, ve znění pozdějších předpisů [Decree No. 505/2020 Coll., establishing the list of expert branches of individual expert fields, other certificates of professional competence, certificates issued by professional chambers and specialization studies for fields and branches, as amended], Czechia.

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A Case Study of Factors Impacting Aspiring Esport Athletes in South Korea

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ABSTRACT

This study examines the structural relationships of factors like attitudes, subjective norms, perceived behavioral control (PBC), and career pursuit intentions among aspiring esport athletes using the theory of planned behavior, and exploring the moderating influence of athletic identity on these relationships. We assessed the measurement scale's validity and reliability with confirmatory factor analysis, Cronbach's alpha coefficients, and correlational analysis. Structural equation modeling evaluated the effects of three factors – attitudes, subjective norms, and PBC – on career pursuit intentions. Additionally, a hierarchical regression analysis was performed to confirm the moderating effect of athletic identity. The results revealed positive impacts of attitudes ($\beta = 0.300$, $p < 0.001$), subjective norms ($\beta = 0.414$, $p < 0.001$), and perceived behavioral control ($\beta = 0.274$, $p < 0.001$) on career pursuit intentions. However, athletic identity did not moderate the relationships among the research variables. We confirmed that subjective norms were the most influential factor in improving career pursuit intentions; and, although PBC has been considered as a moderating variable, our study found that PBC was a direct determinant of career pursuit intentions.

Keywords: esport, theory of planned behavior, athletic identity, career pursuit intentions, perceived behavior control

INTRODUCTION

According to Hamari and Sjöblom (2017, p. 211), esport, that is "electronic sports," may be defined as "a form of sports where electronic systems facilitate the primary aspects of the sport; the input of players and teams, as well as the output of the esport system, are mediated by human-computer interfaces." These are becoming popular with the younger generation today due to the proliferation

of high-speed internet and smartphones. However, there are significant academic debates about whether esport can be considered as "real" sport. Recently, Park (2020) argued that esport is a real sport since it includes a competition to determine winners and losers, rules for fair play, various skills, and team strategies for victory, endurance, and concentration. Due to their increasing global popularity, esport will be an official event at the 2022 Asian Games in Hangzhou, China. Moreover, many professional sports clubs in the U.S. and Europe, and sportswear companies – such as Nike and Adidas – are actively investing in esport to create new business opportunities (Choi, 2020).

Although it is not the birthplace of esport, South Korea created the early boom of esport and is now considered the capital and suzerain of esport (Jin, 2020). The reason behind Korea's emergence as an esport powerhouse is related to the 1997 financial crisis. The Korean government has laid the foundation for esport to grow by focusing on telecommunications and Internet infrastructure as a response to the crisis (Jin, 2020; Lee, 2019). Thanks to the widespread high-speed Internet and PC bang (a LAN gaming center), Korean esport has won the biggest esport tournaments such as Korea StarCraft League, League of Legends World Championship, and Overwatch World Cup. Lee Sang-Hyeok, a League of Legends esport athlete, became a teenage idol for youngsters in Korea, and more and more teenagers hope to become famous professional esport athletes (Park, 2020).

However, due to the deep-rooted negative perception of esport among adults in Eastern Asia and South Korea's social preference for professional occupations, such as judges, prosecutors, lawyers, doctors, and professors, a large number of esport aspirants are rethinking their pursuit of esport careers. Many Korean parents desire their children to engage in professional occupations instead of pursuing professional esport careers. Moreover, as the National Assembly and Ministry of Gender, Equality and Family – in response to some women's groups –approved and implemented the controversial "shutdown law" in 2011 that banned younger teens from playing esport after midnight (Lee et al., 2017), minors with talent in esport have been labelled as addicts, which is discriminatory, and they have difficulty practicing esport. Thus, to develop the Korean esport industry, it is important for esport coaches, investors, and interested parties to create an encouraging environment for aspiring esport athletes to pursue their career aspirations.

Thus, it seems essential for researchers to explore factors that positively influence aspiring esport athletes, either in high school, college or on an amateur esport team. Thus, the current study applies the theory of planned behavior (TPB) (Bosnjak et al., 2020), an extension of the theory of reasoned action (TRA), which is one of the most widely recognized social-psychological models for understanding human behavior (Ulker-Demirel and Ciftci, 2020). Since its publication in 1991, many researchers in a multitude of behavioral domains, such as healthy eating behavior, education, green consumerism, tourism, online retailing, and sports marketing, have used the theory to explore determinants of intentions and behavior (Ajzen, 2020; Ulker-Demirel and Ciftci, 2020). There are three main attributes in the TPB: attitude toward the behavior, subjective norms concerning the behavior, and perceived behavioral control (PBC), which are likely to influence the intention to perform the behavior (Ajzen, 2020). Additionally, to fill previous TPB studies' gaps and deeply understand aspiring esport athletes' psychology and behavior, the present study examines the moderating effect of athletic identity – that is, the degree to which an individual equates to the social role of an athlete. Intuitively, athletes with strong athletic identity are more likely to pursue

athletic careers than athletes with low athletic identity because the former could help athletes avoid burnout by fostering motivation (Martin and Horn, 2013). If athletic identity moderates the relationships among the TPB variables, then esport instructors can segregate aspiring esport athletes according to the level of athletic identity using different strategies.

Accordingly, this study examines the structural relationships between attitudes, subjective norms, PBC, and career pursuit intentions by applying the TPB in a sample of aspiring esport athletes. Furthermore, to address gaps in the previous studies, this study analyzes the moderating effect of athletic identity.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

The Theory of Reasoned Action and Theory of Planned Behavior

The TRA proposed by Fishbein and Ajzen (1975) has long been recognized as the most widely used social-psychological approach for predicting human behaviors. In the TRA, the intention is viewed as an individual's cognitive motivation to utilize the effort in performing a specific behavior (Ajzen, 1985; Han et al., 2010). According to TRA, because most specific human behaviors are under complete volitional control of intention, the behaviors are determined by intention (Azjen, 1980). People have a high degree of willingness or readiness in their decision-making process, thus obtaining positive outcomes among several alternatives (Han et al., 2010).

In the TRA model, there are two major variables to predict behavioral intentions: attitude toward performing the behavior and subjective norms (Fishbein and Ajzen, 1975). Attitudes can be described as "the degree to which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question" (Ajzen, 1991, p. 188). An individual's attitude towards a behavior is favorable when the predicted outcomes of participating in behavior are positive (Kim et al., 2020). Attitude toward a behavior is a function of one's salient belief concerning the possible consequences of the behavior, termed behavioral beliefs (Ajzen, 2020). Thus, it is viewed as one's subjective probability that performing a behavior will have certain consequences (Ajzen, 2020). For example, esport customers could perceive participating in an esport tournament as positive by experiencing the clean and well-maintained facilities and stadium, receiving unexpected kindness or hospitality from event volunteers or staff, and engaging with a variety of events and performances such as prize and ticket giveaway events. In the TRA, subjective norms are posited as a second predictor of behavioral intentions. Ajzen (1991, p. 188) views subjective norms as "the perceived social pressure to perform or not to perform the behavior." In other words, subjective norms denote the individual's perceived social expectation from a given referent individual who influences their decision-making (e.g., family, friends, relatives, spouse, coworkers, supervisor, colleagues, associates, or business partners) (Park, 2000). Subjective norms can be affected by normative beliefs described as "the probability of whether significant referents would approve or disapprove the behavior" (Han et al., 2010, p. 327). In our case, as many aspiring esport athletes are young and not financially independent, they are likely to rely on the perceptions of family or close friends about their pursuit of esport careers.

In contrast, if a family does not financially support an aspiring esport athlete, the athlete is in the hospital for a long time or the government tightens restrictions of teenagers playing esport,

or the athlete does not have enough time to practice a game because of a part-time job, injury, or the restriction, this can have a negative influence on the athlete. As a result, many researchers have realized that the applicability of the TRA has some limitations to understand the variety of individuals' behavior (Ajzen, 2020). Therefore, heeding researchers' arguments that the TRA is needed to produce a broadened version of the TRA, Ajzen (1991) developed the TPB that includes an additional important construct, that is PBC. PBC can be defined as "the perceived ease or difficulty of performing the behavior (Ajzen, 1991, p. 122). Precisely, PBC evaluates a people's perceptions of how one can control factors that may bound the actions needed to deal with a specific situation (Verma and Chandra, 2018); that is, when people have enough time, resources, and chances to overcome the problematic situation, PBC should be the highest (Madden et al., 1992). It is believed that PBC is determined to be a function of control beliefs that refer to an individual's perceived requirements of the opportunities and resources to perform a specific behavior (Chang, 1998). Many studies have indicated that individual's behavioral intention is positively influenced by PBC to act in a particular way (Han et al., 2010; Verma and Chandra, 2018).

Athletic Identity

Identity is a key concept in social sciences and has received much attention in social psychology and sports psychology. Researchers studying identity in social psychology have a different approach and focus on group affiliation and social roles (Ronkainen et al., 2016). Two important theories, identity theory and social identity theory, seem quite similar, but there are differences more in terms of emphasis than contradiction (Stets and Burke, 2000). Originated in the discipline of sociology, identity theory "deals with the structure and function of people's identity as related to the behavioral roles they play in society" (Hogg et al., 1995, p. 265). While, originated in the discipline of psychology, social identity theory "deals with the structure and function of identity as related to people' membership in groups" (Hogg et al., 1995, p. 265). In other words, identity theory concerns the relationship between the roles individuals play as members of a social group and the multiple identities that such roles confer (Hogg et al., 1995), whereas the social identity theory first introduced by Tajfel (1978) concerns the relationship between the person's identification and a particular social category, such as a fan base of a particular pop band or a fan community for sport teams, with an emphasis on the generative role of identity in group (Fink et al., 2009).

The study of sports psychology on athletic identity appeared in the 1990s (Ronkainen et al., 2016). Brewer et al. (1993) first systematically conceptualized athletic identity. According to them, athletic identity refers to the degree to which the identity of "I" as an athlete matches the identity of "athletes" in society, and could be considered as an aspect of a multidimensional self-concept (Brewer et al., 1993). That is, they viewed athletic identity as a cognitive structure that "guides and organizes processing of self-related information" (Brewer et al., 1993, p. 238) as well as a social role, which means that the identification primarily stems from feedback from other people (e.g., coaches, teammates, team employees, spectators, and agents) (Ronkainen et al., 2016). Individuals with high athletic identities attach great significance to their success or failure in the athletic realm and may be able to attribute much of themselves to these achievements (Martin and Horn, 2013). Additionally, athletic identity was developed in its own construct but may be deeply related to the passion construct. According to

previous studies suggesting a dualistic model of passion (Lafrenière et al., 2008; Vallerand et al., 2003), individuals who have a solid either harmonious passion or obsessive passion for an activity perceive the said activity as an essential aspect of their identity. If an elite Taekwondo player is hard at training with the goal of an Olympic gold medal, he or she is likely to feel a strong identity as a Taekwondo athlete.

Research Hypotheses development

A vast amount of literature is dedicated to the positive relationship between attitude and behavioral intention. Seonwoo and Jeong (2021) examined the structural relationships among mentoring, attitudes, subjective norms, PBC, and career pursuit intentions by applying the TPB among elite Taekwondo athletes in South Korea, and indicated that attitudes positively affected career pursuit intentions. To identify the determinants of academic entrepreneurial intention, Feola et al. (2019) investigated a model on a sample of young Italian researchers with the TPB. The findings showed that the attitude toward entrepreneurial behavior is relevant in predicting academic entrepreneurial intention. Kim et al. (2020) explored potential factors that affect audience's intention to watch LPGA tournaments, and the result revealed positive influence of attitude on intention. Based on these research findings, the present study proposes that:

Hypothesis 1 (H1): Attitudes will positively influence career pursuit intentions among aspiring professional esport athletes.

Empirical evidence in many studies has indicated that subjective norms is a key antecedent variable of behavioral intention. A study conducted by Jeong et al. (2021), investigated the process behind the decision of sports fans to attend sports matches at stadiums amid the COVID-19 pandemic using the TPB, and the findings displayed the positive influence on attendance intention from the perspective of subjective norms. Verma and Chandra (2018) challenged to extend the social-psychological behavioral model (i.e., the TPB) by including two additional constructs to predict young Indian consumers' green hotel visit intention, and reported that subjective norms led to a green hotel visit intention. In a similar context, to explain Chinese college students' intention to travel to Japan et al. (2017) tested a structural equation model using the extended the TPB, demonstrating that subjective norm positively affected travel intention. These findings led to the following hypothesis:

Hypothesis 2 (H2): Subjective norms will positively influence career pursuit intentions among aspiring professional esport athletes.

The significant role of PBC as a determinant of behavioral intention is well documented in various contexts. Schuster et al. (2016) explored factors that affect walk-to-school behavior through application of the TPB among 512 caregivers, and showed that PBC had a positive effect on caregivers' intentions to increase. Chu and Chen (2016) investigated e-learning technology adoption by extending the TPB, suggested that PBC presented significant positive correlation to e-learning intention. Teng et al. (2015) empirically examined how individual characteristics of the TPB model influence traveler intention to visit green hotel, and the findings found that PBC positively affect customer intention to visit a green hotel. Therefore, to assume that PBC influences career pursuit intentions under the following hypothesis is reasonable:

Hypothesis 3 (H3): Perceived behavioral control will positively influence career pursuit intentions among aspiring professional esport athletes.

Furthermore, there is another important question concerning whether athletic identity exerts a moderating effect on the relationships between attitudes, subjective norms, and PBC each with career pursuit intentions among aspiring esport athletes. As mentioned previously, based on previous studies, attitudes, subjective norms, and PBC are likely to directly influence career pursuit intentions (Jeong et al., 2021; Schuster et al., 2016; Seonwoo and Jeong, 2021). Concerning the relation between identity or identification and behavioral intentions, Suh et al. (2013) examined the impact of team identification, e-service quality, and satisfaction and behavioral intention to revisit sports websites, and revealed that identification had a positive effect on revisitation. Moreover, some researchers have challenged the moderating role of identification in sports contexts. For example, Theodorakis et al. (2009) tested the moderating role of team identification on the link between service quality and repurchase intention among spectators attending a professional soccer game in Greece, and indicated that identification was shown to moderate the effect of between service quality on repurchase intention. While Seonwoo et al. (2021) showed that team identification was not found to moderate the relationships of attitudes, subjective norms, and PBC with career pursuit intentions. Therefore, we propose the following hypotheses:

Hypothesis 4 (H4): Athletic identity will moderate the relationship between attitudes and career pursuit intentions among aspiring professional esport athletes.

Hypothesis 5 (H5): Athletic identity will moderate the relationship between subjective norms and career pursuit intentions among aspiring professional esport athletes.

Hypothesis 6 (H6): Athletic identity will moderate the relationship between and perceived behavioral control and career pursuit intentions among aspiring professional esport athletes.

Based on the preceding thorough review of previous studies, we proposed the conceptual model shown in Figure 1.

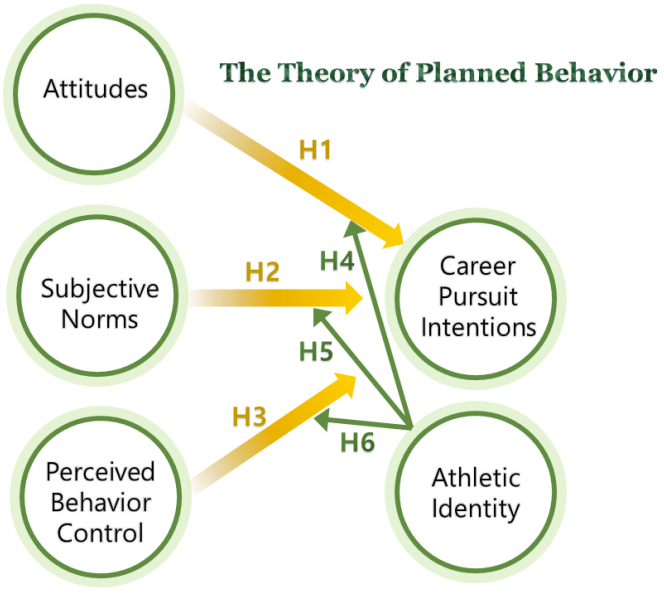

Figure 1. Research framework and hypotheses

METHOD

Participants

The present study utilized a purposive sampling technique. The author and two trained research assistants, who were enrolled in a doctoral course, distributed the survey to aspiring esport athletes, each of whom was attending one of three major esport academies in Korea from 3 March 2021 to 2 April 2021. The major purpose of this private institution is to cultivate talent professional esport athletes. The surveys were not carried out through a visiting survey because of the spread of the COVID-19 in Korea. Instead, they were administrated by e-amil or Kakao Talk (the most widely used messaging app for smartphones and personal computers in Korea) using Google or Naver (the largest web search engine in Korea) surveys. The author contacted the presidents of esport academy, and the questionnaires were distributed to the employees' email or Kakao Talk IDs after obtaining mutual consent. The questionnaire was answered using a self-administration method. We asked a total 240 athletes to take part in the survey. Of these, 229 respondents completed the survey, yielding a response rate of 95.4%. We eliminated data for 14 athletes due to repetitive response patterns; thus, we analyzed 215 usable responses. We gathered demographic information including sex (male: 91.2 %, n = 196; female: 8.8 %, n = 19), age (10s: 89.3 %, n = 192; 20s: 10.7 %, n = 23), and esport experience (less than 2 years: 3.3 %, n = 7; more than 2 years and less than 4 years: 31.2 %, n = 67; more than 5 years and less than 7 years: 42.8 %, n = 92; 8 years or more: 22.8 %, n = 49).

Measurement

The survey instrument was modified and adapted using scales from previous studies. The questionnaire consisted of six main sections: (a) attitudes, (b) subjective norms, (c) PBC, (d) career pursuit intentions, (e) athletic identity, and (f) demographic information. We assessed attitudes using four items adopted from Ajzen (2011), Han et al. (2017), Kim et al. (2020), and Seonwoo and Jeong (2021). We measured subjective norms with four items adopted from Ajzen (2011), Jeong et al. (2021), and Kim et al. (2020). We derived our measure of PBC from Ajzen (1991), Han et al. (2017), and Perugini and Bagozzi (2001). We utilized three items from Davis et al. (1989), and Seonwoo and Jeong (2021). Finally, for athletic identity, we used four items from Lee (2012) and Martin et al. (1994). The response format was a 5-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). A panel of three sociology of sport professors reviewed the instrument's content validity. Based on their feedback, we modified the preliminary questionnaire before distributing it to participants.

Validity and Reliability

We employed confirmatory factor analysis (CFA) with maximum likelihood estimation to assess the dimensionality of the measurement model using AMOS (version 24). The goodness-of-fit indices for the CFA {X^2/df=1.568, Normed Fit Index (NFI)=0.952, Relative Fit Index (RFI)=0.942, Turker-Lewis Index (TLI)=0.978, Comparative Fit Index (CFI)=0.982, and Root Mean Square Error of Approximation (RMSEA)=0.052} were all within the recommended ranges (Hair et al., 2010; Hooper et al., 2008). Next, to confirm the convergent validity based on the measurement model, we calculated the factor loadings, construct reliability (CR), and average variance extracted

(AVE). As shown in Table 1, all factor loadings were greater than 0.698 and significant ($p < 0.001$), with t values exceeding the critical value of 3.29 (Kline, 2005). All CR values (0.800–0.893) exceeded the recommended minimum value of 0.7 and all AVE values (0.552–0.675) exceeded the minimum of 0.5, establishing the scale's convergent validity (Fornell and Larcker, 1981).

Table 1. Summarized results for validity and reliability assessments

Scale items	Standardized Loadings	CR	AVE	Cron-bach's α
Attitudes				
Practicing elite e-sports is				
Extremely unattractive … Extremely attractive	0.911	0.893	0.675	0.967
Extremely worthless … Extremely valuable	0.928			
Extremely boring … Extremely exciting	0.911			
Extremely harmful … Extremely beneficial	0.910			
Subjective norms				
People important to me (e.g., family / friends) would approve of me pursuing my career as an elite e-sports athlete	0.813	0.866	0.619	0.906
People important to me (e.g., family / friends) would support me pursuing my career as an elite e-sports athlete	0.889			
People important to me (e.g., family / friends) would encourage me pursuing my career as an elite e-sports athlete	0.744			
People important to me (e.g., family / friends) would cheer for me pursuing my career as an elite e-sports athlete	0.901			
Perceived behavioral control				
I can do elite e-sports whenever I want	0.949	0.873	0.633	0.939
I have enough time to do elite e-sports	0.919			
I get enough money from my parents to do elite e-sports	0.895			
It is entirely up to me to do elite e-sports	0.808			
Career pursuit intentions				
I will try to continue elite e-sports as my career	0.870	0.800	0.572	0.923
I intend to continue elite e-sports as my career	0.905			
I am willing to devote money and time to continuing elite e-sports	0.909			
Athletic identity				
I think of myself as an athlete	0.698	0.830	0.552	0.903
I have a clear goal about the sports I am practicing now	0.849			
Sports is the most important part of my life	0.855			
I think I will be very depressed if I cannot play because I am sick	0.909			
X^2/df=1.568, NFI=0.952, RFI=0.942, TLI=0.978, CFI=0.982, and RMSEA=0.052				

Table 2. Correlations among the constructs

	AT	SN	PBC	CPI	AI
AT	**0.822**				
SN	0.355**	**0.787**			
PBC	0.287**	0.632**	**0.800**		
CPI	0.494**	0.669**	0.591**	**0.756**	
AI	0.426**	0.593**	0.435**	0.438**	**0.743**

AT: Attitudes, SN: Subjective norms, PBC: Perceived behavioral control, CPI: Career pursuit intentions, AI: Athletic identity. **$p < 0.01$

For the satisfactory discriminant validity, the diagonal elements in Table 2 should be greater than the off-diagonal elements. Comparing all correlation coefficients with the square roots of AVE displayed a satisfactory discriminant validity. In terms of the survey instrument's reliability, the Cronbach's alphas for the five factors ranged from 0.903 to 0.967, all of which exceeded the recommended threshold of 0.7. These results show that the measures were sufficiently reliable (Fornell and Larcker, 1981).

RESULTS

Structural model and Hypothesis Testing

We conducted structural equation modeling (SEM) to investigate the impact of attitudes, subjective norms, perceived behavioral control on career pursuit intentions via AMOS 24. All goodness-of-fit indices for the structural model indicated an acceptable model fit (X^2/df=1.591, GFI=0.926, NFI=0.964, RFI=0.955, CFI=0.986, and RMSEA=0.053) (Hair et al., 2010; Hooper et al., 2008). We utilized this model to examine Hypotheses 1, 2, and 3. As shown in Figure 2, attitudes positively affected career pursuit intentions (β=0.300, p<0.001, t-value=5.862), supporting Hypothesis 1. Subjective norms also positively affected career pursuit intentions (β=0.414, p<0.001, t-value=6.189), which supported Hypothesis 2. PBC significantly affected career pursuit intentions (β=0.274, p<0.001, t-value=4.144), supporting Hypothesis 3.

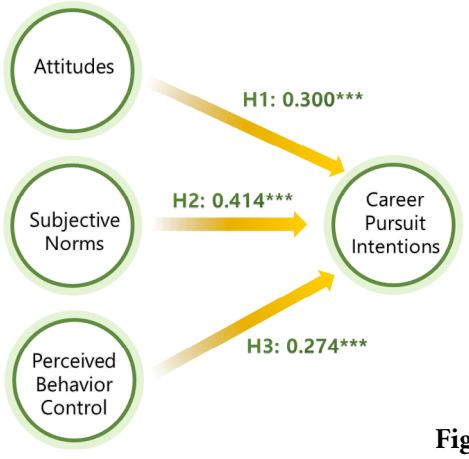

Figure 2. Structural model results. ***$p < 0.001$

We used a hierarchical regression analysis to examine the moderating effect of athletic identity. As shown in 3, in Model 1, the regression was significant ($F = 89.710$, $p < 0.001$, $R^2 = 0.554$). Attitudes ($\beta = 0.275$, $t = 5.618$, $p < 0.001$), subjective norms ($\beta = 0.413$, $t = 6.814$, $p < 0.001$), and PBC ($\beta = 0.251$, $t = 4.245$, $p < 0.001$) had significant impacts on career pursuit intentions. In Model 2, the regression was also significant ($F = 67.461$, $p < 0.001$, $R^2 = 0.554$). When entering athletic identity into the model, the variable was not found to be significant. Finally, in Model 3, the regression equation had a significant effect ($F = 39.254$, $p < 0.001$, $R^2 = 0.556$), and the Durbin-Watson statistic value of 2.055 indicated zero autocorrelation in the sample. When entering three interaction variables (i.e., attitudes X athletic identity, subjective norms X athletic identity, and PBC X athletic identity) into the model, these variables did not emerge as significant predictors of career pursuit intentions. Therefore, athletic identity did not moderate the relationships between attitudes, subjective norms, and PBC with career pursuit intentions each; thus, Hypotheses 4, 5, and 6 were not supported.

Table 3. Moderating effects of athletic identity

Model	Variable	Standardized Coefficient	Std. Error	t	F	R^2 (Adjusted R^2)
1	(Constant)		0.074	41.942***	89.710***	0.561 (0.554)
	Attitudes	0.275	0.079	5.618***		
	Subjective norms	0.413	0.098	6.814***		
	PBC	0.251	0.096	4.245***		
2	(Constant)		0.074	41.929***	67.461***	0.562 (0.554)
	Attitudes	0.289	0.083	5.654***		
	Subjective norms	0.438	0.108	6.593***		
	PBC	0.255	0.096	4.301***		
	Athletic identity	-0.056	0.096	-0.935		
3	(Constant)		0.088	35.115***	39.254***	0.570 (0.556)
	Attitudes	0.300	0.086	5.638***		
	Subjective norms	0.470	0.111	6.839***		
	PBC	0.257	0.097	4.313**		
	Athletic identity	-0.075	0.098	-1.236		
	Attitudes X athletic identity	0.085	0.084	1.657		
	Subjective norms X athletic identity	-0.100	0.114	-1.398		
	PBC X athletic identity	0.041	0.115	0.595		
	Durbin Watson = 2.055					

**$p < 0.01$, ***$p < 0.001$

DISCUSSION

Theoretical implications

While examining the relationship between attitudes and career pursuit intentions, this study considered the argument advanced by existing sports studies that attitudes can improve behavioral intentions. For example, Wang et al. (2021) explored what affects college students' behavioral intention towards sports gambling using the TPB, and found that attitude was the most important antecedent of behavioral intentions. Bae et al. (2020) examined adolescents' participation behavior in new sports through the extended TPB, demonstrating that attitude positively influenced subjects' participation intention. Braksiek et al. (2021)' study drew on the TPB to investigate the effects of attitudes, subjective norms, and PBC on intentions of environmentally friendly behavior in community sports clubs, and the results showed that attitude led to intention. Likewise, Han et al. (2017) emphasized that a volitional factor, such as attitudes, plays an essential role in increasing individuals' intention in the context of sports. Therefore, esport coaches should consider the crucial role of attitude towards practicing esport when developing aspiring esport athletes' career pursuit intentions.

Unlike existing studies that approached the TPB, the present study found that subjective norms was the most influential factor in increasing career pursuit intentions. According to recent previous studies, attitude was the most influential factor in predicting behavioral intention. For example, to explain eco-friendly behavioral intention formation, Kim and Hwang (2020) attempted to merge two theories, the norm activation model and TPB, and reported that the attitudes was the most predictor of the behavioral intention. Based on the TPB, Wang et al. (2020) investigated the dimensions of tourists' environmental behavior and the mechanisms of different types of tourists' environmental behavior, and showed that attitude was the most influential factor in building environmental behavioral intention. In the context of sports literature, the present study found that subjective norms had the highest effect size, which was aligned with other recent research in sports (Jeong et al., 2021). This result means that family and close friends support play a vital role in the decision-making process related to the sports setting. Thus, esport coaches should have an excellent relationship with aspiring esport athletes' families and explain esport academy's goal, dream, and visions, contributing to increasing career pursuit intentions.

The current study contributed to a debate about the role of PBC in the TPB model. Ajzen (2020), a pioneer of the TPB, has indicated that theoretically, PBC can be considered as a moderating variable. Indeed, he argued that PBC was assigned the role of a moderator in the 1980s (Ajzen, 1985), which is line with several studies (Castanier et al., 2013). However, the majority of previous studies viewed PBC as a direct determinant of intention. For example. Rahaman et al. (2019) explored the antecedents of ethical leadership intention by drawing on the TPB, and the results demonstrated that PBC was a direct determinant of ethical intentions. Similarly, Park et al. (2017) tested a structural equation model using the extended TPB to explain Chinese college students' intention to travel to Japan. They found that PBC was a direct antecedent of intention to travel. Thus, aspiring esport athletes' decisions about continuing to pursue their careers can partly depend on their ability. In other words, if aspiring esport athletes have enough money, time, knowledge,

and skills, they are more likely to foster their career pursuit intentions, which means that family and coaches should provide the athletes with support or sensible solutions.

Contrary to our predictions, the results failed to support the moderating effects of athletic identity on the relationships among the "attitudes and career pursuit intentions," "subjective norms and career pursuit intentions," and "PBC and career pursuit intentions." This result can be explained. The characteristics of the sample in the current study were different from those in previous studies. Testing the moderating role of team identification concerning the relationship between service quality and repurchase intentions among 257 spectators attending a professional soccer game, Theodorakis et al. (2009) collected data from various age groups. However, the present study collected data from teenagers and early 20s. Furthermore, the present study focused on aspiring esport athletes in South Korea. Although South Korea is an esport powerhouse, the nation will not be representing an entire esport. Analysis of the moderating effects with samples from other countries can lead to different results. In sum, esport coaches do not have to segregate aspiring esport athletes according to the level of athletic identity using different strategies. Thus, esport coaches should increase attitudes, subjective norms, and PBC using same effective coaching strategies to improve career pursuit intentions.

Practical implications

The role of esport coaches is crucial to increase the positive attitude of aspiring professional esport athletes towards practicing elite esport, which means that mentoring can play a key role in improving the positive attitudes. Mentoring is the most cooperative at-will relationship among a senior and junior to improve the mentee's growth and career development. In South Korea, aspiring professional esport athletes are worried about fierce competition, negative perceptions of esport, and college entrance. Some give up on their career because of experiencing severe internal conflict. Therefore, esport coaches should be highly interested in the athletes and actively help them by various mentoring programs. The best mentoring type is to deliver the coach's success stories consistently. Through the coach's success story, athletes can see what they lack and prepare for future success.

For improving the subjective norm, esport coaches should have amicable relations with the athletes' parents. This is because aspiring professional esport athletes can decide whether to continue to pursue their elite esport career on their parents' opinions. Therefore, esport coaches should report the athletes' current skill level, explain their educational philosophy to the athlete's parents and establish trust. These efforts will help the athletes to pursue their career. Additionally, parents' economic support is also a non-negligible factor in improving career pursuit intentions. Even if aspiring professional esport athletes show outstanding abilities in esport, they cannot pursue their careers unless they receive financial support from their parents or esport institutions since they are young. Thus, parents or institutions must try to offer financial aid to any athletes who cannot afford the expenses for esport academy so that the athletes can focus on practicing esport.

CONCLUSION

The objective of this study was to explore the structural relationships among attitudes, subjective norms, PBC, and career pursuit intentions among aspiring esport athletes, by applying the TPB and

assessing the moderating effect of athletic identity. The results demonstrated positive impacts of attitudes, subjective norms, and PBC on career pursuit intentions. However, it was found that athletic identity did not moderate the relationships between the given factors and career pursuit intentions. The findings have significant implications: (1) the present study considered the argument advanced by previous sports studies that attitudes can lead to behavioral intentions; (2) subjective norms were the most influential factor in building career pursuit intentions; (3) although PBC has been considered as a moderating variable, our study found that PBC was a direct determinant of career pursuit intentions.

Despite these meaningful findings, this study has some limitations. First, our study did not extend the TPB. Hence, future studies could add variables in the research model to extend the TPB. Second, the TPB may not have had sufficient explanatory power. Hence, it is worth applying the model of goal-directed behavior, which has been considered as a limitation of the TPB, for future studies. Third, we did not explore the behavioral, normative, and control beliefs influencing attitudes, subjective norms and PBC, respectively. Thus, future research must examine the antecedents of attitudes, subjective norms and PBC to understand them better. Finally, more research is required to explore the impact of educational service quality on attitudes, subjective norms, and PBC, as it plays a vital role in this context.

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Measuring the Technical Efficiency of Hockey Players: Empirical Evidence from Czech Hockey Competition

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ABSTRACT

Ice hockey is a very popular sport in the Czech Republic. Nowadays, hockey player efficiency analysis is a useful tool that helps sports managers with player selection, team composition and team performance evaluation. The literature offers only a limited number of scientific studies that deal with the evaluation of the efficiency of hockey players or clubs. The aim of this research is to use data envelopment analysis to help Czech hockey clubs, managers and coaches to evaluate the efficiency of their players. This research evaluates the technical efficiency of Czech hockey players using three data envelopment analysis models, ranks the best players based on their super-efficiency scores, and then tries to uncover the main sources of player inefficiency. The models are empirically applied to players playing in the Tipsport extraliga in the 2021/22 season. The evaluation used in this paper attempts to incorporate greater objectivity into decision making and thus may be an important step in developing a systematic methodology for evaluating hockey players.

Keywords: sport; ice hockey; efficiency; inefficiency; data envelopment analysis

INTRODUCTION

Efficiency is a performance criterion for any organizational system based on the quantity of inputs and outputs (Kian, 2009). In this research, efficiency is defined as the ratio of outputs to inputs needed to produce those outputs. In the current economically challenging times, sports clubs need to use their resources judiciously and pay attention to measuring their efficiency. Due to the nature of sports clubs, it is often quite difficult to measure their efficiency and performance. Sports clubs are a special kind of business because, although they operate within the same legal framework as other companies, they are very strongly conditioned by sporting activities. Every sports organization in

the current adverse times needs a comprehensive system to measure its efficiency to be aware of the desirable and undesirable elements in its operations. The sports industry has been undergoing a development in the last two years, especially economically. Sports competitions around the world have been negatively affected by the global Covid-19 pandemic in 2020 and 2021. Czech sports clubs are currently struggling with high energy prices and a post-viral decline in spectator attendance. Every sports organisation should therefore try to assess its strengths and weaknesses. Success in a professional sports league today goes hand in hand with a successful team, coach and ultimately team leadership. The focus should be on determining whether the sports club is using its human resources appropriately to achieve the best possible sporting results. It is conceivable that a club whose players are relatively cheap can get "interesting" sporting results. Evaluating the efficiency of individual players is currently a key issue in the sports industry. Because the success of the club and the success of the team is built primarily on individual players. This raises the question of how to measure the sporting efficiency of players.

Efficiency measurement in professional sport has an extensive list of empirical analyses in the sport economics literature. The following list contains only a few examples from different sports. These are mainly foreign researches focusing on football (Collier et al., 2011; Hadley et al., 2000; Haas, 2003; Haas et al., 2004; Guzmán and Morrow, 2007; Espitia-Escue and García-Cebrián, 2004; Palafox-Alcantar and Vargas-Hernández, 2015; Zambom-Ferraresi et al., 2019; Guzmán-Raja and Guzmán-Raja, 2021; Kirschstein and Liebscher, 2018), basketball (Zak et al., 1979; Fizel and D'Itri, 1996; Cooper et al., 2009; Cooper et al., 2011), baseball (Porter and Scully, 1982; Ruggiero et al., 1996; Andersen and Sharp, 1997; Mazur, 1994; Suk, 2014), golf (Fried et al., 2004) and tennis (Halkos and Tzeremes, 2012; Ramón et al., 2012). Most of the aforementioned efficiency studies evaluate the technical efficiency of sports clubs or teams as a whole. Despite numerous studies conducted in many different countries, few studies have attempted to include measures of the technical efficiency of individual players. The player is an important element behind the success of the team and the sports club. The literature review further revealed that there is almost no attention paid to ice hockey among researchers. Ice hockey is a very popular sport worldwide nowadays. The hockey industry is a major industry in many countries. Ice hockey has a long history and tradition in the Czech Republic and its popularity is at a high level. Therefore, efficiency analysis is as important in ice hockey as in other sports.

The literature review further revealed that operational research techniques are mainly used to measure efficiency in professional sport. One of the most commonly used techniques is data envelopment analysis (further DEA). The following section briefly summarizes the authors who apply data envelopment analysis or other operational research techniques in their research to evaluate the efficiency of hockey clubs or individual players. These are mainly authors who evaluate the efficiency of clubs from the National Hockey League (further NHL). Kuosmanen (1998) evaluates the efficiency of NHL hockey clubs in the 1996/97 season using data envelopment analysis. The DEA model includes data on player salaries (inputs), league points in the regular season and playoff results (outputs). The result of his research is a calculated efficiency score for each team, which indicates the team's efficiency compared to other teams in the NHL. The resulting efficiency score shows how many league points in the regular season and playoff wins each team

could have achieved with the right team composition and correct tactical decisions. The results of the research showed that player salaries do not fully explain the success of teams in the regular season and playoffs. Inefficiency in achieving playoff wins and league points in the regular season with a given roster can be caused by mistakes in player selection or coaching.

Jablonský (2021) examines the relationship between individual player efficiency and team efficiency and models team efficiency as a function of player efficiency. Individual player efficiency is measured using traditional radial and additive Slacks-Based Measure DEA models. The efficiency of teams is then determined by traditional DEA models with variables describing the actual achievements of teams and parallel DEA models that take into account all player positions and the actual performance of teams in the league. The study is based on NHL statistics for the 2019/20 season. The results of the analysis show that actual team performance is not always directly dependent on the individual performance of team members. The biggest deviations occurred with the Florida Panthers and Montreal Canadiens. The best team in the regular season, the Boston Bruins, was ranked 10th by the DEA model. The ranking of the teams derived from the overall efficiency is further away from the actual ranking. The average deviation of the derived ranking from the actual ranking is 4.00. The conclusion is consistent with the fact that a team is always more than the sum of individuals.

In his efficiency analysis, Kahane (2005) attempts to identify sources of inefficiency in NHL clubs using a stochastic frontier production function. Inefficiency in the NHL can be traced in part to differences in coaching ability, team ownership, local sports competition, and management experience. His research concluded that teams with unusually high or very low numbers of French-Canadian players are less efficient. Another source of inefficiency is poor coaching instructions and other factors such as the age of the club. Another possible source of inefficiency in hockey clubs is the type of ownership structure. For example, clubs owned by corporations tend to be more efficient than clubs owned by individuals. Bedford and Baglin (2009) measure team performance during hockey games using regression analysis. Their model is based on direct interaction between two competing teams. They include a performance measure in their model to assess the performance of a team over the course of a match. The research was applied to NHL teams playing in the 2005/06 and 2006/07 seasons. The results of the analysis provided an objective, simple and versatile measure of team performance that would be a valuable evaluative tool for coaches, media and spectators. Weissbock et al. (2013) propose a machine learning approach to predict success in the NHL. The approach combines traditional statistics, such as the number of goals scored and conceded, and performance metrics, such as the number of goals scored in games, to create a classification model. The best results were obtained using neural networks with an accuracy of 59.38%. This model can be used to predict the winner of the playoffs and the winner of the Stanley Cup.

In the Czech environment, hockey efficiency was only examined by the consultancy PwC (2015), which analysed each country's conditions for success at the 2015 World Ice Hockey Championships held in Prague and Ostrava. The research used regression analysis to estimate the so-called PwC point index. This index assesses the historical performance of national teams over the past 20 years at World Cups. Z It takes into account each place in the final ranking. The analysis also takes into account the number of stadiums, the number of registered hockey players, demographic and

economic indicators and the average annual temperature in the country. The research confirmed the hypothesis that well-functioning national teams are mostly in countries with a long hockey tradition and popularity. The research also concluded that a country's economic prosperity does not affect the efficiency of national teams. A regression analysis was also used to determine a model-based estimate of team performance based on the included input variables. These values represent the performance that teams should achieve.

It is clear from the above that the literature focuses mainly on the most famous hockey competition - the NHL. No attention is paid to other hockey competitions. Efficiency measurement focuses predominantly on the club level. Researchers pay minimal attention to efficiency at the level of national hockey teams or at the level of individual players. Czech hockey in general and the Czech top hockey league have not received any attention in the literature. The aim of this research is to use data envelopment analysis to help Czech hockey clubs, managers and coaches to evaluate the efficiency of their players. The presented research determines the level of technical efficiency of Czech hockey players using basic methods of data envelopment analysis, determines the ranking of the best players based on their super-efficiency scores and then tries to reveal the main sources of player inefficiency. The models are empirically applied to players of the Czech top hockey competition (i.e. Tipsport extraliga) in the 2021/22 season. The results of the research may be interesting not only for sports managers, coaches and hockey scouts, but also for fans.

METHODS AND DATA

Data

As mentioned in the introduction, the aim of the research is to use data envelopment analysis to determine the level of technical efficiency and then to compare the efficiency of hockey players playing in the Czech top hockey competition, i.e. Tipsport extraliga. Player efficiency was analyzed in the 2021/22 season and was evaluated based on player statistics from the regular season and then from the playoffs. Furthermore, the research seeks to uncover the main sources of player inefficiency from both the regular season and the playoffs.

The data used for research purposes come from the official statistical database of Czech hockey, which is operated by BPA sport marketing a.s. (2022) and eSports.cz, s.r.o. (2022). The database includes a wide range of data related to different levels of hockey competitions. The period under consideration covers the entire 2021/22 season. A total of 15 hockey clubs participated in the Tipsport extraliga in the analyzed 2021/22 season. Namely: Sparta Praha (SPA), Kometa Brno (KOM), Motor České Budějovice (CEB), Bílí Tygři Liberec (LIB), Mladá Boleslav (MLB), Dynamo Pardubice (PCE), Mountfield Hradec Králové (MHK), Verva Litvínov (LIT), Vítkovice Ridera (VIT), Oceláři Třinec (TRI), Rytíři Kladno (KLA), Škoda Plzeň (PLZ), Olomouc (OLO), Berani Zlín (ZLN) and Energie Karlovy Vary (KVA). A total of 437 players who played at least 60 minutes in the 2021/22 regular season were analyzed. In addition, 272 players who played at least 15 minutes in the 2021/22 playoffs were analyzed. Players were divided into three groups according to their game position (goalkeepers, defenders and forwards). Data on individual players was obtained from the website of BPA sport marketing a.s. (2022). These data include mainly ice time, shots

on goal, number of goals, number of assists, hits, number of shots blocked by a player, number of games won, save percentage and number of shootouts.

Data Envelopment Analysis

As mentioned in the introduction, the research is aimed at evaluating the efficiency of hockey players in Tipsport extraliga using the data envelopment analysis (further DEA) method. The DEA method generalizes Farrell's (1957) measure of technical efficiency to the case of multiple inputs and multiple outputs. The DEA was first defined by Charnes, Cooper and Rhodes in 1978. It is a method that measures the relative efficiency of so-called decision-making units (further DMUs). DEA is based on linear programming and compares the levels of inputs and outputs of the decision-making unit with those of other DMUs in its peer group (Cooper, 2011). In sports, a DMU can be an athlete, team manager, coach, sports club, etc. In this article, the decision-making units are players of individual hockey clubs playing in the Tipsport extraliga. The DEA method was developed to analyze the relative efficiency of DMUs with heterogeneous inputs and outputs. Therefore, the use of this method seems to be appropriate in the sports industry mainly because a set of different variables can be evaluated (Dlouhý et al., 2018). In this case, the DEA method evaluates the efficiency with which the player can transform his inputs into outputs, i.e., how much outputs the player can achieve given the amount of available inputs (Jablonský and Dlouhý, 2015).

DEA models can be classified according to their orientation into input-oriented, output-oriented and non-oriented models. Input-oriented models help to determine how much inputs need to be reduced to make the evaluated unit efficient. Output-oriented models, on the other hand, help determine by how much outputs need to be increased to make the evaluated unit efficient. In relation to the choice of DEA model orientation, a literature search revealed that the most common orientation used in studies using the DEA method is input orientation. An input-oriented model was also used in this research, with the choice guided primarily by previous literature and the fact that sports clubs generally have more control over their inputs than their outputs. Further subdivision of DEA models is possible based on the nature of the production process. In this case, a distinction can be made between models based on the assumption of constant returns to scale (further CRS), e.g. the CCR model (named after its creators Charnes, Cooper and Rhodes) and models based on the assumption of variable returns to scale (further VRS), e.g. the BCC model (named after its creators Banker, Charnes and Cooper). In the present research, both models are used simultaneously. By using both models, it is possible to identify the main sources of inefficiency of the evaluated DMUs.

From a mathematical point of view, DEA is a technique to obtain information about a given sample of observations in a situation where the production function is not known in advance. An input-oriented CCR model was applied to the obtained data on individual players. The aim of this model is to utilize the minimum level of inputs at the same level of output. The dual form of its mathematical model is formulated using relations (1) and (2). Where λ_j, $j = 1, 2, ..., n$ are weights of all DMUs, $i = 1, 2, ..., m$ and , $k = 1, 2, ..., r$ are slack/surplus variables, is the efficiency score of the DMU_q (Charnes et al., 1978).

$$\text{Minimize} \quad \theta_q \tag{1}$$

$$\text{S.t.} \quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_q x_{iq}, \quad i = 1,2,\dots,m,$$

$$\sum_{j=1}^{n} y_{kj}\lambda_j - s_k^+ = y_{kq}, \quad k = 1,2,\dots,r, \tag{2}$$

$$\lambda_j \geq 0, \ \ j = 1,2,\dots,n,$$

The model described by relations (1) and (2) works under conditions of constant returns to scale. In the literature, the input-oriented CCR model is referred to as CCR-I (Charnes et al., 1978). The CCR-I model makes it possible to calculate the so-called overall technical efficiency (OTE) score. OTE measures efficiencies due to the input/output configuration and as well as the size of operations (Avkiran, 2006). The OTE score is therefore influenced by the so-called scale efficiency. This OTE score is within a range from zero to one, $0 < \text{OTE} \leq 1$. Using the CCR-I model, OTE score were determined for each hockey player. An efficient hockey player gains an OTE score = 1. An OTE score < 1 indicates an inefficient hockey player. The lower the score, the worse the player. It should be noted that the OTE score also helps to identify the source of the technical inefficiency, which can be caused by pure technical inefficiency (PTIE), scale inefficiency (SIE), or both inefficiencies at the same time i.e. overall technical inefficiency (OTIE). The source of such a player's inefficiency may be a lack of game performance, an incorrectly chosen game strategy, or a combination of both.

The input-oriented BCC model was also applied to the obtained data on individual players. The BCC model is based on the assumption of variable returns to scale. The BCC model, originally introduced in Banker et al. (1984), extends the model described by relations (1) and (2) by the convexity condition $\Sigma_{\lambda j} = 1$. The mathematical form of BCC model is as follows:

$$\text{Minimize} \quad \theta_q \tag{3}$$

$$\text{S.t.} \quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_q x_{iq}, \quad i = 1,2,\dots,m,$$

$$\sum_{j=1}^{n} y_{kj}\lambda_j - s_k^+ = y_{kq}, \quad k = 1,2,\dots,r, \tag{4}$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, \ \ j = 1,2,\dots,n,$$

In the literature, the input-oriented BCC model described by relations (3) and (4) is referred to as BCC-I (Banker et al., 1984). The BCC-I model allows the calculation of a so-called pure technical efficiency (PTE) score. The PTE score is without the influence of scale efficiency. This PTE score is within a range from zero to one, $0 < \text{PTE} \leq 1$. Using the BCC-I model, PTE score were determined

for each hockey player. An efficient hockey player gains a PTE score = 1. PTE score < 1 indicates an inefficient hockey player. The lower the score, the worse the player. The only source of this player's inefficiency is his lack of game performance. Scale efficiency (SE) for each DMU can be obtained by a ratio of OTE score to PTE score (see formula 5). This SE score is within a range from zero to one, $0 < SE \leq 1$. The SE score for each player was determined using relationship (5). An efficient hockey player gained SE score = 1. SE score < 1 indicates an inefficient hockey player. The source of this player's inefficiency may be an incorrectly chosen game strategy. If a DMU is characterized as efficient in the CCR model, it will also be characterized as efficient in the BCC model. However, the reverse is not necessarily true.

$$SE = \frac{OTE}{PTE} \tag{5}$$

It is important to note that all efficient DMUs have an OTE score equal to 1 in the CCR model. Therefore, the efficient DMU cannot be ranked or distinguished using the CCR model. The ability to rank or discriminate efficient DMUs is of theoretical and practical importance. So-called super-efficiency models were formulated to rank DMUs with an efficiency score equal to one. The best known model is that of Andersen and Petersen (1993). In principle, the super-efficiency score for an efficient DMU can take any value greater than or equal to 1. The whole concept of super-efficiency is based on the exclusion of efficient DMUs from the considered set, thus shifting the original efficient frontier. This procedure allows the ranking of efficient DMUs (i.e., the higher the super-efficiency score, the higher the ranking). Inefficient DMUs that are not at the efficiency frontier and whose initial DEA score is less than 1 are not affected by the exclusion of efficient DMUs from the reference set.

Jablonský and Dlouhý (2015) formulate the Andersen and Petersen model (further AP model) with an input-oriented CRS assumption using relations (6) and (7). Its input oriented formulation is very close to the traditional input oriented formulation of CCR-I model, see relations (1) and (2). If the unit under consideration is marked as efficient, then $\theta q^{AP} > 1$ applies (Jablonský, 2016). All calculations were performed using MaxDEA software.

$$\text{Minimize} \quad \theta_q^{AP} \tag{6}$$

$$\text{S.t.} \quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_q^{AP} x_{iq}, \quad i = 1, \dots, m,$$

$$\sum_{j=1}^{n} y_{kj}\lambda_j - s_k^+ = y_{kq}, \quad k = 1, \dots, r, \tag{7}$$

$$\lambda_j \geq 0, \quad j = 1, \dots, n, j \neq q,$$

$$\lambda_q = 0.$$

In the next step, a suitable number of input/output variables should be selected. According to Cooper (2011), the number of DMUs should be at least two to three times higher than the sum of inputs and outputs. Since hockey players are evaluated, the DEA model will have a sufficiently

large number of DMUs with respect to the sum of inputs and outputs. Due to the large number of DMUs evaluated, 9 variables could be selected for the DEA model based on correlation analysis. The CCR-I, BCC-I and AP models are based on a single input variable common to all game positions. The input variable is time on ice (TOI). A player's importance in the team increases every time he is selected for a game and also if he plays a significant amount of game time. The output variables included game statistics relevant to each game position. For defenders, the following output variables were included in the research: number of shots (S), number of goals (G), number of assists (A), hits (H) and the number of blocked shots by the player (BkS). For forwards, the following output variables were included in the research: number of shots (S), number of goals (G) and number of assists (A). For goalkeepers, the following output variables were included in the research: number of matches won (W), save percentage (Sv%) and number of shootouts (SO).

RESEARCH RESULTS

This part of the paper is devoted to the results of an empirical research in which a non-parametric DEA methodology was used. The DMUs in this research are the players of the top Czech hockey competition Tipsport extraliga in the 2021/22 season. Hockey players were divided into three groups according to their game positions. In the first part of the research, players were evaluated on statistical data from the regular season.

DEA – regular season 2021/22

The CCR-I model and the AP super-efficiency model were applied to the statistical data on goalkeepers, defenders and forwards who played at least 60 minutes in the 2021/22 regular season. Subsequently, the BCC-I model was also applied to help identify sources of inefficiency.

Using the CCR-I model, OTE score was determined for all goalkeepers who played at least 60 minutes in the regular season. The average OTE score for all goalkeepers in Tipsport extraliga is around 0.737. The median OTE score is 0.726, based on this value it can be concluded that half of the goalkeepers had worse OTE score and half had better ones. Furthermore, based on the calculated OTE score, it can be stated that out of the 37 goalkeepers evaluated, 5 goalkeepers (13.5%) were efficient. Two efficient goalkeepers were identified in the hockey club Sparta Praha (Július Hudáček and Matěj Machovský). One efficient goalkeeper was identified in Olomouc (Branislav Konrád), Oceláři Třinec (Ondřej Kacetl) and Motor České Budějovice (Jan Strmeň). In order to further classify efficient goalkeepers, the AP super-efficiency model was applied to the data. Table 1 shows the efficient goalkeepers ranked by AP score. The best goalkeeper of the regular season was Július Hudáček (1.1370). Table 1 also shows the mean and median values of the variables included in the DEA.

Table 1. Efficient goalkeepers in the 2021/22 regular season and descriptive statistics of variables

Ranking	Goalkeeper	Club	AP score	TOI	W	Sv%	SO
1.	Július Hudáček	SPA	**1.1370**	425	5	91.67	1
2.	Branislav Konrád	OLO	**1.1196**	1031	9	92.37	3

3.	Ondřej Kacetl	TRI	**1.0121**	1394	17	93.00	2
4.	Jan Strmeň	CEB	**1.0029**	746	9	92.69	1
5.	Matěj Machovský	SPA	**1.0004**	1005	12	92.00	2
Average				920.20	10.40	92.35	1.80
Median				1005.00	9.00	92.37	2.00

For the other clubs, none of the goalkeepers was named as an efficient unit. Thus, a total of 32 goalkeepers (86.5%) can be classified as inefficient units. Relatively good OTE scores (> 0.9) were achieved by goalkeepers Marek Mazanec (0.9750), Jakub Sedláček (0.9639), Marek Schwarz (0.9176) and Filip Novotný (0.9148). The goalkeepers with the lowest OTE scores were Libor Kašík (0.4346), Daniel Huf (0.2639) and Šimon Zajíček (0.1882). These goalkeepers played for Berani Zlín and Verva Litvínov in the 2021/22 season. Berani Zlín ranked 15th, while Verva Litvínov finished in 13th position.

The BCC-I model was also applied to the data to reveal the main sources of goalkeeper inefficiency. The result of this phase of the analysis was the calculation of pure technical efficiency and then scale efficiency. These two values helped to decompose the overall technical efficiency and to identify the main sources of inefficiency. The calculation showed that out of 32 inefficient goalkeepers only five goalkeepers had scale inefficiency (Aleš Stezka, Petr Kváča, Filip Novotný, Jaroslav Janus and Marek Mazanec). The average SE score for these five goalkeepers was 0.8340. Thus, the main source of inefficiency was an incorrectly chosen game strategy. For three goalkeepers, the source of inefficiency is pure technical inefficiency (Gašper Krošelj, Henri Kiviaho and Jan Lukáš). The average PTE score was 0.7063. The main source of inefficiency of these goalkeepers is only their lack of game performance. For the other 24 goalkeepers, the main source of inefficiency is overall technical inefficiency. The result of the research shows that in the regular season of 2021/22, in most cases the reason for the inefficiency of the goalkeepers was a combination of their insufficient game performance and incorrectly chosen game strategy. The average PTE score is 0.6861 and the average SE score is 0.9602. The main problem with these 24 goalkeepers is largely their poor game performance as captured by the PTE score. Table 2 shows the overall summary.

Table 2. Summary of inefficiency results - goalkeepers

		Number	**%**	**Avg. OTE score**	**Avg. PTE score**	**Avg. SE score**
	Total inefficient	32	86.5	0.6882	0.7370	0.9442
Source	scale inefficiency	5	15.6	0.8340	1.0000	0.8340
	pure technical inefficiency	3	9.4	0.7063	0.7063	1.0000
	overall technical inefficiency	24	75.0	0.6556	0.6861	0.9602

Using the CCR-I model, OTE score was determined for all defenders who played at least 60 minutes in the regular season. The average OTE score of all defenders in Tipsport extraliga is around 0.692. The median OTE score is 0.684, based on this value it can be concluded that half of the defenders achieved worse OTE score and half achieved better. Furthermore, based on the calculated OTE score, it can be stated that of the 146 defenders evaluated, 11 defenders (7.5 %) were considered efficient. Two efficient defenders were identified in Vítkovice Ridera (Alexey Solovyev and Patrik Koch), Sparta Praha (Oleg Pogorishnyi and Maksim Matushkin). One efficient defender was

identified in Motor České Budějovice (Ondřej Slováček), Oceláři Třinec (Mikuláš Zbořil), Dynamo Pardubice (Jan Košťálek), Kladno (Jakub Suchánek), Mountfield HK (Bohumil Jank), Kometa Brno (Michal Gulaši) and Verva Litvínov (Jan Strejček). To further classify efficient defenders, the AP super-efficiency model was applied to the data. Table 3 shows the efficient defenders ranked by AP score. The best defender of the regular season was Ondřej Slováček (1.8079). Table 3 shows the mean and median values of the variables included in the DEA.

Table 3. Efficient defenders in the 2021/22 regular season and descriptive statistics of variables

Ranking	Defender	Club	AP score	TOI	H	BkS	S	G	A
1.	Ondřej Slováček	CEB	**1.8079**	106	2	8	9	1	6
2.	Mikuláš Zbořil	TRI	**1.3508**	62	0	6	10	1	0
3.	Jan Košťálek	PCE	**1.2297**	1054	19	49	177	8	33
4.	Alexey Solovyev	VIT	**1.2269**	766	24	33	74	11	17
5.	Patrik Koch	VIT	**1.2158**	1000	94	89	76	2	3
6.	Jakub Suchánek	KLA	**1.1401**	813	59	116	69	2	5
7.	Oleg Pogorishnyi	SPA	**1.0856**	100	4	13	3	1	0
8.	Bohumil Jank	MHK	**1.0590**	665	39	48	72	6	2
9.	Michal Gulaši	KOM	**1.0478**	974	76	136	40	1	7
10.	Maksim Matushkin	SPA	**1.0115**	516	5	14	73	6	14
11.	Jan Strejček	LIT	**1.0044**	504	31	42	36	4	4
Average				596.36	32.09	50.36	58.09	3.91	8.27
Median				665.00	24.00	42.00	69.00	2.00	5.00

For the other clubs, none of the defenders was named as an efficient unit. Thus, a total of 135 defenders (92.5%) can be classified as inefficient units. Relatively good OTE scores (> 0.9) were achieved by defenders Richard Nedomlel (0.9942), Rhett Holland (0.9747), Kevin Tansey (0.9710), David Štich (0.9667), Marian Adámek (0.9235), Daniel Gazda (0.9202), Jiří Ondrušek (0.9189), Tomáš Kundrátek (0.9184) and Jakub Teper (0.9064). The defenders with the lowest OTE score were Patrik Fajmon (0.3174), Šimon Groch (0.3389) and Hakon Nilsen (0.3570).

The BCC-I model was also applied to the data to reveal the main sources of defender inefficiency. The calculation showed that 11 of 135 inefficient defenders had scale inefficiency (Aaron Irving, Daniel Gazda, Jakub Michálek, Jan Štencel, Jiří Ondrušek, Kevin Tansey, Peter Čerešňák, Richard Nedomlel, Tadeáš Talafa, Tomáš Kundrátek and Vojtěch Riedl). The average SE score for these defenders was 0.8192. The main source of inefficiency was an inappropriately chosen game strategy. Pure technical inefficiency was not the source of inefficiency for any of the defenders. For the remaining 124 defenders, the main source of inefficiency is overall technical inefficiency. The result of the research thus shows that in the regular season, in most cases, the cause of the defenders' inefficiency was a combination of their poor game performance and incorrectly chosen game strategy. The average PTE score is 0.6922 and the average SE score is 0.9462. The main problem with these defenders is largely their poor game performance captured by the PTE score. The overall summary is shown in Table 4.

Table 4. Summary of inefficiency results - defenders

		Number	%	Avg. OTE score	Avg. PTE score	Avg. SE score
	Total inefficient	135	92.5	0.6667	0.7173	0.9358
Source	scale inefficiency	11	8.1	0.8192	1.0000	0.8192
	overall technical inefficiency	124	91.9	0.6531	0.6922	0.9462

Using the CCR-I model, OTE score was determined for all forwards who played at least 60 minutes in the regular season. The average OTE score of all forwards in Tipsport extraliga is around 0.5508. The median OTE score is 0.5292, based on this value it can be concluded that half of the forwards achieved worse OTE scores and half achieved better ones. Furthermore, based on the calculated OTE score, it can be stated that out of the 254 forwards evaluated, 4 forwards (1.6%) were considered efficient. Efficient forwards were marked in clubs: Sparta Praha (David Tomášek), Škoda Plzeň (Michal Bulíř), Dynamo Pardubice (Robert Říčka) and Oceláři Třinec (Erik Hrňa). In order to further classify the efficient forwards, the AP super-efficiency model was applied to the data. Table 5 shows the efficient forwards ranked by AP score. The best forward in the regular season was David Tomášek (1.4013). Table 5 also shows the mean and median values of the variables included in the DEA.

Table 5. Efficient forwards in the 2021/22 regular season and descriptive statistics of variables

Ranking	Forward	Club	AP score	TOI	S	G	A
1.	David Tomášek	SPA	**1.4013**	125	20	4	7
2.	Michal Bulíř	PLZ	**1.0942**	977	204	27	29
3.	Robert Říčka	PCE	**1.0549**	807	149	27	20
4.	Erik Hrňa	TRI	**1.0497**	402	60	14	13
Average				577.75	108.25	18.00	17.25
Median				604.50	104.50	20.50	16.50

For the other clubs, none of the forwards was named as an efficient unit. Thus, a total of 250 forwards (98.4%) can be classified as inefficient units. Relatively good OTE scores (> 0.9) were achieved by forwards Filip Chlapík (0.9774), Matěj Blümel (0.9483), Tomáš Záborský (0.9464), Michal Řepík (0.9456), Ahti Oksanen (0.9353), Dominik Lakatoš (0.9267) and Peter Mueller (0.9183). The forwards with the lowest OTE value were Šimon Frömel (0.1430), Jiří Novotný (0.2298) and František Gerhát (0.2362).

The BCC-I model was also applied to the data to reveal the main sources of offensive inefficiency. The calculation showed that out of 250 inefficient forwards only 8 forwards had scale inefficiency (Daniel Kurovský, Filip Chlapík, Martin Štohanzl, Peter Mueller, Samuel Bitten, Tomáš Záborský, Tor Erik Eriksson Immo and Vlastimil Dostálek). The average SE score for these forwards was 0.7761. Thus, the main source of inefficiency was an incorrectly chosen game strategy. Pure technical inefficiency was not the source of inefficiency for any of the forwards. For the other 242 forwards, the main source of inefficiency is overall technical inefficiency. The result of the research thus shows that in the regular season 2021/22, in most cases the reason for the inefficiency of the forwards was a combination of their underperformance and incorrectly chosen game strategy. The average PTE score is 0.5953 and the average SE score is 0.9082. The main problem with these forwards is their poor game performance captured by the PTE score. The overall summary is shown in Table 6.

Table 6. Summary of inefficiency results - forwards

		Number	%	Avg. OTE score	Avg. PTE score	Avg. SE score
	Total inefficient	250	98.4	0.5436	0.6082	0.9040
Source	scale inefficiency	8	3.2	0.7761	1.0000	0.7761
	overall technical inefficiency	242	96.8	0.5359	0.5953	0.9082

Figure 1 compares the sources of inefficiency for each type of game position. It is clear from Figure 1 that scale inefficiency is not as common a problem for players. These players could be helped by a change of club (trade) as they most likely don't suit the set style of play of the team or the strategy of the coaches. Figure 1 also shows that overall technical inefficiency prevails for all game positions. For these players it is necessary to work mainly on performance development in combination with a possible change of game strategy. Only for some goalkeepers pure technical inefficiency was detected by the research. This can be caused by an avalanche effect, where poor play by the forwards affects the defenders, who in turn negatively affect the goalkeepers.

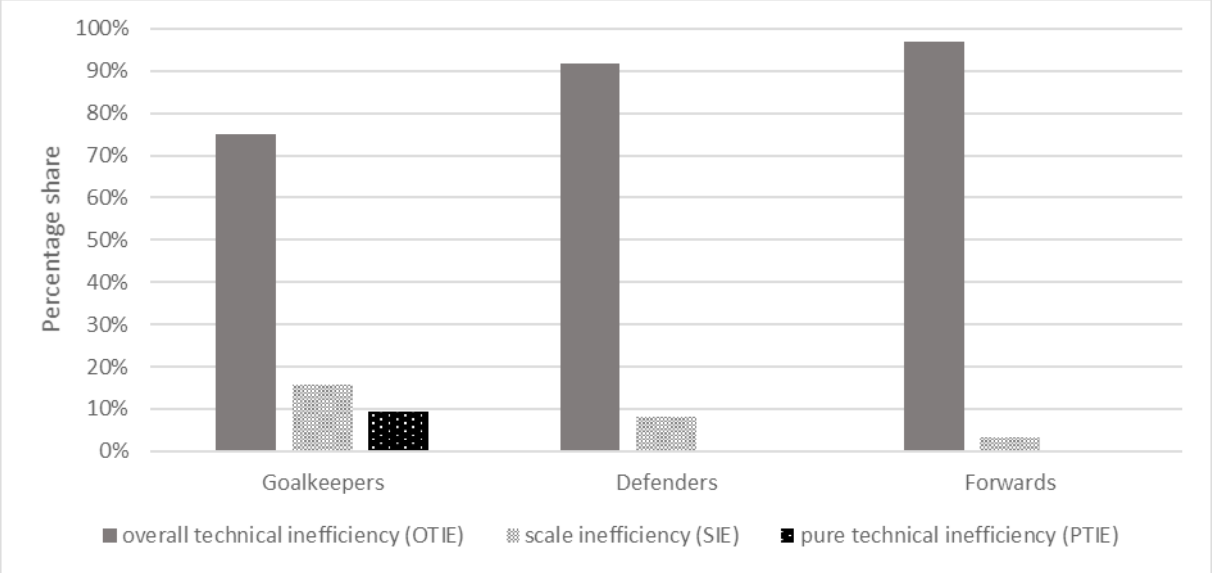

Figure 1. Comparison of sources of inefficiency within individual game positions (regular season)

DEA – 2021/22 playoffs

The CCR-I model, an AP super-efficiency model, was applied to the statistical data on goalkeepers, defenders and forwards who played at least 15 minutes in the 2021/22 playoffs. Subsequently, the BCC-I model was also used to help identify sources of inefficiency.

Using the CCR-I model, OTE score was determined for all goalkeepers who played at least 15 minutes in the playoffs. The average OTE score for all goalkeepers in the playoffs is around 0.569. The median OTE score is 0.532, based on this value it can be concluded that half of the goalkeepers achieved worse OTE scores and half achieved better ones. Furthermore, based on the calculated OTE score, it can be stated that out of the 21 goalkeepers evaluated, 4 goalkeepers (19.05%) were efficient. Two efficient goalkeepers were identified in Oceláři Třinec (Marek Mazanec and Ondřej Kacetl). One efficient goalkeeper was identified in Motor České Budějovice (Jan Strmeň) and Škoda

Plzeň (Miroslav Svoboda). To further classify the efficient goalkeepers, the AP super-efficiency model was applied to the data. Table 7 shows the efficient goalkeepers ranked by AP score. The best goalkeeper in the playoffs was Miroslav Svoboda (2.1733). Table 7 also shows the mean and median values of the variables included in the DEA.

Table 7. Efficient goalkeepers in the 2021/22 play-off and descriptive statistics of variables

Ranking	Goalkeeper	Club	AP score	TOI	W	Sv%	SO
1.	Miroslav Svoboda	PLZ	**2.1733**	119	1	94,74	1
2.	Marek Mazanec	TRI	**1.2798**	128	2	95,24	0
3.	Jan Strmeň	CEB	**1.1429**	15	0	66,67	0
4.	Ondřej Kacetl	TRI	**1.0982**	733	10	93,75	3
Average				248.75	3.25	87.60	1.00
Median				123.50	1.50	94.25	0.50

For the other clubs, none of the goalkeepers was identified as an efficient unit. Thus, a total of 17 goalkeepers (80.95 %) can be classified as inefficient units. Other goalkeepers had OTE values lower than 0.88. The goalkeepers with the lowest OTE were Štěpán Lukeš (0.1102) and Henri Kiviaho (0.1338).

The BCC-I model was also applied to the data to reveal the main sources of goalkeeper inefficiency in the playoffs. The result of this phase of the analysis was the calculation of pure technical efficiency and then scale efficiency. These two values helped to decompose the overall technical efficiency and to identify the main sources of inefficiency. The calculation showed that out of 17 inefficient goalkeepers only two goalkeepers had scale inefficiency (Jaroslav Pavelka and Pavel Jekel). The average SE score for these two goalkeepers was 0.7260. Thus, the main source of inefficiency was an incorrectly chosen game strategy. For two goalkeepers, the source of inefficiency is pure technical inefficiency (Branislav Konrád and Marek Čiliak). The average PTE score was 0.5633. The main source of inefficiency of these goalkeepers is only their lack of game performance. For the remaining 13 goalkeepers, the main source of inefficiency is overall technical inefficiency. The result of the research thus shows that in the playoffs, in most cases the reason for the inefficiency of goalkeepers was a combination of their poor game performance and incorrectly chosen game strategy. The average PTE score is 0.5424 and the average SE score is 0.7508. So the main problem with these goalkeepers is rather their poor game performance captured by the PTE score. The overall summary is presented in Table 8.

Table 8. Summary of inefficiency results – goalkeepers

		Number	%	Avg. OTE score	Avg. PTE score	Avg. SE score
	Total inefficient	17	80.95	0.4672	0.5987	0.7772
Source	scale inefficiency	2	11.8	0.7260	1.0000	0.7260
	pure technical inefficiency	2	11.8	0.5633	0.5633	1.0000
	overall technical inefficiency	13	76.5	0.4126	0.5424	0.7508

Using the CCR-I model, OTE score was determined for all defenders who played at least 15 minutes in the playoffs. The average OTE score for defenders in the playoffs is around 0.698. The median OTE score is 0.659, based on this value it can be concluded that half of the defenders

achieved worse OTE scores and half achieved better ones. Furthermore, based on the calculated OTE score, it can be stated that out of the 86 defenders evaluated, 10 defenders (11.6%) were considered efficient. Two efficient defenders were identified in Vítkovice Ridera (Petr Gewiese and Patrik Koch), Mountfield HK (Filip Pavlík and Petr Kalina), Škoda Plzeň (Vladimír Kremláček and Peter Čerešňák) and Kometa Brno (Marek Ďaloga and Radek Kučeřík). One efficient defender was identified in Dynamo Pardubice (Jan Košťálek) a Sparta Praha (Tomáš Pavelka). To further classify the efficient defenders, the AP super-efficiency model was applied to the data. Table 9 shows the efficient defenders ranked by AP score. The best defender of the playoffs was Filip Pavlík (1.4039). Table 9 also shows the mean and median values of the variables included in the DEA.

Table 9. Efficient defenders in the 2021/22 play-off and descriptive statistics of variables

Ranking	Defender	Club	AP score	TOI	H	AB	S	G	A
1.	Filip Pavlík	MHK	**1.4039**	114	3	4	21	0	1
2.	Petr Gewiese	VIT	**1.3768**	23	2	5	1	0	0
3.	Vladimír Kremláček	PLZ	**1.3389**	30	1	5	3	0	1
4.	Patrik Koch	VIT	**1.3380**	125	13	8	14	0	2
5.	Petr Kalina	MHK	**1.2992**	70	3	5	7	1	1
6.	Peter Čerešňák	PLZ	**1.1741**	130	5	9	12	1	4
7.	Marek Ďaloga	KOM	**1.1463**	99	0	8	11	1	3
8.	Jan Košťálek	PCE	**1.1169**	128	1	4	17	0	4
9.	Radek Kučeřík	KOM	**1.1122**	95	6	15	11	0	0
10.	Tomáš Pavelka	SPA	**1.0448**	268	2	9	21	4	2
Average				108.20	3.60	7.20	11.80	0.70	1.80
Median				106.50	2.50	6.50	11.50	0.00	1.50

For the other clubs, none of the defenders was identified as an efficient unit. Therefore, 76 defenders (88.4%) can be classified as inefficient units. Defenders Dominik Graňák (0.9983), Karel Nedbal (0.9862), Jeremie Blain (0.9576), David Škůrek (0.9432), David Němeček (0.9226), Jan Zahradníček (0.9185) and Tomáš Černý (0.9125) had relatively good OTE scores (> 0.9). The defenders with the lowest OTE scores were David Moravec (0.0029), David Kvasnička (0.2421) and Mitchell Fillman (0.3272).

The BCC-I model was also applied to the data to reveal the main sources of inefficiency. The calculation showed that out of 76 inefficient defenders, 16 defenders had scale inefficiency. The average SE score for these defenders was 0.8514. The main source of inefficiency may have been an incorrectly chosen game strategy. Pure technical inefficiency was not the source of inefficiency for any of the defenders. For the remaining 60 defenders, the main source of inefficiency is overall technical inefficiency. The result of the research thus shows that in the playoffs, the cause of the inefficiency of the defenders was in most cases a combination of their poor game performance and incorrectly chosen game strategy. The average PTE score is 0.6966 and the average SE score is 0.8577. The main problem with these defenders is largely their poor game performance captured by the PTE score. The overall summary is shown in Table 10.

Table 10. Summary of inefficiency results – defenders

		Number	%	Avg. OTE score	Avg. PTE score	Avg. SE score
	Total inefficient	76	88.4	0.6578	0.7605	0.8564
Source	scale inefficiency	16	21.1	0.8514	1.0000	0.8514
	overall technical inefficiency	60	78.9	0.6062	0.6966	0.8577

Using the CCR-I model, OTE score was determined for all forwards who played at least 15 minutes in the playoffs. The average OTE score for all forwards in the playoffs is around 0.5015. The median OTE score is 0.4844, based on this value it can be concluded that half of the forwards achieved worse OTE scores and half achieved better ones. Furthermore, based on the calculated OTE score, it can be stated that out of the 165 forwards evaluated, 6 forwards (3.6 %) were considered efficient. Efficient forwards were identified in Sparta Praha (David Tomášek), Škoda Plzeň (Michal Bulíř), Energie Karlovy Vary (Tomáš Redlich), Mladá Boleslav (Matyáš Kantner), Kometa Brno (Peter Mueller) and Motor České Budějovice (Daniel Voženílek). In order to further classify the efficient forwards, the AP super-efficiency model was applied to the data. Table 11 shows the efficient forwards ranked by AP score. The best forward in the playoffs was Tomáš Redlich (1.9429). Table 11 also shows the mean and median values of the variables included in the DEA.

Table 11. Efficient forwards in the 2021/22 play-off and descriptive statistics of variables

Ranking	Forward	Club	AP score	TOI	S	G	A
1.	Tomáš Redlich	KVA	**1.9429**	20	3	0	2
2.	Matyáš Kantner	MLB	**1.1744**	43	9	2	0
3.	Michal Bulíř	PLZ	**1.1627**	95	27	2	2
4.	Peter Mueller	KOM	**1.1087**	90	22	3	3
5.	Daniel Voženílek	CEB	**1.1001**	112	13	5	2
6.	David Tomášek	SPA	**1.0088**	184	35	6	7
Average				90.67	18.17	3.00	2.67
Median				92.50	17.50	2.50	2.00

For the other clubs, none of the forwards was identified as an efficient unit. Thus, a total of 159 forwards (96.4 %) can be classified as inefficient units. Forwards Ondřej Beránek (0.9613), Michal Birner (0.9287), Michal Kunc (0.9205) and Tomáš Vondráček (0.9089) had relatively good OTE scores (> 0.9). The forwards with the lowest OTE score were Vojtěch Lednický (0.0009), Tomáš Knotek (0.0690) and Vít Jiskra (0.1466).

The BCC-I model was also applied to the data to reveal the main sources of inefficiency of the forwards. The calculation showed that out of 159 inefficient forwards only five forwards had scale inefficiency (Filip Chlapík, Michal Řepík, Miloš Kelemen, Tomáš Filippi and Tomáš Urban). The average SE score for these forwards was 0.8172. Thus, the main source of inefficiency was an incorrectly chosen game strategy. For 20 forwards, pure technical inefficiency was the source of inefficiency. The average PTE score was 0.4693. The main source of the inefficiency of these forwards is only their lack of game performance. For the other 134 forwards, the main source of inefficiency is overall technical inefficiency. The result of the research shows that in the playoffs of the 2021/22 season, in most cases the reason for the inefficiency of the forwards was a combination

of their lack of game performance and incorrectly chosen game strategy. The average PTE score is 0.5741 and the average SE score is 0.8301. The main problem with these forwards is their poor game performance captured by the PTE score. The overall summary is shown in Table 12.

Table 12. Summary of inefficiency results - forwards

		Number	%	Avg. OTE score	Avg. PTE score	Avg. SE score
	Total inefficient	159	96.4	0.4826	0.5743	0.8511
Source	scale inefficiency	5	3.1	0.8172	1.0000	0.8172
	pure technical inefficiency	20	12.6	0.4693	0.4693	1.0000
	overall technical inefficiency	134	84.3	0.4722	0.5741	0.8301

Figure 2 compares the sources of inefficiency for each type of game position in the playoffs. Figure 2 shows that the main source of inefficiency is overall technical inefficiency. For goaltenders, the sources of inefficiency changed only slightly compared to the regular season. There was a change in the defenders, where the proportion of scale inefficiency increased slightly compared to the regular season. There was also a change in the group of forwards. The playoffs saw a very significant pure technical inefficiency compared to the regular season (increase from 0 to 20 forwards). For these players, the main cause of inefficiency was probably performance or physical unpreparedness for the playoffs. A possible reason for this phenomenon is the different length of the two Tipsport extraliga periods. In the playoffs, players' performance or physical deficiencies, which are not so noticeable in the regular season (played for 56 rounds), were more evident.

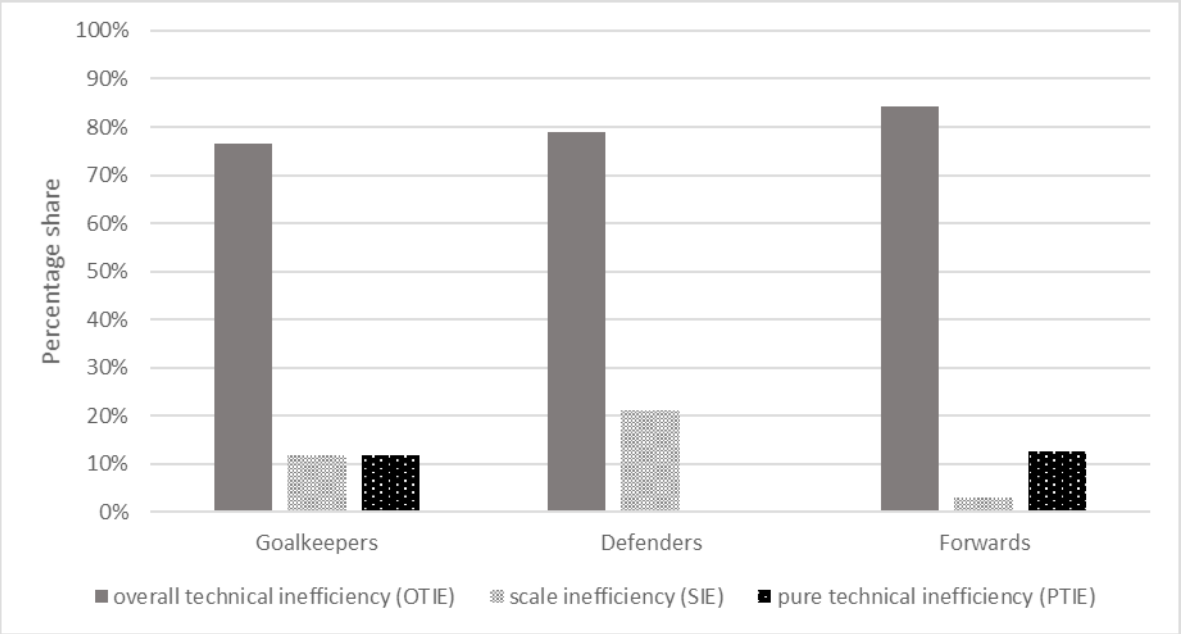

Figure 2. Comparison of sources of inefficiency within individual game positions (play-off)

DISCUSSION

Considering the current economic and financial situation of hockey clubs, it is more than necessary to know how efficiently a club uses its financial and human resources. The analysis of the efficiency

of hockey players is an important research topic in the field of player evaluation and selection, as well as the composition of hockey teams for the new season. The analysis enables the identification of sources of inefficiency and helps to find corrective measures to avoid wasting resources. The presented research uses basic methods of data envelopment analysis to determine the level of technical efficiency of Czech hockey players, ranks the best players based on their super-efficiency scores, and then tries to uncover the main sources of player inefficiency.

The results showed that the relative frequency of efficient goalkeepers is higher in the playoffs (19.05%) than in the regular season (13.5 %). On the other hand, both the average and median OTE scores were lower for goalkeepers in the playoffs than in the regular season. For goalkeepers, all sources of inefficiency were identified. For most goalkeepers, overall technical inefficiency prevailed. The differences in the structure of sources of inefficiency in the regular season and playoffs were minimal. Research on defenders has shown that the relative frequency of efficient defenders is higher in the playoffs (11.6 %) than in the regular season (7.5 %). The average and median OTE scores in the playoffs and regular season showed only minimal differences. For defenders, only two sources of inefficiency were identified - overall technical inefficiency and scale inefficiency. Overall technical inefficiency was predominant. It can also be concluded that in the playoffs there was a higher proportion of defenders suffering from scale inefficiency. The results also showed that the relative frequency of efficient forwards is higher in the playoffs (3.6%) than in the regular season (1.6%). Both the average and median OTE scores were slightly lower in the playoffs. The structure of sources of inefficiency differed in the regular season and the playoffs. No forward showed pure technical inefficiency in the regular season. On the other hand, 12.6% of forwards suffered from pure technical inefficiency in the playoffs. In the short-term part of the competition, the players‘ performance or physical deficiencies were more evident.

The research reaches similar conclusions to Kahane (2005), who states that inefficiency in the NHL can be traced in part to differences in coaching ability and management experience. This source of player inefficiency has also been confirmed in the Czech Tipsport extraliga. The inefficiency resulting from poor coaching decisions was confirmed for all groups of players and was captured by scale inefficiency. However, the main source of player inefficiency in the Czech league was overall technical inefficiency. Most players need to work on performance development in combination with a change in game strategy. Performance is not as big a problem in the NHL as it is in the Czech league due to the very wide player base.

Unfortunately, the Czech Tisport extraliga failed to prove the conclusions of Kuosmanen (1998), who claims that player salaries do not fully explain the success of teams in the regular season and playoffs. Player salary could not be included in the models in the Czech hockey environment due to unavailability of data and the research had to be based on playing time.

CONCLUSION

The aim of this research was to determine the level of technical efficiency of hockey players in the Czech Tipsport extraliga. Furthermore, to create a ranking of the best hockey players and to reveal the main sources of player inefficiency.

The presented methodology allows to use a comparative system to evaluate the efficiency of players and teams at both club and national level. It can primarily help sports managers of clubs to gain knowledge about the performance of their players and subsequently contribute to improving their performance or help with the composition of players for the new season. Along with general knowledge and experience, coaches can also take DEA efficiency analysis into account for team development and for tactical preparation of goalkeepers, defenders and forwards for matches. This evaluation model could contribute to a more accurate differentiation of the quality of individual players and to the evaluation of the overall efficiency of the team after the end of the season, if information about players' salaries is included. The quality of individual players is also important for hockey scouts who can also use the DEA method. The DEA is based on quantitative variables and can be used as a complementary method to attributes such as player's personality, behaviour, player's game thinking, skating attitude, stability, skating economy, speed and agility.

For better and more accurate results, it would be desirable to supplement the data envelopment analysis with another input variable, which would be the players' salary. Currently, however, player salaries are not a publicly available variable and it is difficult for an outside analyst to determine this data. Czech hockey differs significantly from other hockey competitions when it comes to player salary disclosure. For example, the NHL or Scandinavian hockey competitions are more transparent in this respect and provide data on players' salaries to the wider public. In the future, this input variable would make it possible to make the efficiency results of individual players and subsequently of entire teams more precise. For example, players who have average or below-average salaries can achieve very interesting game results and can be identified as an efficient unit in terms of the DEA model. Such a player could be an interesting acquisition for the club when building the team for the new season. On the other hand, inefficient players with above-average financial compensation represent a waste of the club's financial resources and contribute to a decrease in the overall efficiency of the team. Other output variables can also be added to the research, such as face-offs won, penalty minutes, plus-minus statistics, etc. Future research in the field of ice hockey can also target individual players' game or technical skills and include variables in the DEA model that are only related to offensive or defensive activities.

The presented methodology can also be applied to Czech hockey players playing at the national team level. Then compare the results with foreign rivals. It is also important to mention that the research was applied only for one season. Future research should focus on determining the technical efficiency of players and clubs with more seasons. Based on a longer time series, it should be clear how the club responded to the calculated efficiency and whether it tried to make changes in subsequent seasons. For this purpose, the data envelopment analysis would be complemented by the Malmquist index, which helps with tracking technical efficiency in a time series.

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Opinion of the Spectators of a Grand Tour In Spain: A Qualitative Analysis

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ABSTRACT

Purpose: The objective of this study is to carry out a qualitative analysis of the ratings of tourists and residents attending the road cycling sporting event "La Vuelta" held in Spain in 2019, 2020 and 2021 editions. Methods: The sample consisted of 1,203 comments/observations from tourists and residents in the in situ and post-event phase of each edition. For this qualitative analysis, an open question was used at the end of a quantitative questionnaire on social and tourism impact. Once each comment had been categorised, a summary was made of the responses and frequencies of each idea according to each category, positive and negative comments and the words most used in each type of comment. Nvivo v.10 software (QSR International, Burlington, MA 01803, USA) was used to analyse the comments and frequencies of each idea. Results: Most of the positive comments focus on the positive feelings and emotions generated by attending the event (emotion or enjoyment; 12.4%), great experience (14.8%), atmosphere of the event (10.4%), good organisation of the event (12.1%) and future intentions to return and recommend the event (7.4%). Negative comments mainly refer to the COVID-19 pandemic (11.8%), the advertising caravan (7.4%) and traffic and parking problems (5.9% of comments). Among the words associated with negative comments, the word "advertising caravan" stands out, while the most used words in positive reviews were "experience" and "emotion". Conclusion: Most of the positive comments focus on positive feelings and emotions generated by attending the event (emotion or enjoyment) and the great experience and atmosphere surrounding the sporting event. In the 2020 edition, the COVID-19 pandemic negatively affected the event, although parking problems and traffic congestion are the worst-rated categories.

Keywords: residents; tourists; impacts; perception; sport event

INTRODUCTION

The celebration of sporting events is a strategy widely used by local communities to generate positive impacts and benefits. Holding an event is an opportunity for communities seeking to promote their tourist attractions, attract visitors, gain international recognition, or improve their media coverage, regenerating the locality and revaluing the community (Balduck et al., 2011).

In recent years, the number of sporting events has increased considerably, and it is difficult to find a day of the year when a sporting event is not held, even if several sporting events coincide on the same day. This growth in the number of sporting events has led to an increase in scientific studies analysing their impact, especially research related to the analysis of social, cultural, and economic impacts of events (Getz, 2008).

Social impact assessment has become one of the fields within sport management that has become more relevant in recent years (Parra-Camacho et al., 2016). In most studies considering social impact of sporting events a quantitative methodology, mainly through questionnaires, was employed.

La Vuelta a España is one of the most important annual sporting events held in Spain, and it is the country's top cycling event as well as one of the most important road cycling events in the world along with the Tour de France and Giro d'Italia. La Vuelta is a distinctive and singular stage event held in different areas of the country with different routes (Kettner-Høeberg & Lopez, 2015).

The objective of this study was to conduct a qualitative analysis of the ratings made by tourists and residents attending the road cycling sporting event *La Vuelta* held in Spain in 2019, 2020 and 2021.

METHOD

The qualitative analysis was based on the opinions of both residents and tourists attending *La Vuelta*. A total of 1,203 comments/observations from tourists (64.4%) and residents (36.6%) in the *in situ* and post-event phase in all three years were analysed (2019–2020–2021). The mean age of the respondents was 45.6 ± 11.4 years. The majority of the respondents (56.9%) were male, and 43.1% were female. In all years the highest percentage of educational level was high school/vocational training (about 40.7%). As many as 70.1% were married or living with a partner, and 22.7% were single.

A group of eight to four researchers (depending on the stage and year in question) travelled with the caravan of *La Vuelta* in the selected stages. The type of sampling used was non-probabilistic convenience sampling. A tent with fixed tablets was set up at the start and finish areas where those attending the event (residents and tourists/excursionists) could approach and complete the survey.

In addition, the members of the group of surveyors were positioned in the start and finish areas, and randomly interviewed the attendees personally. The flyers with a QR code containing a link to a web page giving access to the questionnaires were also handed out, so that the attendees could access the survey from their own mobile phones.

An open-ended question was used at the end of a larger questionnaire researching into social impact of sporting events. Responses were categorized following the recommendations of Rincón-Gómez (2014). First, following Strauss and Corbin's (2002) advice, an inductive descriptive coding

of each comment was performed, identifying and describing the material in free categories (*in vivo*). Then, the total of 16 boxes were created according to the main theme of the comment.

Once each comment was categorized, a summary of the responses was made and frequencies of each idea according to each category were calculated, together with positive and negative comments as well as the words most frequently used in each comment Nvivo v.10 software (QSR International, Burlington, MA 01803, USA) was used to analyse the comments and frequencies. Two researchers analysed the comments separately and selected the categories. Once the categories were determined, all concepts, words and phrases were sorted into their respective categories and quantified.

RESULTS

The results of the analysis were grouped into 16 boxes according to the main theme of the comment (accessibility; atmosphere at the event; traffic and parking; litter; advertising caravan and La Vuelta Park; COVID-19 pandemic; enjoyment and emotion; unusual experience; socialization; future intentions; promotion of locality; promotion among young people; event organization; event information; promotion of sport and tourism). Table 1 shows the percentage of each of the thematic groupings. *Experience* was the most frequently mentioned theme (14.8% of all answers), followed by *enjoyment and emotion* (12.4%) and *event organization* (12.1%).

Table 1. Themes of the comments made by residents and tourists

Order	Theme	%	Order	Theme	%
1	Unusual experience	14.8	10	Promotion among young people	2.4
2	Enjoyment and emotion	12.4	11	Event information	1.8
3	Event organization	12.1	12	Accessibility	1.5
4	COVID-19 pandemic	11.8	13	Litter	1.2
5	Atmosphere at the event	10.4	14	Socialization	0.9
6	Vuelta Park and caravan	7.4	15	Promotion of sport	0.9
7	Future intentions	7.4	16	Tourism	0.9
8	Traffic and parking	5.9	17	Other themes	2.4
9	Promotion of locality	5.9			

Positive comments focused mostly on positive feelings and emotions generated by attending the event (emotion or enjoyment) as well as the great experience and atmosphere of the event. They also referred to the good organization of the event and the future intentions of coming back and recommending the event. The negative comments focused mainly on the COVID-19 pandemic, the publicity caravan, traffic and parking problems and lack of prior information.

Depending on the year in question, there were variations in the main topics discussed. Table 2 shows the main themes of the qualitative analysis in the three editions analysed. In the 2019 the experience was the most commented theme, followed by enjoyment and emotion, and organization. In the 2020 the comments related to the COVID-19 pandemic were the most relevant, and in 2021 enjoyment and emotion, followed by the atmosphere at the event, LaVuelta park and advertising caravan.

Table 2. Main themes of the comments made in each year

La Vuelta 2019	La Vuelta 2020	La Vuelta 2021
Experience		Enjoyment and emotion
Enjoyment and emotion	COVID-19 pandemic	Atmosphere at the event
Organization		Vuelta Park and caravan

Experience was the most commented theme, and both residents and tourists showed a very positive attitude towards it, particularly in 2019 when this was the most commented theme. A 43-year-old British tourist commented the 2019 race in the following manner: "*I have attended two stages during my holidays, both well organized and with very pleasant experiences.*" A Swedish tourist made this comment to one of the pollsters: "*Tell me a sport where you can be so close to your idols and talk to them? Also, free*". The residents were also positive about their experience: "*It had been more than 40 years, in times gone by, that this great atmosphere hadn't been seen in the town. For one day, everyone was seen to be happy and away from each of their problems*" (a 76-years-old female resident of Molina de Aragón (Guadalajara, 2021). "*It was an excellent day for a historic event never experienced in our municipality*" (a 66-years-old male resident of El Burgo de Osma (Soria), 2021 edition).

The theme *enjoyment and emotion* was the second most commented theme, being the most relevant in the 2021. Comments such as the following ones could be observed: "*My mother was moved to tears when the first cyclists arrived*" (a 42-years-old female tourist, 2021); or "*On TV it seems somewhat more boring and live it's super exciting, it gives you a tremendous adrenaline rush and it was cool*" (a 52-years-old male resident of La Manga del Mar Menor (Murcia), 2021). "*We were all moved to see La Vuelta go by and we were also at the finish line, and it was exciting, it gave us an adrenaline rush to see how they crossed the finish line. I recommend it to everyone, for me it was a unique experience*" (a 32-years-old female resident of Albacete, 2021).

The third most commented topic was the organization of the event, with most comments praising good organization of the event: "*Congratulations to the good organization of La Vuelta and the friendliness of the staff*" (a 34-years-old female resident, 2021). "*It seems to me that La Vuelta is very well organized*" (a 42-years-old male tourist, 2019).

The 2020 edition was conditioned by the COVID-19 pandemic and the fear for health and possible increases in infections due to the development of the event, so it is no wonder that the most commented topic by residents was the COVID-19 pandemic. Moreover, 76% of the comments on this topic were negative. Different residents expressed their concern about the disregard for the measures against COVID-19: "*There were crowds at various points despite the restrictions. They shouldn't have organized it*" or "*People huddled together, without a mask, without social distance*". Others referred to the consequences of the pandemic and the effects on the event: "*With the bars closed there was not much impact*" or "*In the circumstances that have been carried out, it has been a huge expense for the City Council, with practically no benefit for anyone*". Although to a lesser extent, some residents were satisfied with the measures against COVID: "*The COVID measures were exquisite, and it was very well organized.*" Even in the same municipality and place, there were discrepancies regarding this issue. A couple of residents commented: "*It has been very exciting to reach the finish line and people have respected the security measures*" (man) while his partner said: "*It is very hot and there are many people without a mask for the situation we are in*" (both 19-year-old residents).

The atmosphere of the event is the next of the most mentioned topics, representing 10.4% of the comments. "*Excellent event, I enjoyed the atmosphere*" (a 24-years-old female tourist, 2019). In 2021, the atmosphere of the event was the second most relevant theme, following *enjoyment and emotion*. For example: "*I had never seen this up close and it seemed incredible to me and the atmosphere that existed after so long with COVID was great*" or "*The atmosphere that it generated had never been in the locality compared to other events, such as football matches, foot races...*" (residents, 2021).

Another theme that appeared among the most commented ones in the 2021 was the Vuelta Park and the advertising caravan, two of the parallel activities of La Vuelta. Most of these comments were negative, expecting a greater number of advertising activities and products: "*The publicity caravan is quite poor. I was expecting more activities and merchandising for the kids, and they are far away from the finish area.*" (a 42-year-old female resident, 2021).

Finally, some examples of other topics were observed and even though they were less recurrent than the previous topics, they have had relevance for the tourists and residents attending the event. For example, regarding prior information, there were comments such as: "*I missed more information on traffic and road closures, as well as their alternatives*"; "*Little information for young children to participate in the sponsor area";* or "*A day to remember, the next day my nephew wanted to be a cyclist, and like him, I imagine, almost all the children in the town*" (a 41-years-old male resident 2021).

DISCUSSION

This paper aimed at the qualitative analysis of the opinions of tourists and residents attending the road cycling sporting event across three years.

Most previous studies that have analysed the social and tourism impact of sporting events have used quantitative methodology. Several of these quantitative studies added a qualitative question to the questionnaire, but on most occasions, the responses to this type of question were not analysed (Rincón-Gómez, 2014).

In this work, an open-ended question in the final section of the questionnaire was used. Open-ended questions used in surveys provide textual information such as opinions, explanations, and justifications. The open-ended question does not require a choice between a set of alternatives. It is a free response, and therefore, depending on the nature of the question and the interest of the person, the answers vary greatly in length and depth.

Despite the difficulty that can be involved in the coding and the analysis of answers (Gómez, 2014), the use of open-ended questions is justified on many occasions due to the advantages they offer. Some of these advantages according to Pope (2002) are: (i) the collection of spontaneous information; (ii) the enrichment of the final report (through the inclusion of real quotas of the responses that are considered significant); (iii) the usefulness to explain and understand the response to a closed question; and (iv) provide information about the opinion of a group of people.

It is recommended to involve residents in the active participation of the event as spectators (Bursa and Mailer, 2021). In international literature, few studies use a qualitative methodology for the analysis of perceptions of the impacts of sporting events. Lockstone-Binney et al. (2020) conducted a study on two events held in Australia as a part of the Cricket World Cup by interviewing over 150

tourists and event attendees. Among the short-term social impacts that emerged from the results was a positive feeling about the atmosphere and ambience of the events, as has been the case at La Vuelta as well since the atmosphere of the event was one of the most frequently (and positively) mentioned themes by attendees. Ortiz (2020) conducted a qualitative study with managers of hotel establishments in Cantabria on the passage of La Vuelta through their community, and most of the comments and future intentions were positive.

The emotions attendees felt when cyclists pass them by, and the atmosphere generated in the event has played an essential role in their assessments. The festive nature of sporting events can create a limonoid space, allowing attendees to escape from their daily lives (Chalip, 2006). During the celebration of sporting events, according to the previously mentioned author, "*there is a sense that something more important, something that transcends sport, is happening. It feels as if new energy has been injected into the community atmosphere, energy that everyone can share. Social rules and social distinctions seem less important and sometimes are suspended altogether*" (p. 110).

However, not all qualitatively analysed comments were positive. By using qualitative methodology, Abdullah et al. (2016) explored through semi-structured interviews the perceptions of residents and their engagement in an international regatta in Malaysia. Feedback from the host community suggested that the event organizers should focus on developing better lines of communication and dissemination of event information. These results are in line with our research, as pre-event information was considered one of the problems of La Vuelta.

Parking problems and traffic congestion have been the next most commented topics by the attendees on the negative impacts of La Vuelta. In previous research by Martin and Barth (2013) used quantitative questionnaires and semi-structured interviews with Glasgow residents during the 2014 Commonwealth Games and highlighted the concerns about traffic congestion and parking problems.

The publicity caravan also figured prominently in the comments of the residents and tourists who attended the event. It should be noted that even though the caravan is a complementary activity to the sporting event, the advertising caravan has become a spectacle, a parade with colourful and modified vehicles to entertain the spectators before the passage of the cyclists (Fagnoni & Castoldi, 2018). According to Fine and Speer (1985) who analysed an event very similar to La Vuelta, the advertising caravan has become an attraction, where 47% of fans who attended the event did so mainly to watch the caravan (CNN, 2017).

Finally, comments related to the COVID-19 pandemic were the main theme of the 2020 research. In this edition, there was a higher incidence of the virus, and a number of measures and restrictions was introduced. In summary, 76% of the comments on this theme were negative towards the event. No other qualitative research was found to analyse the COVID-19 pandemic and its effect on the perception of a sporting event. Shigemura et al. (2020) explain that fear and perceptions of risk to the unknown can condition negative social behaviours. Fear of a collapse of the healthcare system due to the medical burden of dealing with an outbreak has a negative effect on attitudes toward sporting events (Kato, 2021).

CONCLUSION

The qualitative analysis of the comments made by spectators, residents, or tourists, who attended in person at least one stage of the Vuelta and participated in the on-site evaluation of the event itself showed interesting results.

On the one hand, the attending spectators opined that the experience of this sports spectacle and the fun derived from it were the aspects most commented on and highlighted by the majority of those who attended the event. The public considered fun and family atmosphere generated by the organization of the event at the start and/or finish line sites as very significant. This fact is marked by the organization's goal of creating a festive atmosphere by having multiple stands and activities aimed at having an entertaining afternoon with one's family. This is why comments of the Vuelta Park are the second most mentioned aspects by spectators. In this park, there are different activities in which people of all ages can participate and receive a gift from the sponsor or collaborating brands.

On the other hand, the negative comments are related to the publicity and information given about the event in the host locations, especially about the COVID-19 pandemic. During 2020, the COVID-19 pandemic forced the ban of all recreational and social activities of the event due to the limitations set by different regional authorities in an attempt to block the spread of the virus. The results indicate that the pandemic had significant influence on mental health of the population, and therefore on their perception of the event in the absence of such a social and touristic purpose.

In addition, the lack of information is a very important aspect that must be considered, both by those responsible for the organization of La Vuelta and by other directors of sporting events. This lack of information to the population produces negative comments from the residents as shown in the results of this study, for example, parking problems or temporary traffic cuts.

Thus, as a practical proposal, sports event organizers and local authorities should pay more attention to informing residents about such events. In this way, they will be able to prevent possible problems arising from organizing such an event, e.g., parking problem. Simultaneously, more people would be informed about the event, and consequently increase local support for it.

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STUDENT SECTION

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Evaluation of the Quality of Life of University Students in Prague After the Annual Covid–19 Restrictions

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ABSTRACT

Background: The COVID 19 disease brings about a variety of restrictions that affect the quality of life. For Czech students across all tiers of the educational system, the 2020/2021 academic year was very challenging as they basically spent all of it in a distance learning mode. In addition, the restrictions put in place by the Czech government did not allow for the value of health to be upheld in all of its components. Objective: The objective of this study was to look into the views on the quality of life in a group of 381 Prague university students who had gone through distance learning. As part of the study, we divided the set along faculty and year-of-study lines. Methods: As a research tool, we used the Czech version of the World Health Organisation's WHOQLBREF Quality of Life Questionnaire. Within the descriptive statistical analysis we worked with the basic quantities of central tendency and variability. For the purposes of inferential statistical analysis, we used Cronbach's alpha (to determine the set consistency), correlation to determine domain dependencies, and ANOVA to test statistical hypotheses. Results: The set was content with the overall quality of life, with Faculty of Physical Education and Sport students and second- and third-year students coming on top as the most satisfied once the set had been divided. The lowest values were reported in the physical health domain, which is inconsistent with the findings of other research conducted on this topic; on the contrary, the highest values were shown for the set in the environmental health domain; this is in line with foreign research. In our set, we found statistically significant variations in the metal health and social health and environmental domains once the set was divided along the faculty, and year-of-study lines, respectively. There are statistically significant differences between the individual sets. Conclusions: Based on a comparison with foreign research, we recommend a deeper investigation into this issue since the perception of the quality of life in secondary and tertiary students is a key factor in the development of society.

INTRODUCTION

Countries currently apply a variety of measures to prevent the spread of COVID 19. In the Czech Republic, the restrictions put in place were relatively tight and, more importantly, they were kept for a long time.

Zhang (2012) conducted a research on medical students in China. The Chinese medics' perception of the quality of life differed significantly in mental and social health. The lowest average score was found in third-year students in mental and social health. Clinical medicine students were found to have the most positive perceptions of the quality of life. The noted factors influencing perceptions of the quality of life included gender, interest in the field of study, hometown location and physical activity (Zhang, 2012).

Many authors have dealt with the impact of quality of life on mental health of individuals. Oztasan (2016) highlights the ties between a deteriorating mental health and low quality of life. Similar results were obtained by Walker (2016) and Moura (2016), who established a correlation between those variables (Moura, 2016; Oztasan, 2016; Walker, 2016;).

Pagin (2015) compared the quality of life as perceived by medical students and the general public. In his research, medical students showed worse mental well-being and social ties than members of the general public. The research demonstrated gender was a huge factor: female students rated the quality of their lives worse than their male counterparts, especially as regards the physical and mental component. This is supported by Walcott (2018), who points to the importance of physiological indices such as rest and sleep, which, according to his study, contribute to a higher quality of life (Pagin, 2015; Walcott, 2018).

The aim of the study is to assess the quality of life of students at a time of restrictions against COVID-19 disease. The World Health Organisation's WHOQL-BREF quality of life questionnaire was used as a research tool, a version of which has been translated into a number of languages and standardised in many countries (Serbia, Germany, China, the Netherlands, Turkey, Saudi Arabia, Argentina, Brazil, USA, Czech Republic, etc.). In the Czech Republic, several versions of the questionnaire have been created and standardised. In our research, we followed Rogalewicz's recommendation (2017) and used Dragomerická's translation of the questionnaire (Rogalewicz, 2017).

Paprštеinová, a researcher who studies the lifestyle of university students in the Czech Republic, chose the EHIS (European Health Interview Survey) questionnaire for her research. Non-medical health care students show significantly higher levels of physical activity than their colleagues from technical schools. Also, the group comprised of non-medical health care students was more active in the fitness department and showed optimal BMI values. As already well known, physical activity leads to a loss of fat reserves without causing a loss of muscle mass. Physical activity has a positive effect on metabolism and may negate risk factors in the development of cardiovascular diseases. No statistically relevant differences were observed for risky behaviour such as smoking and alcohol and drug use. Statistically, stronger social ties were reliably demonstrated with respect to non-medical health care students compared to technical students (Fox, 2007; Paprštеinová, 2018).

MATERIALS AND METHODS

Participants

The set consists of year one to five students from three schools of Charles University: Faculty of Science (FoS), Faculty of Education (FoE) and Faculty of Physical Education and Sport (FoPES) and one faculty of the University of Life Sciences (UoLS) (Faculty of Economics and Management). This composition ensures set diversity. We published the questionnaire on various websites and social networks, so every student could participate in the research. Using this method, after correction, we eventually arrived at the set of n = 381. Participation in the survey was voluntary; each participant was presented with the Helsinki Declaration and had the opportunity to refuse to participate. The interviewees were guaranteed anonymity.

Table 1 shows the size and age of the set divided according to each of the criteria. As can be seen, when the set is divided along the faculty affiliation line, the resultant sets are not exactly identical in terms of their size. The Faculty of Education is the most represented and the Faculty of Physical Education and Sport is the least represented. A more suitable approach seems to be the one where the students are divided along the year-of-study lines. Here, the differences in group sizes are no longer so marked.

Table 1. Size and age of specific sub-sets

	Size	Age	Average	Deviation	Modus	Median	Variation range
Whole set	381		22.1	2.25	21	22	19–27
Gender							
Male	57		22.6	2.17	22	22	19–26
Female	324		21.95	1.9	20	22	19–27
Faculties							
FPES	25		22.24	1.7	21	22	19–27
FE	174		22.5	2.04	24	23	19–27
FS	141		21.55	1.67	21	21	19–27
FEM	41		21.4	2.13	20	20	19–26
Year of study							
Year 1	101		20.5	1.7	20	20	19–27
Year 2	84		21.5	1.77	21	21	20–27
Year 3	89		22.2	1.35	22	22	21–27
Year 4	66		23.3	1.002	23	23	22–26
Year 5	41		24.5	1.08	25	24	23–27

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Research tool

An abbreviated version of the WHOQL-BREF quality of life questionnaire was chosen as a research tool. Several translations of the questionnaire WHOQL–BREF and WHOQL 100 have

been presented in the Czech Republic; on the recommendation of Rogalewicz 2017 we used the one prepared by Dragomerická. This translation corresponds more closely to the Czech language.

The guidelines for completing the questionnaire stated that students should assess the current situation influenced by restrictions against the spread of COVID- 19.

The first two questions determine overall satisfaction with the quality of life and health, the rest of the questionnaire is divided into four domains: physical health, mental health, social health and environmental health. The answers are on a scale of 1-5. In the scoring manual, the scales are transformed into a net score.

Statistical analysis

We used the following descriptive and inferential statistics methodology for the purposes of a statistical data analysis. The quantities of central tendency and degree of variability were used to describe the set. As regards the inferential statistics methodology, we used correlation to determine the dependence between specific domains in the whole set. Cronbach's alpha and ANOVA were used in assessing the internal consistency of the set and evaluating the hypotheses. Before running the variance analysis itself, we used graphical methods to determine whether or not this represented the normal data distribution.

RESULTS

Table 2 shows the average scores per specific items for the entire set and individual groups. In this table, we will focus mainly on Q1 and Q2. They are stand-alone items assessing the overall quality of life and satisfaction with health. The other items were combined into domains according to the manual used to evaluate the questionnaire. The whole set perceives the overall quality of their lives as very good and the same applies to overall health. If the division along the school affiliation lines is followed, the Faculty of Physical Education and Sport students showed the highest level of satisfaction with their lives and their health conditions. The regular physical activity they undergo as part of their study may be a factor in this. If the set is divided along the year-of-study lines, the fifth-year students report the highest quality-of-life satisfaction levels across schools, while the second and third-year students are the most satisfied with their health. The final year students' satisfaction with the quality of their lives may be owing to the individual students gradually emerging as full-fledged members of society.

Table 2. Average scores for individual WHOQL-BREF items

	Item	All	UoLS	FoPES	FoE	FoS	Year 1	Year 2	Year 3	Year 4	Year 5
Q1	Overall quality of life	3.9	3.8	4.1	3.9	3.8	3.9	4.0	3.8	3.8	4.2
Q2	Satisfaction with health	3.6	3.5	3.9	3.6	3.6	3.6	3.7	3.7	3.4	3.9
Q3	Pain and feelings of discomfort	4.1	3.8	4.5	4.1	4.1	4.2	4.2	4.1	4.0	4.3
Q4	Dependence on medical care	4.2	4.2	4.2	4.2	4.2	4.3	4.0	4.2	4.2	4.3
Q5	Joy of life	3.9	3.7	4.2	3.9	3.8	3.8	3.8	3.9	3.8	4.1
Q6	Meaning of life	3.8	3.4	4.4	4.0	3.6	3.7	3.8	3.7	3.9	4.2
Q7	Concentration	3.0	2.8	3.3	3.1	3.0	3.0	3.1	2.9	3.1	3.4
Q8	Personal safety	4.0	3.7	4.2	3.9	4.0	3.9	4.1	4.0	3.9	4.0
Q9	Environment	3.9	3.8	4.1	3.9	3.9	3.9	4.0	3.9	3.9	4.0
Q10	Vigour and fatigue	3.4	3.3	4.0	3.4	3.4	3.3	3.4	3.5	3.5	3.4
Q11	Acceptance of physical appearance	3.6	3.5	4.0	3.5	3.7	3.5	3.6	3.7	3.5	4.0
Q12	Financial situation	3.7	3.4	3.8	3.7	3.8	3.7	3.9	3.6	3.5	4.0
Q13	Access to information	4.3	4.0	4.4	4.4	4.4	4.2	4.5	4.3	4.3	4.5
Q14	Hobbies	3.3	3.2	3.3	3.3	3.3	3.2	3.4	3.2	3.0	3.5
Q15	Agility	4.2	4.1	4.4	4.2	4.1	4.2	4.2	4.2	3.9	4.4
Q16	Sleep	3.6	3.7	3.9	3.6	3.6	3.6	3.6	3.5	3.6	3.9
Q17	Everyday activities	4.0	3.4	3.8	3.4	3.3	3.4	3.4	3.4	3.3	3.5
Q18	Work performance	3.4	3.6	3.8	3.5	3.2	3.4	3.5	3.3	3.4	3.6
Q19	Self-satisfaction	3.3	3.1	3.5	3.4	3.2	3.2	3.3	3.3	3.4	3.4
Q20	Personal relationships	3.6	3.6	4.1	3.6	3.5	3.6	3.7	3.8	3.4	3.4
Q21	Sexual life	3.4	3.5	4.0	3.3	3.4	3.3	3.4	3.6	3.2	3.2
Q22	Support of friends	4.2	4.3	4.5	4.0	4.0	4.1	4.1	3.9	3.9	4.1
Q23	Environment at the place of residence	3.9	3.9	4.1	3.9	3.8	3.8	2.9	3.9	4.0	4.0
Q24	Availability of health care	4.1	4.1	4.3	4.1	4.2	4.0	4.2	4.1	3.9	4.6
Q25	Transport	3.7	3.8	3.9	3.7	3.7	3.6	3.8	3.7	3.6	4.1
Q26	Negative feelings	3.3	3.4	2.9	3.3	3.4	3.3	3.5	3.2	3.3	3.4

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Table 3 shows correlations between results per domains for the full set. As can be seen, environmental health correlates most strongly with mental health; the second strongest dependence was observed between environmental health and overall satisfaction, and the third strongest link was identified between overall satisfaction and mental health. As part of the evaluation of the set, we also determined internal consistency using the Cronbach's alpha coefficient (0.763).

Table 3. Correlation between results in specific domains for the full set

	Overall satisfaction	Overall health	Physical health	Mental health	Social health	Environmental health
Overall satisfaction						
Overall health	0.5267					
Physical health	0.3293	0.2968				
Mental health	0.5683	0.4774	0.3994			
Social health	0.4574	0.4508	0.3377	0.5533		
Environmental health	0.5748	0.4986	0.4931	0.6298	0.5410	

Table 4 shows the results for individual domains. To provide a clearer picture, we present the individual results in Charts 1 and 2. Chart 1 shows the results per domains for the set divided along the faculty lines. Chart 2 shows the results for the set divided along the year-of-study lines. The lowest and highest average values were found for physical health and environmental health, respectively; this applies to both our sets. The trends were very similar here. Dissatisfaction with physical health may be related to neglected exercise during the last year due to the restrictions put in place to curb the spread of COVID 19.

For the purposes of inferential statistics, we used the variance analysis calculation. Based on the boxplot evaluation, we can state that the data in each of the domains showed normal distribution.

Table 4. Results per domains

	Physical health		Mental health		Social health		Environmental health	
	Average	**Deviation**	**Average**	**Deviation**	**Average**	**Deviation**	**Average**	**Deviation**
All Faculties	13.17	1.65	13.98	2.33	13.72	3.88	15.63	2.47
FoE	13.11	1.67	14.16	2.21	13.67	3.74	15.57	2.5
FoS	13.16	1.69	13.65	1.44	13.54	4.01	15.72	2.36
FoPES	13.36	1.52	15.2	2.00	15.48	3.85	16.44	2.71
FEM	13.32	1.43	13.54	2.32	13.48	3.74	15.08	2.36
Year of study								
Year 1	13.15	1.65	14.04	2.56	13.43	4.04	15.31	2.64
Year 2	13.34	1.56	13.82	2.15	13.86	3.07	15.98	2.29
Year 3	12.97	1.74	13.85	2.31	14.37	3.68	15.51	2.41
Year 4	12.93	1.60	14.01	2.09	13.27	3.65	15.31	2.29
Year 5	13.63	1.54	14.36	2.43	13.48	4.35	16.51	2.44

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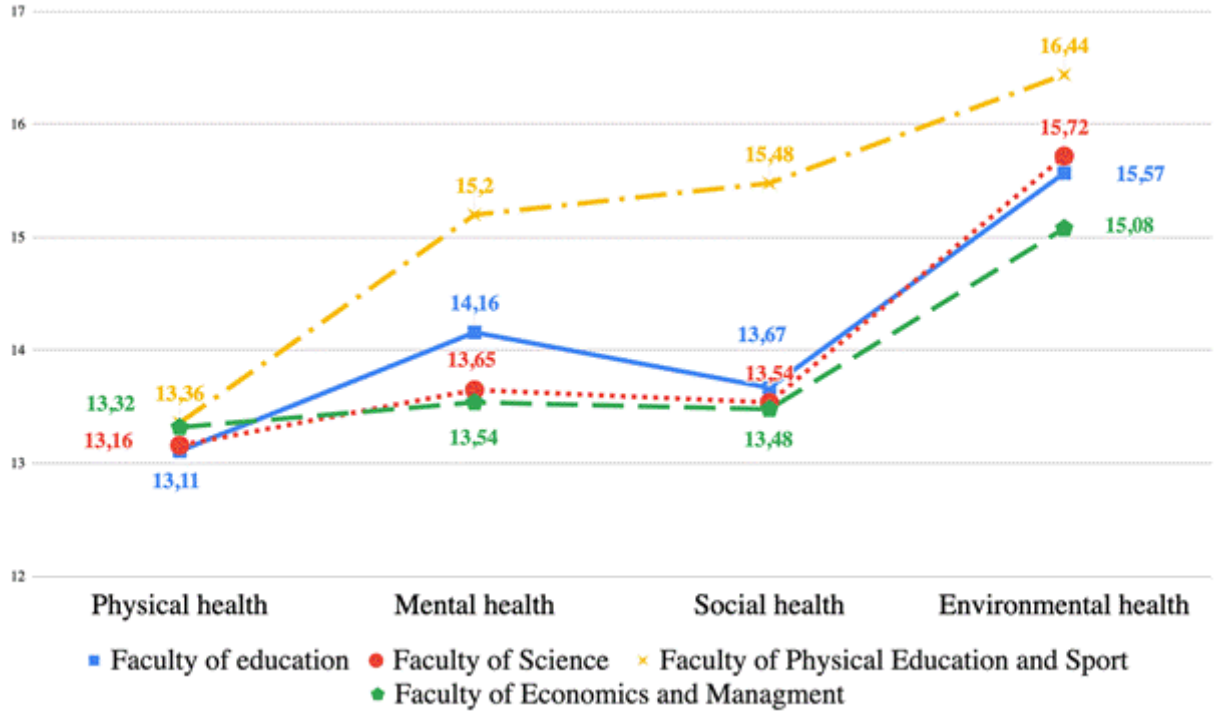

Figure. 1 Results per domain for the set divided along the faculty lines

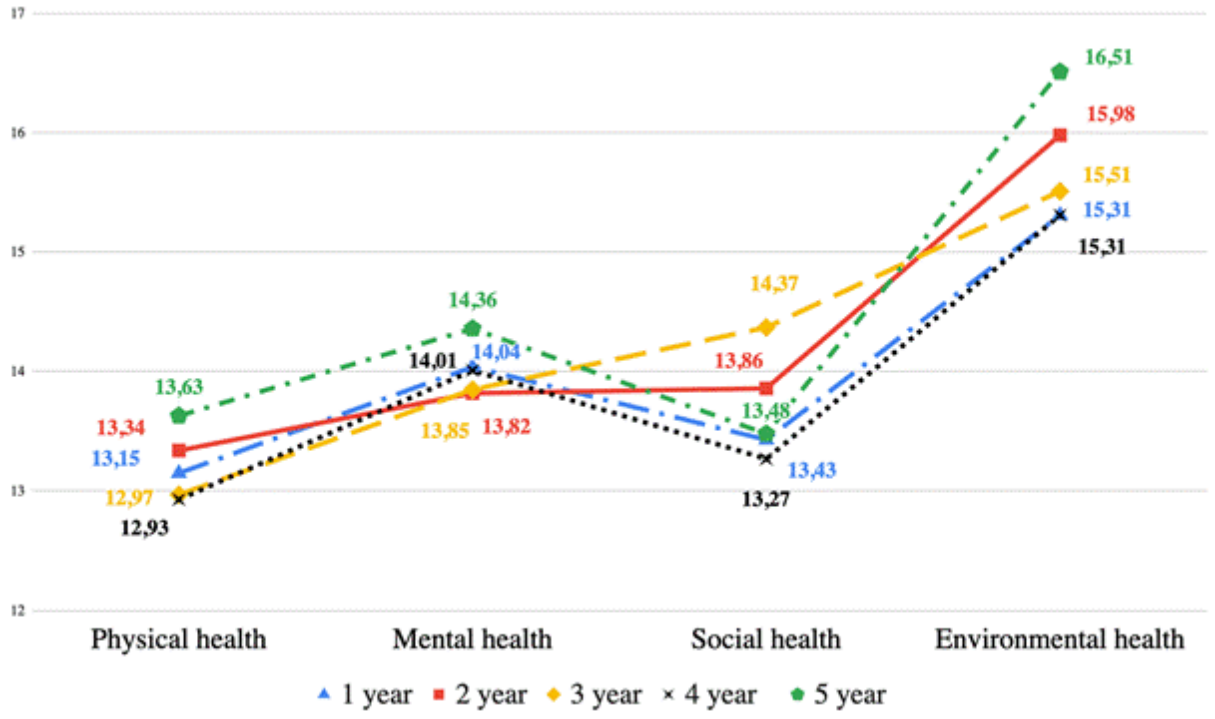

Figure 2. Results per domain for the set divided along the year-of-study lines

For ANOVA results, see Table 5. We compared the calculated values with the table values. There was no difference between the sets in the null hypothesis. If the value we calculated was higher than the table value, the null hypothesis was rejected and, therefore, a statistically significant variance existed.

Table 5. ANOVA results per domains and sub-sets

Set	Table value	Physical health	Mental health	Social health	Environmental health
Faculties	2.6285	0.4063	**4.4202**	1.9538	0.8249
Year of study	2.3956	0.4682	0.4273	**2.4554**	**3.8639**

We found a statistically significant relationship between the schools in the mental health domain and also in the set divided along the year-of-study lines in the social health and environmental health domains.

DISCUSSION

There are many variables affecting perceptions of quality of life. Family, parents' level of education, demographic indicators and, last but not least, a student's affiliation with the faculty or study programme. We have not investigated these changes as part of our research.

Overall quality of life, the average score of the whole set was 3.9, which is a very good result. After the set was divided, the Faculty of Physical Education and Sport students and second- and third-year students emerged as most satisfied with the overall quality of their lives and the overall quality of their health. Similarly to dental medicine students in Turkey, in this study, it concerned the fourth-year students who were most satisfied with the overall quality of their lives (Burdurlu, 2020). Montenegro students also show a similar perception of the quality of life; according to Jovanovic (2016) most students are satisfied with the quality of their lives and they also look with optimism into the future (Jovanovic, 2016). On the contrary, different results were found with respect to medical students in Saudi Arabia. The students identified unhealthy lifestyles, mental distress, and academic failure as the sources of their dissatisfaction (Malibary, 2019). According to Quang research, students in South Vietnam identified as factors affecting health gender, academic year, ethnicity, frequency of physical activity, financial expenses, scope of Internet use, length of sleep, use of sleeping pills, frequency of social activities, and stimulants' use (Quang, 2020).

Alboliteeh (2020) highlights the relationship between responsibilities and satisfaction with the quality of life. He works with the Grade Point Average (GPA), based on which students in the United States are admitted to schools and apply for scholarships. However, no evidence was found for a link between GPA and views of the quality of life. However, it was shown that students who have no other but study-related responsibilities at home are more likely to be satisfied with the quality of their lives (Alboliteeh, 2020).

Also, our research highlights a statistically significant difference between the schools as regards mental health, and also between the years of study when it comes to social health and environmental

health. Al- Shibani (2019) and Malibars (2019) point to the environmental component of health. With the sets divided along school affiliation and year-of-study lines, the lowest and the highest average scores were reported for physical activity and environmental health. This is similar to the results recorded for dental medicine students in Saudi Arabia, who showed the highest levels of satisfaction in environmental health, while in social and physical health, the results were poor. It was established that students with better grades scored lower averages in mental health (Al-Shibani, 2019, Malibary, 2019).

CONCLUSION

At a time affected by the COVID- 19 pandemic, there are many changes taking place in society that will influence the assessment of quality of life. The aim of our investigation was to assess the quality of life of students at a time of restrictions against COVID-19 disease. As there are not many research investigations on this topic so far, we have to wait for a direct comparison of similar groups. The results indicate that students rate quality of life positively, which is not significantly out of line with pre-pandemic COVID- 19 studies compared.

We believe it is important to monitor perceptions of quality of life with respect to secondary and university students for several reasons. Based on the discovered links between quality of life and its factors, we can adjust the factors and thus potentially allow future generations to view their quality of life more positively and increase their contribution to society. It is also important to monitor the quality of life currently due to the effects of the COVID-19 pandemic so that we can avoid any negative consequences.

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Impact of cancer and 12 weeks of chemotherapy on the balance of the autonomic nervous system in cancer patients

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ABSTRACT

Cancer and its treatment itself (especially chemotherapy) is associated with number of negative effects on the human body. These include mainly cardiac toxicity, peripheral neuropathy, bone loss, depression, anxiety, nausea, pain, cognitive changes, fatigue, fitness reduction and more. Fatigue is one of the most common negative effects, often persists long after treatment and is described as insurmountable and is associated with lower parasympathetic activity. The autonomic nervous system (ANS) is the main homeostatic regulatory system of the body, it regulates involuntary physiological processes. We believe that this part of the peripheral nervous system can be negatively affected by cancer and chemotherapy, which can have a negative impact on all the processes that control this system. Most drugs used in oncology lead to chemotherapy-induced peripheral neuropathy and are expected to have an influence on the autonomic nervous system. Activity and balance of the autonomic nervous system depend on a range of dynamically changing and quantitatively different conditions such as age, stress, physical activity, sleep, illness, fatigue and more. Methods: To evaluate ANS activity, spectral analysis of heart rate variability (HRV) was assessed. During treatment, 19 oncological patients with prescribed adjuvant chemotherapy measured HRV 3 times a week using a chest strap with a HRV monitor mySASY and mySASY software. Parasympathetic activity (PA), sympathetic activity (S), total score (TS) and total power (TP) were selected as indicators of ANS activity. The patients were women aged 50.38 ± 10,29 with BMI 25,72 ± 4,16. The mean values for the first 14 days of treatment and then for 14 days after 12 weeks of treatment were compared. Data normality was verified by Kolmogorov-Smirnov test (K-S) and static significance was calculated by t-test. All statistical tests were performed at a significance level of 5%. Results: There was a significant decrease in values for three parameters. The PA decreased from 3,80 ± 1,56 to 3,14 ± 1,67 (p = .03), TP decreased from 3,65 ± 1,87 to 2,82 ± 2,08 (p = .04), TS decreased from 3,40 ± 1,67 to 2,67 ± 1,73 (p = .01).

Sympathetic activity was somewhat but not significantly higher, increased from 6,74 ± 1,22 to 6,80 ± 1,44 (p = .83). Conclusion: During the 12 weeks of treatment with adjuvant chemotherapy, there was a significant reduction in parasympathetic activity, total score, and total power. A decrease in PA is usually associated with lower regenerative abilities of the organism, a decrease in TP is associated with a decrease in the activity of the entire ANS. TS evaluates the total power and balance of both ANS branches. The higher the values, the more the body is regenerated and ready for further stress and response to stress.

Keywords: heart rate variability, oncology, neoplasm, tumors

INTRODUCTION

Cancer is a non-communicable disease and is one of the leading causes of death worldwide. There were almost 20 million new cases per year and almost 10 million deaths in 2020 (Ferlay et al., 2020). The most common types of oncological diagnoses are breast, lung, colon and rectal, prostate, skin and stomach cancer (WHO, 2022). Emphasis on primary prevention (early screening) and improvement in the treatment protocols of oncological diseases meant a significant increase in the number of survivors for some types of cancer (Rock et al., 2022). The overall 5-year relative survival rate for all cancers combined in America is now 68 % according to Siegel et al. (2022), although there is noticeable variability across types of cancer.

Cancer and its treatment itself (especially chemotherapy) is associated with number of negative effects on the human body. Chemotherapy side effects and cancer can affect the daily activities of cancer patients and their families on many levels, faced with changes in health status and lifestyle, leading to impaired self-care effectiveness. The most common side effects include cardiac toxicity, peripheral neuropathy, bone loss, depression, anxiety, nausea, pain, cognitive changes, fitness reduction and especially fatigue (Islam et al., 2019; Pearce et al., 2017).

Cancer related fatigue (CRF) is the most common side effect. CFR differs from other types of fatigue in its persistence and severity, often described by patients as unbearable and insurmountable. CRF restricts patients and survivors in daily life (return to work, family life, return to sports and physical activity) and significantly reduces quality of life (Agbejule et al., 2021). According to Fabi et al. (2020) 65% of all patients suffer from CRF, two-thirds of them still suffer from fatigue 6 months after treatment, and almost one-third report fatigue even several years after treatment. The highest incidence is observed in patients who undergo chemotherapy as part of the treatment process (80-90%). The etiology of CFR is not yet precisely described and defined; it is probably a multifactorial process. The influence of the type of tumor, the stage of the disease and the chosen treatment is assumed. In recent years, the influence of inflammation has mainly been investigated. The dependence between the level of inflammatory markers, especially cytokines (IL-1 (interleukin), IL-6, TNFα (tumor necrosis factor alfa)) and the occurrence of CRF is widely investigated (Berger et al., 2015; Bower, 2014). CRF is further associated with autonomic nervous system (ANS) dysregulation. Preliminary data point to the fact that CRF could be associated with

lower heart rate variability, specifically with reduced parasympathetic activity(Crosswell et al., 2014; Fagundes et al., 2011; Simó et al., 2018).

The ANS is considered a key system for maintaining homeostasis, its main function is the regulation of the internal environment, ensuring the proper functioning of internal organs, innervation of smooth muscle, blood vessels and glands, and it also affects the activity of the myocardium. Furthermore, the ANS is considered important in regulating the function of the immune system (reciprocal regulation of both systems). This is a very complex process, but in general, higher sympathetic activity is associated with an increase in inflammation and activity of the parasympathetic branch of the ANS with a decrease in inflammation (Crosswell et al., 2014; Irwin & Cole, 2011). Activity and balance of the autonomic nervous system depend on a range of dynamically changing and quantitatively different conditions such as age, stress, physical activity, sleep, illness, fatigue and more. Cancer and chemotherapy have a negative effect on the function of the peripheral nervous system. Most drugs used in chemotherapy cause peripheral neuropathy as a side effect. It can therefore be assumed that these drugs will have a negative effect on the entire peripheral nervous system, which includes the ANS(Adams et al., 2015; Crosswell et al., 2014).

The aim of this work was to evaluate what changes occur at the level of ANS activity during the treatment of an oncological disease and how significant these changes are. The basic premise was the negative effect of cancer and the side effects of its treatment on the human organism. Another goal was to find objective indicators of these changes. These indicators can then be used for further research as monitored parameters for evaluating the effect of various interventions.

METHODS

Participants

The research included 19 participants; the recruitment of participants began in September 2021. All patients were treated at the Masaryk Memorial Cancer Institute. All participants were women with breast cancer aged 50.38 ± 10,29 with BMI 25,72 ± 4,16. Inclusion criteria were set as follows: histologically confirmed diagnosis of malignant tumor with indicated adjuvant chemotherapy based on platinum compounds, taxanes or vinca alkaloids (1), Easter Cooperative Group performance status 0, 1 or 2 (2), the ability to walk 400m without sitting or the help of another person (3) and an estimated survival time of at least 9 months (4). Exclusion criteria were set as follows: inability to perform physical activity (1), terminal stage of an oncological or other disease (2), untreated disease of the lungs, joints or cardiovascular system (3), acute or chronic disease of the immune system or other disease that directly affects this system (e.g. Lupus erythematodes, rheumatoid arthritis, immunosuppressive treatment) (4), pregnancy or breastfeeding (5), current treatment with beta-blockers (6).

Measurement – heart rate variability

HRV spectral analysis was used to assess ANS activity. A chest strap with a mySASY monitor and mySASY software was used to measure HRV. When entering the project, the process of measuring and using the strap and application was explained to each participant. Measurements took place in

home conditions 3 times a week; 2x during the working week and 1x on the weekend. Participants were educated to measure themselves in the morning after waking up, without distracting elements (such as talking to someone, watching TV). The measurement itself takes place in the form of an orthostatic test. The first phase takes place lying down, when the monitor reads 120 heartbeats, the next phase is standing, when the monitor reads 360 heartbeats, and the last phase is lying down again and the monitor reads 360 heartbeats again. Parasympathetic Activity (PA), Sympathetic Activity (S), Total Score (TS) and Total Power (TP) were selected as indicators of ANS activity and balance.

Statistical analysis

The basic hypothesis was that chemotherapy has a negative effect on the activity and balance of the ANS. Basic parameters - PA, S, TS and TP were selected from HRV measurements. For evaluation mean values (M) and standard deviations (SD) were calculated for the first 14 days of measurement and subsequently for 14 days after 12 weeks of chemotherapy. The normality of the data was assessed according to the Kolmogorov-Smirnov test (K-S test), which confirmed that the data came from a normal distribution. All statistical tests were performed at the 5% significance level. Statistical significance for individual parameters was tested using a t-test.

Results

Table 1 shows mean values and standard deviations for key parameters in study. The values for the 1st period (the first 14 days of measurement) and for the second period (14 days after 12 weeks of chemotherapy) are shown here. For S there was a slight increase in the value from 6.746 ± 1.223 to 6.804 ± 1.444. However, the increase was not statistically significant (p = .838). There was a statistically significant decrease in values for other three parameters. The PA decreased from 3.804 ± 1.563 to 3.139 ± 1.674 (p = .032), TP decreased from 3.653 ± 1.872 to 2.824 ± 2.088 (p = .045), TS decreased from 3.402 ± 1.669 to 2.675 ± 1.731 (p = .012).

Table 1: Means of key study variables for first and second period of measurment

Variable	1st period (n=19) (M ± SD)	2nd period (n=19) (M ± SD)	*p* value[a]
Symphatetic Activity	6.746 ± 1.223	6.804 ± 1.444	.838
Parasymphatetic Activity	3.804 ± 1.563	3.139 ± 1.674	.032*
Total Power	3.653 ± 1.872	2.824 ± 2.088	.045*
Total Score	3.402 ± 1.669	2.675 ± 1.731	.012*

a comparison between periods was tested with t-test

* $p < 0,05$

M mean value

SD standard deviation

DISCUSSION

Data from previous research assume a negative effect of chemotherapy on the balance of the autonomic nervous system(Adams et al., 2015; Crosswell et al., 2014). Cakan et al. (2022) proved in

their study that chemotherapy has a negative effect on HRV in children with cancer, but according to their results, it seems that this change is not permanent or long-lasting in children. Parasympathetic activity (vagal activity) is most often investigated. According to the mySASY manual, the value of parasympathetic activity can range from -5 to 5. The higher the value of parasympathetic activity, the better the organism is regenerated and capable of handling further stress. According to the results, this value decreased from 3.804 ± 1.563 to 3.139 ± 1.674 due to ongoing chemotherapy. In oncology patients, a lower value is associated with a higher risk of cardiovascular complications and higher cardiovascular mortality(Caro-Morán et al., 2016; Vanderlei et al., 2009). Some drugs used for chemotherapy (anthracyclines, cisplatin, taxanes) are expected to have a negative effect on autonomic cardiac regulation. However, it is not yet completely clear whether this is a direct toxic effect on the cells or a negative effect via the vagus nerve (Adams et al., 2015; Simó et al., 2018). Conversely, higher vagal activity is associated with a longer estimated survival time (Zhou et al., 2016). Therefore, a number of studies are devoted to investigating different types of interventions for cancer patients and survivors. Controlled physical activity, mindfulness-based interventions and breathing exercises appear to be effective and have a positive effect on parasympathetic activity (Laborde et al., 2022; Lavín-Pérez et al., 2021; Niederer et al., 2013; Wang et al., 2022).

Sympathetic activity can take on the same values as parasympathetic activity, but here, on the contrary, the lower the value, the better the organism is able to withstand stress (greater system capacity). According to the results, there was an increase in sympathetic values from 6,746 ± 1,223 to 6,804 ± 1,444, but the increase was not statistically significant. In general, sympathetic activity increases when the organism is exposed to a stressor. Stress, which is undoubtedly associated with oncological diagnosis and treatment, leads to an influence on the hypothalamus, the main autoregulatory center, the release of adenocorticotropic hormone and subsequently cortisol, which results in an increase in sympathetic activity and its effect on the regulation of inflammation (Cooper et al., 2015). Total power is a parameter that points to the overall performance of the ANS, it does not differentiate the activity into individual branches. TP can also take values from -5 to 5. The lower the TP value, the lower the activity of the entire system. In the study, TP decreased from 3,653 ± 1,872 to 2,824 ± 2,088 during chemotherapy. Low HRV is associated with shorter survival time in cancer patients (Zhou et al., 2016). Lower HRV is also more common in advanced stages of cancer (De Couck & Gidron, 2013). TS is a complex indicator that, in addition to overall performance, also includes the balance between the branches of the ANS (vagal activity and sympathetic activity). The higher the value, the better the regeneration and the ability to deal with stress. TS decreased from 3.402 ± 1.669 to 2.675 ± 1.731, in terms of statistical significance, this was the largest change of all parameters.

HRV is a very variable indicator that can be influenced easily. Therefore, in the study, it was chosen to use the average of 14 days of measurement to eliminate distortion of the results as much as possible. HRV is influenced by age, stress, quality of sleep and general fatigue, alcohol intake, physical activity and by the state of health of the organism (acute and chronic diseases and their treatment). It was also important to inform participants about the correct measurement methodology and to tried to ensure that they are measured immediately in the morning. However, the measurement took place in home conditions, and it is therefore not possible to directly supervise each participant.

CONCLUSION

In conclusion, during the 12 weeks of ongoing chemotherapy, there were significant changes in HRV parameters. There was a decrease in PA, TS and TP in contrast to an increase in the value of sympathetic activity, which was, however, not statistically significant. For further research, it would be better to have more participants and a wider range of diagnoses. Only women with breast cancer participated in this research, although this was not limited by the inclusion criteria. It would also be interesting to find out whether the decrease in HRV is permanent or long-lasting even after the end of oncological treatment, or whether it will spontaneously return to the original values. Current knowledge shows us that the change is likely to be long-lasting and the goal is to find a suitable intervention for these patients that would help them return to normal family and working life. It is therefore important to choose the right intervention, so that it has a positive benefit not only for HRV values, but also for the overall health of the patient. Above all, the implementation of the given intervention in practice and its availability for patients are essential.

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Differences Between Traditional and Modern Technology In the Acquisition of New Ski Knowledge

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ABSTRACT

Purpose: Video materials have been used as teaching tools for many years. With the development of modern technology, new video devices have appeared that have greatly improved the quality and capabilities of video materials. This study was conducted with the purpose of investigating and comparing the current traditional and modern ways of recording ski elements. In the traditional way of recording, the cameraman stands on the ski slope and uses a camera to record a demonstration of the ski element of the skier moving toward him. On the other hand, the modern way of recording was made with the Gopro 360 max, which allows you to record video while skiing.

Methods: The sample of respondents who evaluated the quality of the traditional and the Gopro 360 max videos for three skiing elements consisted of 149 students (105 male and 44 female) from the Faculty of Kinesiology Osijek. Prior to the video quality assessment test, the performance of the ski elements was explained to the students using traditional and modern video footage. When solving the ski knowledge test, students had the opportunity to watch and use traditional and/or modern videos.

Results: The average score that students achieved on the ski knowledge test was 8.9 ± 2.48 points (74.16 ± 0.21%). When evaluating the quality and contribution of the videos, students rated the usefulness of the traditional method of video recording with an average score of 3.01 ± 1.25, while the modern method of video recording received an average usefulness score of 3.79 ± 1.07. The difference between the traditional and modern video recording was statistically significant at the $p < 0.01$ level.

Conclusion: The obtained results indicate that the way the Gopro360 max records and presents the skiing elements contributes significantly to the quality of the presentation and the acquisition of specific skiing knowledge compared to the traditional recording method.

Keywords: Gopro360 max, ski elements, knowledge test

INTRODUCTION

Skiing is a motor activity in which skiers use a wide range of skiing techniques to successfully overcome various snow slopes (Danijela Kuna et al., 2020). Vanat (2020) estimates that approximately 400 million people (skier visits) visit ski resorts annually. Due to the great popularity of recreational and professional skiing, several authors have studied the health benefits of alpine skiing. Burtscher et al. (2019) found that skiing, especially when practiced daily, can contribute to healthy aging, which is associated with a healthier lifestyle that includes higher levels of physical activity. Recreational alpine skiing promotes strength gains (Finkenzeller et al., 2011; Pötzelsberger et al., 2015) reduces cardiovascular risk factors (Burtscher et al., 2013; Dela et al., 2011) and has a positive effect on the overall locomotor system (Mladenović et al., 2015; Narici et al., 2011; Wojtyczek et al., 2014).

In addition to these benefits, alpine skiing can also lead to musculoskeletal injuries, especially in novice skiers who are three times more likely to be injured (AOSSM, 2008). Stenroos and Handolin (2015) in their longitudinal study found that in the largest Finnish ski resort in 6 years there were 1991 injuries, most of which were lower extremities (42%), subsequently upper extremities (34%), head (15%) and spine (6%). Due to the high incidence of injuries among novice skiers, great attention should be paid to learning skiing techniques.

For successful and high quality teaching of ski school students, a ski teacher must have a wide range of motor skills, ski knowledge, methodological and didactic principles of work, and basic psychological approaches to work with people (D Kuna et al., 2018). In addition to the above, a ski teacher must be a good diagnostician and programmer or know how to recognize the mistakes that occur in skiers who adopt and improve their skiing skills and apply appropriate exercises to eliminate them. Of all sensory modalities, visual perception and memory are one of the most important segments in acquisition of new motor information (Gallace & Spence, 2009). This occurs as a consequence of the totality of information that a person incorporates and stores, the most significant percentage receives it through the senses of sight (Hutmacher, 2019).

Video materials have been used as a teaching aid for many years (Hartman, 2007; Ste-Marie et al., 2016). The use of video material in the teaching process enables monitoring, assessment, and correction of motor performances (Kok & van der Kamp, 2018).

While teaching alpine skiers, the visual and audiovisual content of the demonstration of skiing elements can significantly enhance and facilitate the teaching process. The use of video technology is an integral part of the organized field skiing teaching program for kinesiology students, courses for teachers and demonstrators of skiing, and is often used in ski school programs.

Videos of ski performances can facilitate and speed up the process of teaching and improving specific ski skills by enabling skiers to visually present their performances, and with analysis by expert skiers to obtain accurate feedback on structural analysis of performance and correction of characteristic errors.

The traditional way of filming that is most often used in the process of teaching and improving skiing skills, is the 2D display, which characterizes the shooting of skiers moving toward the cameraman standing on the ski slope, while the 3D display using the GoPro 360 max device depicts

skiers in motion and 360 °. Several papers have used this type of medium in their work (Musculus et al., 2021; Yoganathan et al., 2018). Most works utilizing this type of recording use the collected video materials to form virtual reality. It is believed that the use of video technology contributes to the learning of skiing and that the new way of presenting video materials can have a significantly greater impact. No paper yet has studied contribution of new possibilities of video technology in order to help in learning theoretical knowledge related to the structural analysis of ski elements.

The primary goal of this research is to examine the differences between the contributions of the traditional and modern video presentation of skiing elements during their adoption.

METHODOLOGY

Examinees samples

A total of 149 students from the Faculty of Kinesiology in Osijek participated in the research, of which 105 were male and 44 were female, with an average age of 20.5 years. The criteria for inclusion of examinees in the research was that students did not attend skiing classes organized as part of classes at the Faculty of Kinesiology Osijek. Examinees were informed about the reason for conducting the research, which was anonymous, and before accessing it, they gave their voluntary consent to participate. The research was conducted by the current Helsinki Declaration.

Measuring instruments

Two video devices were used in this study. To collect video material in traditional way, a Panasonic LUMIX FZ1000 camera was used. The resolution for traditionally recording video material was 1920 x1080 pixels with 50 frames per second. GoPro 360 max was used to collect video material in a modern way. The recording resolution was set at 3840 x 2160 pixels with 50 frames per second and the camera was placed on a stick when collecting video material.

Sample variables

The sample of variables in this research encompassed the points obtained by the exam and the subjective assessment of the examinees about the usefulness of different ways of video material in the acquisition of ski knowledge. The exam consisted of questions on the structural analysis of the performance of the snow plow turn, the snow plow bow, and the uphill turn. Questions about structural analysis were formed from a part of the written exam that is conducted as part of Skiing which is one of the Mandatory courses on Faculty of Kinesiology in Osijek. All questions were conducted by lecturer in charge of Skiing class who has extensive work experience in the field of testing theoretical and practical skiing knowledge All three skiing elements belong to the group of basic skiing elements and are an integral part of field ski teaching. Example of one question of exam is presented in figure 1.

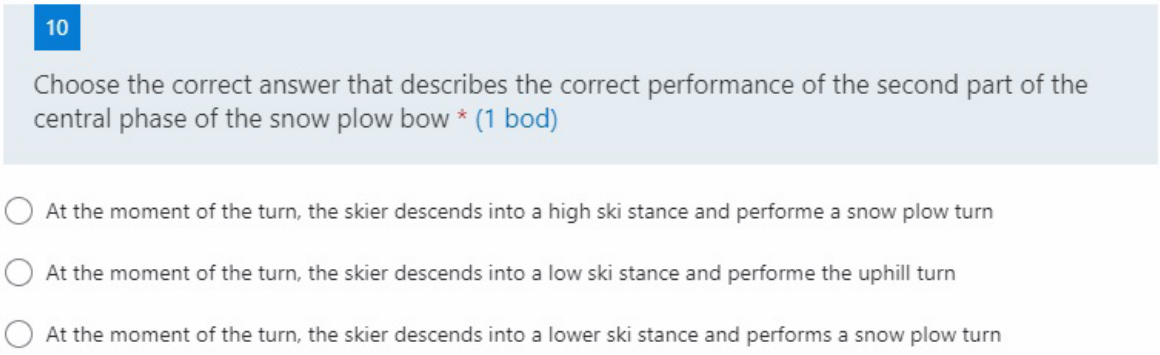

Figure 1. Example of one question about structural analysis

Procedure

In the same snow conditions and on the same ski slopes, performance demonstrations were taken for all three skiing elements in a traditional and modern way. The demonstration of skiing elements was performed by an experienced demonstrator and ski teacher with many years of skiing experience. The traditional way of filming was performed in a way that an experienced cameraman stood in the middle of the ski slope and filmed a demonstrator who performed one skiing element at a time. After filming with Panasonic LUMIX FZ1000 video camera was done, demonstrator took GoPro 360 max and recorded same ski elements. The modern way of filming was performed in a way that the demonstrator held a stick with a GoPro 360 max camera on it while performing the skiing elements. The main difference between these two filming modes is that in the traditional filming mode the demonstrator moved towards the static camera, while in the modern filming mode the camera moved together with the demonstrator.

Tibco Statistica Enterprise (version 14.0.0.15) was used for video editing. After recording, all videos were transferred to the Lenovo IdeaPad L340 (Intel Core i5 9300H processor, 8 GB RAM, and 1920x1080 screen resolution). A Philips 345E2AE/00 external monitor with a resolution of 3400x1440 was used for this research. Video footage recorded with GoPro 360 max was edited in GoPro player which is the official program for editing video footage collected with this camera. After determining the desired part of the video and after processing it, the video materials were exported in MP4 format. The video materials of each element were processed in a way in which they have the same number of turns (4) and duration (15). The uphill turn was the only ski element which was consisted of 1 turn.

Following editing of the video materials, a detailed test to assess the acquisition of ski knowledge with video materials, and through four phases of structural description for all three skiing elements, was entered into the MS teams web form. Students received an invitation by e-mail to participate in the research and were arranged in groups and asked to come and bring their PCs. Each group received an email with a link to access the exam, followed orally by brief instructions for solving the test. At the beginning of the exam, students listened to 10-minute recorded lecture consisting of an audio and visual part with a presentation and description of the structural analysis of skiing elements. The mentioned lecture included a presentation that described the structural analysis of

skiing elements, an auditory explanation, and two videos (one traditionally recorded and the other in a modern way). Afterward, an exam of 12 questions (4 questions per skiing element) followed. When solving the exam, students had the opportunity to use available video materials. Students had 30 minutes to solve questions related to the structural analysis of ski elements with the help of all video materials. After completing the exam, students assessed the usefulness of video material, the difficulty of the exam, the level of their concentration when solving the exam, and the usefulness of video material in the education of beginner skiers.

Data processing

The Shapiro-Wilk W test found that the distribution was not in line with the normal distribution, which is why non-parametric statistics were used to process the data. Basic descriptive parameters: arithmetic mean (M), standard deviation (SD), minimum (Min), and maximum (Max), for each skiing element with the corresponding number of points obtained by the exam, the subjective assessment of, the importance of video material in education and level concentrations while solving the exams of all examinees together and by gender, are shown in Table 1 in percentage values. The scores of the difficulty of the exam ranged from 1 (the exam was very difficult) to 5 (the exam was very easy). Ratings of the importance of the usage of video material in the education of basic skiing elements ranged from 1 (I think that the use of video material is not important in education) to 5 (I think that the use of video material is very important in education). Examinees rated their concentration during the exam with a score of 0 if they could not concentrate at all when solving the exam, to a score of 3 if they could concentrate when solving the exam. The Mann Whitney U test was used to determine gender differences, while the Wilcoxon matched-pairs test was used to identify differences between modern and traditional video collection methods. The statistical significance level was set at $p<0.05$.

RESULTS & DISCUSSION

The vast majority of students, after a short presentation and with the use of video material, achieved a passing score on the exam. These results indicate that the combination of a recorded lecture with the possibility of using video materials was a great help in learning the necessary theoretical knowledge about structural analysis of ski elements. The highest percentage of correct answers was related to the skiing element the uphill turn, while the lowest correct answers were related to the skiing element the snow plow bow. Students were mostly able to maintain concentration while tackling exams they considered to be of medium difficulty. All students find the use of video material useful in teaching basic skiing elements. Most students find videos extremely important for teaching. There was no statistically significant difference between the sexes and the points scored on the exam, the points scored for each skiing element, the difficulty of the exam, the concentration, or the video importance in the skier's instruction.

Table 1. Basic descriptive parameters for all subjects

Variable	All together		Male		Female		p
	N	M ± SD Min–Max	N	M ± SD Min–Max	N	M ± SD Min–Max	
Exam	149	74,16 ± 20,66 16,67–100,00	104	72,94 ± 21,77 16,67–100,00	44	77,08 ± 17,62 25,00–100,00	0,41
Points	149	8,90 ± 2,48 2,00–12,00	104	8,75 ± 2,61 2,00–12,00	44	9,25 ± 2,11 3,00–12,00	0,41
Snow plow turn	149	75,67 ± 26,31 25,00–100,00	104	75,48 ± 26,40 25,00–100,00	44	76,14 ± 26,39 25,00–100,00	0,59
Snow plow bow	149	75,00 ± 27,11 0,00–100,00	104	75,48 ± 27,73 0,00–100,00	44	73,86 ± 25,83 25,00–100,00	0,60
Uphill turn	149	81,04 ± 24,08 0,00–100,00	104	78,81 ± 25,19 0,00–100,00	44	86,36 ± 20,50 25,00–100,00	0,10
Exam difficulty	149	3,21 ± 0,95 1,00–5,00	104	3,22 ± 0,99 1,00–5,00	44	3,18 ± 0,87 1,00–5,00	0,35
Level of concentrations	149	2,10 ± 1,08 0,00–3,00	104	2,15 ± 1,06 0,00–3,00	44	1,98 ± 1,11 0,00–3,00	0,75
The importance of video material	149	4,54 ± 0,72 2,00–5,00	104	4,50 ± 0,77 2,00–5,00	44	4,61 ± 0,58 3,00–5,00	0,88

In comparison with the traditional and modern ways of filming, the students found modern filming more useful when acquiring ski knowledge (p = 0.00). Figure 2 graphically shows the difference between the subjective assessment of the usefulness of traditional and modern methods of recording in the coaching of skiers.

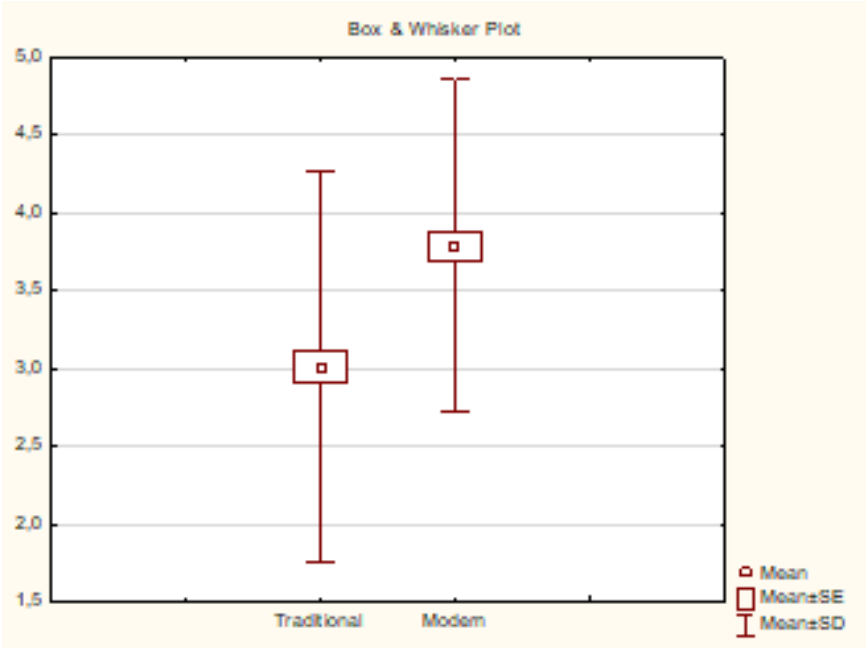

Figure 2. Differences between subjective assessment of the importance of video material in education

A greater benefit of the modern method of recording was found in both male (p = 0.00) and female (p = 0.00) examinees. The statistical significance of the subjective assessment of the usefulness of the traditional (p = 0.38) and modern (p = 0.59) recording video material between male and female examinees was not determined.

The results of this paper indicate that students who did not attend skiing classes and therefore have no notion about skiing and skiing elements, or previous ski knowledge, consider video materials extremely useful for instructing basic skiing elements. The high pass rate on the exam indicates a great contribution to the teaching of skiing elements, and that such a way of transferring knowledge can be great for learning structural analysis of skiing elements. Compared to the traditional and modern way of collecting video material, the modern one proved to be superior. When taking the exam, the students used more video materials recorded with a GoPro 360 camera, and they considered this way of collecting video material to be superior to the traditional one. Gender differences did not exist in any of the observed variables indicating that it was easier for all examinees to perceive the technical segments of each element when the camera moved along with the demonstrator compared to the traditional way in which the demonstrator moved toward a static camera.

This way of theoretical teaching basic skiing elements has proven to be extremely successful, which can result in better quality adoption of basic skiing elements on ski slopes. Combination of traditional way of teaching theoretical ski knowledge with this, modern way, can lead to better transfer of ski knowledge, shorter learning time and increase students' interest in skiing. Accordingly, a better level of adoption of skiing elements would reduce the risk of injuries that are more common in novice skiers (AOSSM, 2008).

CONCLUSION

This research provided innovative scientific knowledge related to the specifics of the education of basic ski knowledge. It has been established that the modern way of displaying basic skiing elements with the help of GoPro 360 ° video material facilitates the process of acquiring ski knowledge, which in the future can improve the entire teaching process of skiing. The obtained results of the study will be able to be practically applied in the programs of the ski school and the seminars for ski teachers and demonstrators. This research provides guidelines for the implementation of future experimental research studies in the training of alpine skiers to obtain the most accurate visual feedback on performance and correction of characteristic errors that occur during the training of alpine skiers.

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The Effect of Physical Activities on Somatic Parameters of the Selected Czech University Students – Some Selected Results

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ABSTRACT

Purpose: The current trend is an increasing sedentary lifestyle in all age categories. Among university students, there is an alarming decline in physical activity while increasing the percentage of total body fat compared to high school students. The main goal of the study is to describe the current state of body composition of university students and to assess the impact of physical activity / inactivity in this specific age group, which has changed very dynamically in recent years due to the coronavirus pandemic. Methods: A total of 358 probands with a mean age of 20.87 ± 1.43 years were involved in the research, of which 234 women (65.4 %) had a height of 167.9 ± 6.3 cm and a body weight of 61.3 ± 10.0 kg, BMI 21.7 ± 3.2, body fat 25.9 ± 6.4 %, skeletal muscle mass 24.7 ± 3.3 % and 124 men (34.6 %) with body height 180.9 ± 7.7 cm, body weight 77.6 ± 12.4 kg, BMI 23.6 ± 2.8, body fat 15.8 ± 5.4 %, skeletal muscle mass 37.0 ± 5.6 %. For the purposes of valid categorization into high active, minimally active, and inactive probands, the International Standardized Physical Activity Questionnaire (IPAQ) was used, which monitors physical activity in the last 7 days. The questionnaire includes questions regarding the frequency and time spent in each intensity of physical activity, as well as the time spent sitting. The non-invasive method of bioelectric tetrapolar impedance using the InBody 230 device was used for the analysis of somatic parameters. The Takei hand dynamometer was used for the diagnosis of muscle strength. Some selected results: According to IPAQ, probands were classified as inactive (16 %), minimally active (58 %) and high active (25 %), the analysis of selected aspects of physical activity shows that men are more active than women, but both sexes spend more than 5.5 hours a day sitting on average. A total of 39 % of probands have higher level of total body fat than the recommended norms. Conclusion: The study showed that lower levels of physical activity are associated with higher values of total body fat in university students. At the same time, within our sample both sexes out of 84 % comply with general recommendations regarding the volume and intensity of physical activity.

Keywords: physical activity, body composition, IPAQ, body fat, skeletal muscle mass, university students

INTRODUCTION

The increasing trend of sedentary behavior together with obesity is one of the biggest societal problems of the current population (Blair et al., 2009). Obesity is caused mainly due to faulty eating habits and low physical activity (PA). It contributes significantly to the development of a number of serious chronic diseases, which are well-documented by many studies, such as coronary heart disease, breast and colon cancer, osteoporosis, noninsulin-dependent diabetes or depression (Sattelmair et al., 2011; Friedenreich et al., 2011; Wolin et al., 2009; Jeon et al., 2007; Weyerer et al., 1992; Lane et al., 2006; Pietiläinen et al., 2008).

More than 57% of the adult population in the Czech Republic, especially men, are overweight or obese, and this proportion has not been able to decrease in the long term (Daňková, 2010; MZČR, 2014). That is why PA plays an irreplaceable role in a person's life. It is a physical movement that is associated with increased energy output and skeletal muscle activity. PA can be implemented as a leisure activity, a form of active transport or within an organized/unorganized activity. The basic factors that determine the optimal level of health-promoting PA are frequency, intensity, duration, and type of activity. Recommendations from the World Health Organization (World Health Organization, 2020) and the American College of Sports Medicine and the American Heart Association (Haskell et al., 2007) state that adults between the ages of 18 and 64 should perform moderate-intensity PA at least 150-300 of moderate-intensity aerobic PA, or at least 75-150 minutes of vigorous intensity aerobic PA a week and should also do muscle-strengthening activities at moderate or greater intensity that involve all major muscle group on 2 or more days a week. The recommendation must be understood as a supplement to routine activities of daily living, which are usually of moderate intensity or last less than 10 minutes. Adherence to these recommendations has demonstrable benefits in all components of health, which is also confirmed by studies (Máček & Radvanský et al., 2011; Reiner et al., 2013; Warburton et al., 2006; Sigmundová et al., 2013; Sofková et al., 2011). Unfortunately, 80% of children and adolescents worldwide do not follow this recommendation, and most of them carry this unhealthy habit to a later age (Hallal et al., 2012; Sallis et al., 2016). Bray et al. (2004) reported that almost half of US university students do not participate in moderate or vigorous PA. Antošová et al. (2014) demonstrate that 32 % of adults show low physical activity, moreover, in the Czech Republic as well as in the world, there is a noticeable decrease in physical activity among the population. Also, a large proportion of children are insufficiently physically active, and only 20% of girls and 25% of boys fulfilled the recommendation to devote at least 60 minutes a day to physical activity. Girls are more likely to leave sports as they get older, and interest in organized sports among adolescent youth also stagnates (Rychtecky & Tilinger, 2017).

The World Health Organization (WHO) has long termed the transition from high school to university as a critical period in terms of the development of obesity and a decrease in the volume of physical activity intensity. (WHO Consultation on Obesity (1999: Geneva & Organization, 2000; Sacheck et al, 2010; American College Health Association, 2008; Bray et al., 2004). It is in this context that major changes, including a sharper increase in sedentary behavior and increased values of the fat component (Magoc et al., 2010). The aim of the study is to describe the current

state of body composition of selected Czech university students and to evaluate the influence of physical activity/inactivity in this specific age group.

METHODS

The research methodology was based on empirical scientific approach with the use of quantitative approach based on the deductive process of implemented measuring. The main aim was to obtain objective data and results based on them, subsequent interpretations and answers to the formulated research questions with final conclusions. The main goal of the study is to describe the current state of body composition of university students and to assess the impact of physical activity / inactivity in this specific age group on some parameters of body composition.

Based on the set goals, two research questions (RQ) were formulated:

RQ1: Is body composition related to different levels of physical activity in university students?

RQ2: What are the differences in selected somatic parameters between men and women university students?

Subjects

A total of 358 probands (124 males and 234 females) aged 18-26 years (mean age 20.87 ± 1.43 years) were involved in the study. The research sample were consisted of students from all ten faculties of Masaryk University. They were initially briefed of the measurement procedures and the aims of the study, and then requested to sign informed consent forms. The research was voluntary without any financial contribution and followed valid code of ethics committee of Masaryk University and legal regulations of the Czech Republic. Consenting students were invited in spring semester of 2022 in the week of 7th to 11st March 2022, always in the office to complete online standardized International Physical Activity Questionnaire (IPAQ) and participate in somatic parameters measurements. The measurement takes place without shoes. All jewelry and watches must be removed before the measurement. The measurement cannot be performed if the proband has a pacemaker, metal implants or during pregnancy.Probands could leave the research at any time. Interpretation of the results from the analysis of body composition were provided to each proband to use for their personal purpose and as a benefit possible recommendation of PA and health risks were included for free.

Physical activity

The International Standardized Physical Activity Questionnaire (IPAQ) was used for the purposes of valid categorization into high active, minimally active, and inactive probands (Craig et al.,2003) in the Czech version. The Czech version was created from English and like in other countries, went through a standardization translation procedure, including back translations into English and their analysis. Respondents evaluated the frequency of operating individual types of PA by the number of days and duration (continuously at least 10 minutes) in an average day, over the last seven days. The questionnaire can be used in a short or long version, for the purposes of the study a short version of the questionnaire was used. The questionnaire records physical activity in the last 7 days, the questions are focused on frequency and time spent performing different

intensity of physical activity - vigorous, moderate, walking and also time spent sitting at least 10 minutes continuously. The value obtained from the calculation is the metabolic equivalent (MET) – MET-minutes/week, which is then scaled into physically inactive, minimally active and high active according to the physical recommendations (IPAQ manual, 2006). Time spent sitting is not included in the final calculation.

Somatic parameters

Somatic parameters were measured by calibrated InBody 230 device. The InBody device provides a non-invasive method of bioelectrical tetrapolar impedance (BIA) for analysis of five basic body segments separately (trunk, left arm, right arm, left leg, right leg). BIA method is sought after as a sufficiently valid and reliable method applicable to a wide spectrum of the population (Anderson et al.,2012; Kyle et al., 2004). Body height was measured by stadiometer Seca217 with an accuracy of 0.5cm without any footwear. Body weight (with an accuracy of 0.1kg), body fat percentage (%BF), skeletal muscle mass (SMM), fat free mass (FFM), proteins, minerals, BMI, WHR index, total body water, visceral fat level were measured after emptying the bladder and in light clothing. During the BIA measurement all recommended procedures were observed (Heyward & Wagner, 2004).

Statistical analysis

The obtained somatic parameters were processed through Lookin´Body120 software. Descriptive statistics (mean, median, standard deviation-SD) were calculated for all variables. Statistical processing was conducted using the R software (R Core Team 2016). One-factor ANOVA was used to test the significance of differences three groups (inactive, minimally active and high active). Tukey HSD post hoc test was used to assess differences between IPAQ categories. The significance was set at $p < 0.05$. Standard range of body fat percentage is 10-20% for men and 18–28% for women (Biospace, 2008). All types of PA were converted to MET-min·week-1. Total PA includes vigorous PA, moderate PA, and walking.

RESULTS

Somatic parameters of men and women participants are presented in Table 1. A total of 358 probands with a mean age of 20.87 ± 1.43 years were involved in the research, of which 234 women (65.4%) had a height of 167.9 ± 6.3 cm and a body weight of 61.3 ± 10.0 kg, BMI 21.7 ± 3.2, body fat 25.9 ± 6.4 %, skeletal muscle mass 24.7 ± 3.3 % and 124 men (34.6 %) with body height 180.9 ± 7.7 cm, body weight 77.6 ± 12.4 kg, BMI 23.6 ± 2.8, body fat 15.8 ± 5.4 %, skeletal muscle mass 37.0 ± 5.6 %. Men had 1.9 higher BMI and 10.1% lower body fat percentage than women. They also had a significantly higher prevalence of total PA. Men are more active by 245 MET-min/week than women in the context of total PA. Waist-Hip Ratio (WHR) means ratio of waist and hip circumference was measured by InBody230 device (r= 0.901 comparing with value measured by anthropometry). The average WHR for both sexes were 0.86. Higher WHR values were revealed in women relative to the recommendation. The recommended ranges for WHR are 0.80~0.90 for male and 0.75~0.85 for female. Abdominal obesity is diagnosed in case of over 0.90 for male and 0.85 for female. It was observed that 19% of men and 42% of women have abdominal obesity.

Table 1. Selected somatic parameters of men and women participants

	men (n = 124)		women (n = 234)	
	Mean	**SD**	**Mean**	**SD**
Age	21,21	1,56	20,70	1,33
Height (cm)	180,90	7,73	167,93	6,35
Weight (kg)	77,66	12,46	61,38	10,05
BMI (kg/m^2)	23,64	2,80	21,75	3,21
Body fat (%)	15,80	5,41	25,97	6,40
SMM - Skeletal muscle mass (kg)	37,05	5,63	24,70	3,32
Protein (kg)	12,94	1,86	8,85	1,11
Minerals (kg)	4,49	0,70	3,23	0,42
TBW - Total body water (l)	47,66	6,77	32,97	4,01
FFM - Fat free mass (kg)	65,10	9,32	45,05	5,52
WHR - Waist-Hip Ratio	0,86	0,06	0,86	0,05
BMR - Basal Metabolic Rate (Kcal)	1 776,14	201,41	1 343,01	119,28
Activity (MET-min/week)	2 253,69	1 504,35	2 008,89	1 759,20

Differences between the groups are recorded in Figure 1. We can observe a decreasing trend of the fat component with increasing PA in both sexes. A significant statistical difference within male with different levels of physical activity were demonstrated in body fat percentage ($p = 0.04$). Tukey post-hoc test shows significant differences only between inactive and high active groups of women ($p = 0.04$).

Similar results can be observed with skeletal muscle mass (SMM). A significant statistical difference within male with different levels of physical activity were demonstrated in SMM ($p = 0.01$). Tukey post-hoc test shows significant differences only between minimally active and high active groups of men ($p = 0.01$). No significant statistical differences were demonstrated for women ($p = 0.09$, respectively $p = 0.07$ for high active and inactive group).

According to IPAQ Scoring Protocol (IPAQ, 2008), probands were classified into three levels of physical activity as inactive (16%), minimally active (58%) and high active (25%). It was observed, that 84% of both sexes follow the general recommendations regarding the volume and intensity of physical activity. Anyone who met the one of the following 3 criteria was included in the category minimally active.

- 3 or more days of vigorous activity of at least 20 minutes per day OR
- 5 or more days of moderate-intensity activity or walking of at least 30 minutes per day OR
- 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week.
- Anyone who met the one of the following 2 criteria was included in the category high active.
- Vigorous-intensity activity on at least 3 days and accumulating at least 1500 METminutes/ week OR
- 7 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 3000 MET-minutes/week
- The other probands were classified into inactive category. They reported no activity or some activity was reported but not enough to meet minimally active or high active.

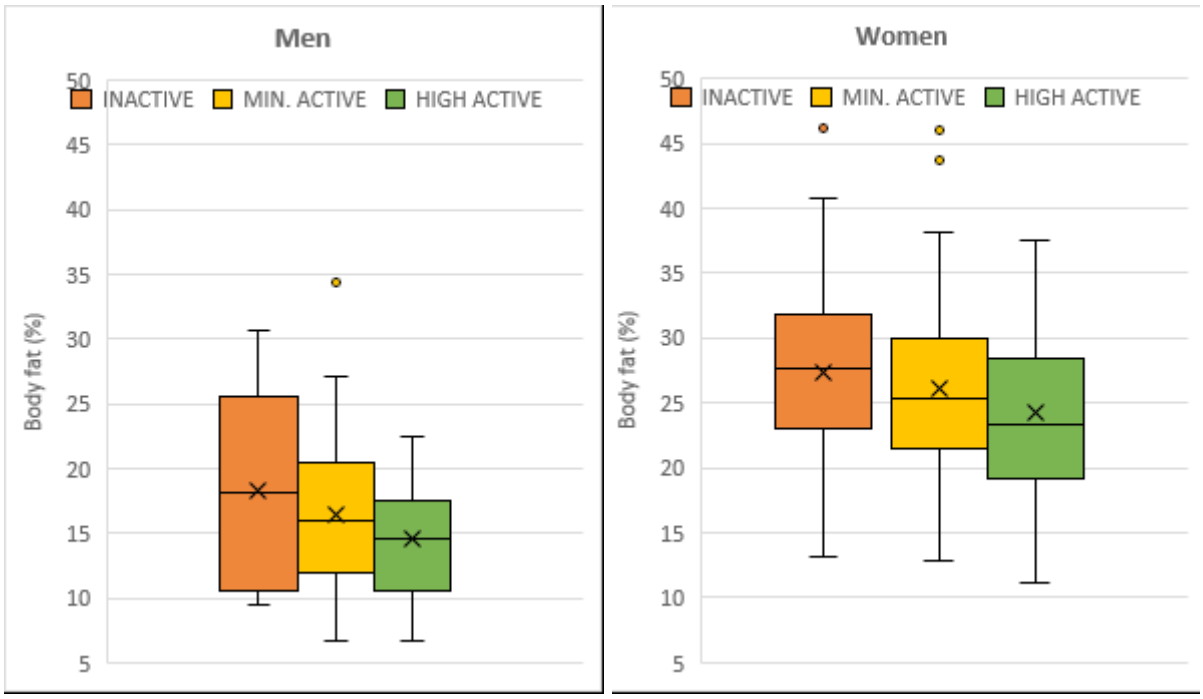

Figure 1. Body fat according to gender and level of PA

A total of 39 % of probands are out of the standard range of body fat percentage than the recommended norms in Figure 2.

67.7 % of men and 57.7% of women were classified as standard of body fat percentage, while 20.2 % of men and 33.8% of women were above the limit. Standard range of body fat percentage is 10–20 % for men and 18–28 % for women. Average body fat percentage in high active men and women is 14.3 % and 24.3 %. Average body fat percentage in inactive men and women is 18.3 % and 27.4 %. The difference of 4 % a 3.1% between two categories is significant statistical difference (p = 0.04).

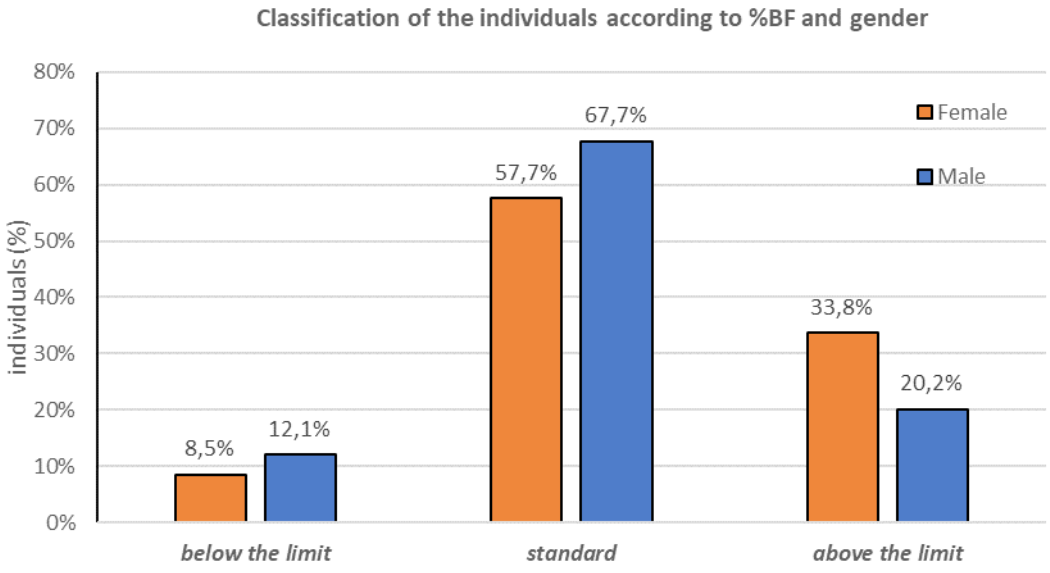

Figure 2. Classification of body fat range percentage by gender

Note: Normal range (according to INBody): men 10-20%, women 18-28% (Biospace, 2008)

BMI mean values were in the normal range according to WHO (18.5 – 24.9).

75 % of women and 73 % of men were classified as standard weight. Men were more overweight (23 %) and obese (2 %), than women overweight (10 %) and obese (3 %).

DISCUSSION

It can be assumed that PA influences somatic parameters. Although many authors confirm the beneficial effect of PA on the body health, the results of research analysing risk factors affecting the university students point out that the health status of university students is generally worse than the health status of the non-student population of the same age (Kvintová, 2016). The authors describe college as an important transition into adolescence, when their lifestyle, PA levels, and eating habits are built. This behaviour can influence the emergence of overweight and obesity and other factors that can increase the risk of chronic diseases that do not yet occur in this age group. The study was focused on volume and intensity, which are substantial for supporting the health benefits of an active lifestyle in university students. As stated in the introduction, it is appropriate to maintain the functional state of the individual to comply with general recommendations that relate to the volume or intensity of PA. Nykodým et al. (2011) reported that 65.3 % of students fulfil at least one of the recommendations for PA. It was observed, that 84 % of both sexes follow the general recommendations regarding the volume and intensity of physical activity. Results of this study are not so critical, compared with 40 to 50 % of American students which were physically inactive (Keating et al., 2005). The IPAQ is considered as a reliable and valid tool for self-reported physical activity levels across a range of age groups and countries of origin, which is confirmed by several studies (Ekelund et al., 2006), that have also examined validity of IPAQ in comparison with other measuring devices.

In this study, we examined the association of somatic parameters with individual level of PA. It was found, that with increasing physical activity the body fat percentage decreases.

Additionally, these findings were independent of gender. The presented results are consistent with findings of previous research conducted. It has been demonstrated that for a total of 39 % of probands are out of the standard range of body fat percentage than the recommended norms. 67.7 % of men and 57.7 % of women had normal level of body fat percentage, while 20.2 % of men and 33.8 % of women were above the limit. Average body fat percentage in high active men and women is 14.3 % vs. 24.3 %. Average body fat percentage in inactive men and women is 18.3 % vs. 27.4 %, which are quite similar values as reported by Savegnago et al., 2014. Average body fat percentage in inactive men and women was 18 % and 26 %. Average body fat percentage in high active men and women was 14.1 % and 25.8 %. Standard range of body fat percentage is 10–20 % for men and 18–28% for women. The assumption demonstrated in studies that men are more physically active than women was confirmed (Frömel, Novosad a Svozil, 1999). Men are more active by 245 MET-min/week than women in the context of total PA (2253 vs. 2008 MET-min/week).

There are a few limitations to the study that need to be considered. The main limitation of the study is the size of the research group with lower sample of male probands. Moreover the selected group is represented only by students at Masaryk University in Brno. Limitation of the study may

be that the probands were self-selected and may represent a healthier sample of university students, which may be one of the reasons it does not reflect the real state. Therefore, it can be assumed that the results of the presented study only reflect the state of specific group of population and cannot be completely generalized. It is assumed that research on a larger population group could bring similar conclusions or specify the trends to outlined.

CONCLUSION

The findings of the study have revealed that higher level of PA is associated with lower body fat percentage in university students. Significant statistical difference was demonstrated between inactive and high active groups of women ($p = 0.04$). However, significant statistical differences between some PA groups were not demonstrated. In terms of WHO PA guidelines both sexes out of 84% comply with general recommendations regarding the volume and intensity of physical activity. Men are more active by 245 MET-min/week than women in the context of total physical activity. 67.7 % of men and 57.7 % of women were classified as standard of body fat percentage, while 20.2 % of men and 33.8% of women were above the limit. The research sample is based on the voluntariness. The results cannot be fully generalized. Although some results of the measurement of somatic parameters in the selected sample of probands do not directly confirm the deteriorating condition of university students, as was evidenced by some presented foreign studies. It is recommended that future studies will be investigated further by using a larger sample of probands and more complex reference methods to measure level of PA and somatic parameters.

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Impact Of Whole-Body Electromyostimulation and Resistance Training Programme on Strength Parameters and Body Composition in Group of Elderly Women at Risk of Sarcopenia

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ABSTRACT

Objective: The purpose of the study is to compare the effect of ten-week lasting whole-body electromyostimulation (WB-EMS) and the circuit resistance training programme (RT) on body composition and strength parameters in women at risk of sarcopenia.

Methods: The WB-EMS programme was carried out once a week and included ten exercise sessions, the RT was carried out twice a week and included 20 sessions. 17 elderly women participated in the study, nine in a WB-EMS intervention group (age: 63.11 ± 1.52 years; weight: 70.07 ± 9.07 kg; height: 165.11 ± 6.4 cm; BMI 25.81 ± 3.96 kg/m2), eight in a RT group (age: 62.13 ± 1.69 years; weight: 73.58 ± 3.87 kg; BMI 27.34 ± 2.58 kg/m2). To assess body composition, dual-energy X-ray absorptiometry (DXA) was used. To determine the level of strength parameters, hand dynamometry and isokinetic dynamometry of knee flexors and knee extensors were used.

Results: Body composition assessment was performed by dual-energy X-ray absorptiometry and strength parameters were evaluated using isometric dynamometry (knee flexors and extensors strength). After completing ten weeks of intervention, significant differences were observed for lean muscle mass (RT group, $Leanmass_{pre\text{-}test}$ 43316.91 ± 1856.77 vs. $Leanmass_{post\text{-}test}$ 43939.56 ± 1869.84, p = 0.0307). No significant differences were found between the pre-test and post-test in the WB-EMS group ($Leanmass_{pre\text{-}test}$ 39472.56 ± 3370.04 vs. $Leanmass_{post\text{-}test}$ 38835.56 ± 3306.84, p = 0.5995). The isokinetic dynamometry analysis showed significant differences for the extensors and the peak torque on the right side in the RT group (Extensors Peak $Torque_{pre\text{-}test}$ 98.00 ± 13.55 vs. Extensors Peak $Torque_{post\text{-}test}$ 38835.56 ± 3306.84, p = 0.0160; Flexors Peak $Torque_{pre\text{-}test}$ 54.25 ± 11.14 vs. Flexors Peak $Torque_{post\text{-}test}$ 59.75 ± 11.13, p = .0059).

Conclusions: The most obvious finding that emerges from this study is that resistance training has shown a greater effect than whole-body electromyostimulation.

Keywords: ageing; dynamometry; strength; physical activity; WB-EMS

INTRODUCTION

Ageing is associated with many changes in physical involution, which dramatically affects the health status and quality of life of the elderly. One of the diseases related to the ageing process is sarcopenia (Peterson et al., 2011; Romero-Arenas, 2013) described as an age-related reduction in the volume of the appendicular skeletal muscle mass, also including the loss of muscle strength and functionality that usually accompany the loss of muscle mass (Fried et al., 2001; Marcell, 2003). Along with muscle mass loss, the level of muscle strength also decreases. Furthermore, older women are more sensitive to the incidence of sarcopenia due to lower initial muscle mass and muscle strength levels. Strong evidence of changes in hormonal production related to advancing age was found. Anabolic hormone levels decrease with age. The level of estrogen decreases after menopause in women. Also, insulin-like growth factors (IGF-1) decrease with age. These changes contribute to impaired protein synthesis (Brady et al., 2014; Ribeiro et al., 2017). Increasing levels of cortisol, insulin resistance, and the amount of fat tissue also contribute to reducing muscle mass (Marcell, 2003; Raguso et al., 2006). With ageing and an increase in fat mass, insulin resistance often develops, which is accompanied by decreased glucose tolerance. Insulin exposure contributes to increased muscle protein. Insulin resistance may therefore be associated with loss of muscle protein and catabolism, and can gradually lead to sarcopenia (Guillet & Boirie, 2005). Furthermore, there is a decrease in bone density (Daly et al., 2013). Sarcopenia with all of these factors has an influence on quality of life in the elderly, a higher risk of falls and fractures, and subsequently loss of self-sufficiency (Rhodes, 2000). Unfortunately, the ability and desire to exercise regularly decrease with increasing age. It leads to the acceleration of involution processes and thus to a reduced quality of life (Cruz-Jentoft et al., 2019; Kemmler et al., 2014; von Stengel & Kemmler, 2018).

Physical activity, specifically resistance training with respect to the health status of ageing adults, can significantly affect the ageing process and lead to the prevention of sarcopenia (Breen & Phillips, 2013; Forbes et al., 2012; Pedersen & Saltin, 2006; Taylor, 2014). Previous research that deals with the influence of physical activity on strength parameters and body composition in older age mentions resistance training or its combination with balance and flexibility exercises, endurance exercises, or walking. The studies also deal with water exercises and alternative variants of resistance training (Ilmar Danilo Santos et al., 2019; Kemmler et al., 2016; Kemmler & von Stengel, 2012; Lopez et al., 2018; Peterson et al., 2011; Ribeiro et al., 2017).

Our research deals with resistance training (RT) and the whole-body electromyostimulation method (WB-EMS). Resistance training appears to be effective in the prevention of sarcopenia in older adults (Cruz-Jentoft et al., 2019; Pedersen & Saltin, 2006; Taylor, 2014). Resistance exercise stimulates the release of anabolic hormones (Vingren et al., 2010) and leads to muscle hypertrophy and increased muscle strength (Kemmler et al., 2014; Kosek et al., 2006; Peterson et al., 2011; von Stengel & Kemmler, 2018). Studies have shown that resistance training improves the parameters of bone density of the femoral neck and lumbar spine (Huovinen et al., 2016; Marques et al., 2012). Socialisation during circuit resistance training leads to a higher level of motivation (Romero-Arenas et al., 2013). In addition to the above, the advantages of RT in older adults are mobility improvement, perceiving more energy, and self-confidence (Taylor, 2014).

Alternative forms of exercise provide health benefits to people who are unable or unwilling to engage in conventional types of exercise due to physical limitations or lack of motivation (Kemmler, et al., 2016; Kemmler & von Stengel, 2013). The WB-EMS method offers an alternative or additional training method to RT and has the potential to activate a higher number of motor units than classical resistance training. A favourable effect of WB-EMS on muscle strength of the upper and lower extremities was found (Pano-Rodriguez et al., 2020; von Stengel et al., 2015). Also, studies mentioned a positive effect on the amount of muscle mass (Kemmler et al., 2014) and on maintaining mineral bone density (von Stengel et al., 2015). The WB-EMS method seems to be a suitable method to prevent the risk of falling. The advantage of the WB-EMS method is the portability of the device and the time-efficiency (Kemmler et al., 2016; Langeard et al., 2017), care of the joints and tendons, which may be a suitable alternative for the ageing population with physical limitations (Kemmler et al., 2018; Kemmler et al., 2016). However, it is still a relatively costly method (Kemmler et al., 2016; Kemmler & von Stengel, 2012). WB-EMS seems to be an attractive alternative for people unable or unwilling to engage in traditional forms of resistance exercise.

Most studies have observed the effect of EMS training compared to a control group or exercise other than resistance training. The purpose of the study is to compare the effect of 10 weeks of WB-EMS and the circuit resistance training programme on body composition, bone density, and strength parameters in women at risk of sarcopenia.

METHODS

Participants

The elderly participants were recruited using the snowball technique from several sources. A cooperating organisation that provided physical activities for the elderly (rehabilitation centres, swimming pools, etc.) was addressed. Recruitment was also carried out on the website and Facebook profile of the Faculty of Sports Studies of Masaryk University Brno in the Czech Republic.

Inclusion criteria were: age 60-65 years, without regular physical activity and contraindications (epilepsy, cardiac pacemaker, severe circulatory system disease, abdominal or inguinal hernia, cancer, advanced arteriosclerosis, severe neurological disease, acute -bacterial or viral disease, diabetes mellitus, haemophilia, liver disease, tuberculosis, severe circulatory system disorders - eg unstable angina pectoris, untreated hypertension, uncontrolled heart rhythm disturbance, heart failure, valve stenosis, hypertrophic cardiomyopathy, reduced mobility, metal implants).

The 21 women aged 60 to 65 years met the inclusion criteria of the ten-week lasting interventional programmes. The participants were randomly divided into 2 groups – the whole body electromyostimulation group (WB-EMS) and the resistance training group (RT). All participants in this experimental study were asked to sign an informed consent form approved by the Ethics Committee of Masaryk University, Brno. The Ethics Committee application number was 0549/2019.

The WB-EMS group consisted of eleven women (nine women completed the intervention programme), and the RT group included ten women (eight women completed the intervention programme).

The participants were asked to maintain their usual daily regimen with the same amount of physical activity and a normal daily lifestyle. The descriptive characteristics (age, BMI, height, weight, number of men and women) of the study sample are shown in Table 1.

Table 1. Descriptive characteristics of the study sample

Variable	EMS-WB group		RT group	
	M	SD	M	SD
Age	63.11	1.52	62.13	1.69
BMI	25.81	3.96	27.34	2.58
Weight (kg)	70.07	9.70	73.58	3.87
Height (cm)	165.11	6.40	165	5.32
N	9		8	

Notes: M – mean, SD – standard deviation, BMI – body mass index, EMS-WB – Whole-body Electromyostimulation, N– number of tested participants

The participants were evaluated at the beginning (baseline) and at the end of the ten-week lasting of intervention (post-test). First, the DXA measurements were found out, followed by a hand and isokinetic dynamometry. All tests and measurements that lasted approximately 40 minutes were carried out by trained persons in laboratories of the Faculty of Sport Studies of Masaryk University Brno.

Measurements

Dual-energy X-ray absorptiometry (DXA) measures body composition and also bone density. DXA is commonly used to diagnose osteoporosis. This non-invasive method uses a very small dose (0,001–0,015 mSv) of ionising radiation. To measure body composition, the whole-body scanner was used. To measure bone density, the lumbar spine and upper part of the femur were monitored.

Hand Grip Dynamometry measures the level of maximum static short-term strength of the grip of hand flexors. The test is performed two times with the left hand and two times with the right hand. The better result of these two attempts is taken into account.

Measurement of the strength parameters of knee flexors/extensors

Concentric strength of the knee flexors/extensors was assessed at 60°/s using a Humac NORM isokinetic dynamometer. All participants were familiar with isokinetic measurements before the study /familiar testing measurement was done one week before the study. All participants were asked to avoid intense physical activity two days before the test. The maximum concentric strength of the knee flexors and extensors was measured from 0 to 90° of knee flexion. The measurements of the isokinetic study protocol started with a warm-up (six min cycling at 1W/kg body weight, four min cycling at 1.5W/ kg body weight). Subsequently, the researcher explained and set the initial position (seat position with the backrest at 85°). Minimalizing compensation movements were secured with safety straps across the tested thigh, pelvis, and chest. The researcher clearly explained the instructions about the testing - each participant gave instructions to push as hard and fast as possible during the full range of motion. The isokinetic test consisted of three sets of four repetitions. The break between sets was three min and 30 s between the repetitions. The best attempt was recorded.

Intervention programme

Whole-Body Electromyostimulation Programme

The WB-EMS is a method in which weak but very frequent electrical impulses activate not only the superficial muscles but also those located in the deep layers of the body. Complex electro-myostimulation works with up to ten pairs of electrodes, each pair is located on the right and left half of the body. The impulse thus takes place in all muscles from one half of the body to the other, and not only in the places where the electrodes are placed. With total electromyostimulation, the duration of the training unit is 20 minutes, during which the muscles are four seconds in the tension phase (85 muscle contractions occur every second) and four seconds in the relaxation phase.

The WB-EMS occurred on the Miha Bodytec device. The WB-EMS Programme took place once a week for ten weeks. The first class lasted 60 minutes and included an entry review that covered information about the intervention programme process. The entry review was followed by a 12-minute class (pulse test and strengthening programme). The intensity of the electric pulses was set according to the actual possibilities of the tested persons. These values were loaded and were the initial values for the next courses. Other courses were held once a week, ideally on the same day, and lasted 20 minutes. The regeneration time (four days minimum between two courses) was obeyed. In the training sessions, exercises of similar character as resistance training were involved (Table 2).

Table 2. WB-EMS training protocol

Sequence	Exercise	Number of repetitions
0	Basic static position	
1	Half-squat	12
2	Trunk rotation (left and right)	8
3	Lunges (left side)	8
4	Lunges (right side)	8
5	Reverse fly (forearms up)	12
6	Chest fly (forearms up; concentric phase only)	6
7	Side lunges (left and right)	8
8	External arm rotation (left and right)	6
9	Back extension	6
10	Triceps kickback	6

Circuit resistance training programme

The minimum attendance with the possibility of replacing the training was set at 80%. The time interval between two trainings and the frequency two times a week had to be kept. One week before starting the intervention programme 2 introducing training sessions were held (manipulation with strengthening machines, correct technique of workouts, individual load setting according to a maximum of ten repetitions). For the first week of the intervention program, the load was calculated at 65 – 70%, for the second week, 70–75% RM.

Before the very beginning of the intervention, there was a training week for the probands, which consisted of two training units, during which the women got acquainted with the gym environment, with fitness machines, with their manipulation, and also with the demonstration of

workouts used in training programmes. A preparatory class with training on the correct execution of the workouts and setting the individual load according to the 1RM (=one repetition maximum) was followed. We used 1RM modification of ten repetitions for the elderly, demonstrating the load they can lift ten times. From the resulting load, 65-70% RM max was calculated (for the first week of intervention), then 70-75% RM max (from the second week of intervention).

Each unit started with a warm-up including walking modifications, joint mobilisation exercises and dynamic stretching. The main part of the unit contained three circuits with ten positions (Table 3). Between each position, a short pause of about 1–1,5 minutes takes place. The pause among circuits lasted 3 to 5 minutes (for drinking, short regeneration, etc.). The unit was finished with static stretching.

Table 3. Resistance training protocol

Sequence	Exercise	Number of repetitions
1	Tabletop Leg Press	10–12
2	Bench Press	10–12
3	Back Lunges (left and right side)	10–12
4	Reverse Pec-deck	10–12
5	Wall Squats (with gymnastic ball)	10–12
6	Lat Pulldown	10–12
7	Leg Extensions	10–12
8	Triceps Pulldown	10–12
9	Lying Hamstring Curls	10–12
10	Biceps Cable Curl	10–12

Statistical analyses

For the analysis of the data obtained, Statistica 12 and Microsoft Excel software were used. Descriptive data are summarised as mean (M) ± standard deviation (SD). The assumption of normality was verified using the Shapiro-Wilk statistic. For reliability analysis, the paired sample t-tests compared the selected parameters between pre-test and post-test.

RESULTS

T-tests were used to analyse the relationship between pre and post-tests for each intervention group. The results obtained from the Dual-energy X-ray absorptiometry are presented in Table 4. Data from this table (Table 4) can be compared with the data in Table 5 which shows the difference between the interventional group (WB-EMS vs. RT).

Table 4. The average values of body composition measurements in the WB-EMS group

Variables	Pre-test (n=9)	Post-test (n=9)	*p* value pre vs. post-test
BMD-WB (g/cm3)	0.98 ± 0.06	0.97 ± 0.05	NS (0.3131)
T score	-1.6 ± 0.80	-1.7 ± 0.71	NS (0.4088)
LMI	14.50 ± 1.14	14.31 ± 1.13	NS (0.9741)
Lean Mass (g)	39472.56 ± 3370.04	38835.56 ± 3306.84	NS (0.5995)
Subtotal total (g)	65797.11 ± 9642.97	65439.89± 9899.86	NS (0.3305)
Subtotal fat	41.26 ± 5.05	41.84 ± 5.38	**0.0081***
Subtotal L+BMC (g)	38235.44 ± 3329.81	37609.78 ± 3270.23	**0.0153***

Notes: BMD - bone mineral density, WB - whole body, LMI - lean mass index; **p < 0.05*; NS: not statistically significant

Table 5. The average values of body composition measurement in RT group

Variables	Pre-test (n=8)	Post – test (n=8)	*p* value pre vs. post-test
BMD-WB (g/cm3)	0.98 ± 0.06	0.98 ± 0.04	NS (0.1677)
T score	-1.6 ± 0.65	-1.7 ± 0.74	NS (0.1704)
LMI	16.01 ± 1.05	16.21 ± 1.10	NS (0.0744)
Lean Mass (g)	43316.91 ± 1856.77	43939.56 ± 1869.84	**0.0307***
Subtotal total (g)	69747.91 ± 3777.37	70496.51± 4066.68	**0.0388***
Subtotal fat	39.61 ± 2	39.42 ± 2.65	NS (0.3281)
Subtotal L+BMC (g)	42057.41 ± 1937.56	42667.11 ± 1975.92	**0.0274***

Notes: BMD - bone mineral density,WB - whole body, LMI - lean mass index;**p < 0.05*; NS: not statistically significant

No significant differences were found between BMD-WB, T score, LMI and Subtotal fat in the RT group. As can be seen from Table 5, the RT group reported a significant difference, especially in the Lean Mass parameter which has highly important health consequences ($Leanmass_{pre\text{-}test}$ 43316.91 ± 1856.77 vs. $Leanmass_{post\text{-}test}$ 43939.56 ± 1869.84, *p= 0.0307*).

Tables 6 and 7 compare the summary statistics for the selected intervention programme (EMS-WB and RT).

Table 6. The average values of strength parameters from isokinetic dynamometry measurements in the WB-EMS group (knee flexors and extensors strength)

Variables	Pre-test (n = 9)	Post-test (n = 9)	*p* value pre vs. post-test
L Extensors Peak Torque (N/m)	89.33 ± 9.36	89.55 ± 15.37	NS (0.9492)
R Extensors Peak Torque (N/m)	96.66 ± 11.07	97.55 ± 15.95	NS (0.7901)
L Flexors Peak Torque (N/m)	49.88 ± 8.56	53.33 ± 10.44	NS (0.0599)
R Flexors Peak Torque (N/m)	47.22 ± 6.99	55.11 ± 11.87	**0.0142***
L Extensors Time to Peak Torque (s)	0.43 ± 0.07	0.43 ± 0.05	NS (0.9751)
R Extensors Time to Peak Torque (s)	0.46 ± 0.09	0.45 ± 0.11	NS (0.8122)
L Flexors Time to Peak Torque (s)	0.44 ± 0.09	0.46 ± 0.09	NS (0.3645)
R Flexors Time to Peak Torque (s)	0.43 ± 0.10	0.38 ± 0.05	NS (0.0505)
Handgrip (dominant hand) (kg)	24.87 ± 3.95	25.12 ± 3.26	NS (0.8426)

Notes: L - left side, R - right side;*$p < 0.05$; NS: not statistically significant

Strong evidence of improvement of strength was found when Flexors Peak Torque or right side was compared (Flexors Peak Torque$_{\text{pre-test}}$ 47.22 ± 6.99 vs. Flexors Peak Torque $_{\text{post-test}}$ 55.11 ± 11.87, *p= 0.0142*). This result is significant at the p = 0.05 level.

Table 7. The average values of strength parameters from isokinetic dynamometry measurements in RT group (knee flexors and extensors strength)

Variables	Pre-test (n = 8)	Post-test (n = 8)	*p* value pre vs. post-test
L Extensors Peak Torque (N/m)	95.12 ± 11.60	100.37 ± 15.08	NS (0.2273)
R Extensors Peak Torque (N/m)	98.00 ± 13.55	106.25 ± 12.29	**0.0160***
L Flexors Peak Torque (N/m)	55.50 ± 12.36	58.75 ± 12.30	NS (0.2663)
R Flexors Peak Torque (N/m)	54.25 ± 11.14	59.75 ± 11.13	**0.0059***
L Extensors Time to Peak Torque (s)	0.44 ± 0.07	0.47 ± 0.11	NS (0.3711)
R Extensors Time to Peak Torque (s)	0.42 ± 0.06	0.42 ± 0.05	NS (0.8551)
L Flexors Time to Peak Torque (s)	0.44 ± 0.09	0.46 ± 0.09	NS (0.3645)
R Flexors Time to Peak Torque (s)	0.46 ± 0.10	0.43 ± 0.03	NS (0.4692)
Handgrip (dominant hand) (kg)	25.62 ± 2.40	25.03 ± 3.30	NS (0.2946)

Notes: L-left side, R-right side; *$p < 0.05$; NS: not statistically significant

The statistical significance differences between pre and post-test are highlighted in Table 7. (R Extensors Peak Torque $_{\text{pre-test}}$ 98.00 ± 13.55 N.m vs. R Extensors Peak Torque $_{\text{post-test}}$ 106.25 ± 12.29 N.m, *p= 0.0160*; R Flexors Peak Torque Torque $_{\text{pre-test}}$ 54.25 ± 11.14 N.m vs. R Extensors Peak Torque $_{\text{post-test}}$ 59.75 ± 11.13 N.m, *p= 0.0059*).

DISCUSSION

The purpose of the study was to compare highly discussed whole-body electromyostimulation with a resistance training program in a group of women at risk of sarcopenia. Regular physical activity on a daily basis plays a vital role in the quality of life (Galloza et al., 2017; McPhee et al., 2016). The whole body electromyostimulation is becoming increasingly popular due to its effectiveness and also the time that is dedicated to training (Kemmler et al., 2017; Pano-Rodriguez et al., 2020; Teschler & Mooren, 2019). Also, it is important to mention that each 1 h increase in sitting time during the day can lead to an increase of 33% of the risk of sarcopenia in the 60-year group regardless of physical activity or lifestyle (Gianoudis et al., 2015). On the other hand, in the last few years, there has been a growing interest in resistance training as a key part of regular physical activity in the elderly (Lopez et al., 2018; Tsuzuku et al., 2018).

This paper presents a unique result of comparing the effect of whole-body electromyostimulation and resistance training. We decided to show the differences between body composition assessment and strength parameters. Strong evidence of an improvement in strength was found when the Flexors Peak Torque on the right side was compared (Flexors Peak Torque$_{\text{pre-test}}$ 47.22 ± 6.99 vs. Flexors Peak Torque $_{\text{posttest}}$ 55.11 ± 11.87, *p= 0.0142*) in the whole body electromyostimulation group. The statistical significance was also found in the resistance training group (R Extensors Peak Torque $_{\text{pre-test}}$ 98.00 ± 13.55 N.m vs R Extensors Peak Torque $_{\text{post-test}}$ 106.25 ± 12.29 N.m, *p = 0.0160*; R Flexors Peak Torque Torque $_{\text{pre-test}}$ 54.25 ± 11.14 Nm vs R Extensors Peak Torque $_{\text{post-test}}$ 59.75 ± 11.13 Nm, *p = 0.0059*).

Furthermore, a better practical use was found in a group of resistance training in values of in the Lean Mass parameter, which has highly important health consequences (Leanmass$_{\text{pre-test}}$ 43316.91 ± 1856.77 vs. Leanmass$_{\text{post-test}}$ 43939.56 ± 1869.84, *p= 0.0307*).

Regarding body composition, studies evaluated the value of lean mass in the elderly women and men who participated in resistance training. After the intervention, the studies determined a significant increase in lean mass in women compared to the control group (Fjeldstad et al., 2009; Marcos-Pardo et al., 2019; Romero-Arenas et al., 2013). In contrast to our results, a study comparing WB-EMS and high-intensity resistance training listed similar effects of both methods on body composition. After 16 weeks of intervention, a significant increase in lean body mass was recorded in both groups. No significant changes between groups occurred (Kemmler et al., 2016). Some studies examined the effect of WB-EMS on body composition in the elderly women. Both studies reported a significant increase in lean body mass compared to the control group (Kemmler et al., 2014; von Stengel et al., 2015).

Regarding the strength parameters, many studies focused on the effect of WB-EMS in elderly non-trained subjects. A recent study compared resistant training and the WB-EMS method on overall physical fitness in untrained elderly women. After ten weeks of intervention, a statistically significant increase in the strength of the upper and lower extremities was determined in both groups. However, greater improvements were recorded in the WB-EMS group (Pano-Rodriguez et al., 2020). Furthermore, another study involving non-sporting elderly women determined the significant effect of WB-EMS training on the strength of leg and trunk extensors after the 54-week intervention. The same parameters were maintained or decreased slightly in the control group (Kemmler et al., 2014).

In addition, studies reported the favourable effect of resistance training on strength parameters. A study comparing the effect of WB-EMS and high intensity resistance training in middle-aged untrained men concluded that leg extensor strength increased significantly in both groups with no significant differences between the groups (Kemmler et al., 2016). Significant improvement in absolute values of maximal dynamic strength and muscle volume on knee extensor strength was determined by a study involving elderly women who underwent 12 weeks of resistance training intervention (Correa et al., 2013).

It was not possible to investigate the significant relationships between the selected parameters and the intervention further because the sample size was too small. Therefore, a further study with more emphasis on the duration of the intervention and with an increase in sample size is suggested. The higher number of participants and the longer duration of the exercise programme would contribute to objective results. Also, we did not monitor and influence the eating habits of the participants, which could have influenced the results of the intervention.

CONCLUSION

In conclusion, the most obvious finding that emerges from this study is that resistance training has shown a greater effect than whole-body electromyostimulation in values of the Lean Mass parameter, which has highly important health consequences. Strong evidence of an improvement in strength was found when the Flexors Peak Torque on the right side was in the WB-EMS group. The statistical significance was also found in the resistance training group. In addition to the observed parameters, the exercise programmes also had an effect on the social factor of the participants. The participants noted that through the exercise programmes they were in contact with their peers, learned the correct technique of exercises and experienced new types of exercises. Some of the participants continue practising physical activity and also, they continue meeting on other occasions. We consider the study to be rigorous in optimising physical activity recommendations of the elderly and in spreading awareness of the possibilities of exercise of the elderly.

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Creativity and Tactical Skill Profiles of Handball Players

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ABSTRACT

The purpose of this study is to examine the creativity and tactical skill levels of the athletes (n = 259) who actively continued their sports life in handball in Turkey in the 2020–2021 season. In order to determine athlete's creativity levels, we used the "Creativity Questionnaire for Athletes" and for tactical skills, we used the "Tactical Skills Questionnaire for Sports". We examined the relationships between these two dependent variables and the independent variables of gender, sports age and league category. As a result of the regression analysis, it was determined that the creativity level of the athletes was predicted by tactical skills at a level of approximately 74%. In terms of the variable of the handball players' years of playing handball, a low positive correlation was found in the sub-dimensions of the Tactical Skills Questionnaire. This relationship is statistically significant in other sub-dimensions, except for the Knowledge of Ball Movements sub-dimension of the Tactical Skills Questionnaire. The same variable was examined in terms of the creativity level and a low level of positive correlation was found. This relationship was found to be statistically significant. Appropriate training settings and environments should be designed in order to develop the creativity skills of the athletes. The similarity of the training environment to real competition conditions can greatly contribute to the development and use of creativity and tactical skills in sports.

Keywords: creativity, tactical skills, handball

INTRODUCTION

The ability of an artist, composer, and scientist to discover or develop something new in their field is seen as a basic quality (Bohm, 2005, pp. 2). The same measure is sought and desired in a teacher, politician or an administrator. Just like these, creativity is a sought-after phenomenon in the nature of sports and athletes. As a matter of fact, it is this creative, forward-looking and exciting continuity of sports that keeps its place in our lives alive. According to Craith (2009), creativity is expressed as having the quality or power of an individual to express himself in an original way. In another definition, creativity is stated as the ability to produce an original (new) and useful (appropriate) work (Sternberg, 1988; Sternberg, & Lubart, 1999).

Creativity requires both originality and effectiveness. Something must be exceptional or distinctive in order to qualify as original. Otherwise it is ordinary. However, if an original (novel) idea or product is not effective, it cannot take its creative name on its own (Runco, & Jaeger, 2012). Therefore, the creativity level of an idea/product necessitates it to be both new and useful/appropriate.

Although the concept of creativity is often thought to be related only to art, it is also a phenomenon needed in all areas of life, from science (MacKinnon, 1963), religion to sport (Bohm, 2005, pp. 78). Creativity has been one of the important concepts that have developed in recent years and on which many researches have been made. Another area where this concept is the subject of research is sports sciences (Furley, & Memmert, 2015; Hristovski et al., 2011; Hristovski et al., 2012; Vaughan et al., 2019). Creativity is an extremely important trend in everyday life (Runco, 2014) as well as in environments where sportive performance is shown (Memmert, 2015). Definition of creativity in sports sciences; It can be done as the ability to make variable, flexible and extraordinary decisions in complex game situations (Memmert, & Roth, 2007). The ability to think creatively in sports is highly desired by coaches and trainers (Memmert, Baker, & Bertsch, 2010), and it can also be visually impressive by the audience.

From the perspective of the sport-specific interpretation of creativity; creativity arises only when there are offensive plays (as the Attacker initiates the action) during the match. Creativity is not expected in defensive situations, as the defender must wait for the opponent's move and react accordingly (Memmert, Baker, & Bertsch, 2010). From this point of view, the concept of creativity plays an important role in sports branches with defensive and offensive variations, namely in team games (Roca, & Ford, 2021). In the literature, it is stated that the concept of creativity in sports cannot be thought independently with convergent and divergent thinking (Guilford, 1959; Memmert, 2011). Convergent thinking (tactical intelligence) is expressed as the ability to find the ideal solution to a certain problem in a certain situation at the behavioral level in sports. Divergent thinking (tactical creativity) is defined as the ability to find unusual, innovative, rare and even unique solutions specific to the relevant sport at the behavioral level (Memmert, 2011). It is stated that participation in various sports and physical activities and gaining experience in different fields for a few years are ideal for the development of creativity (Csikszentmihalyi, 1999; Dietrich, 2004; Runco, 2007). The fact that a creative movement to be applied in the field of sports is effective and at the same time has a positive effect on the result makes the concept of creativity very important.

Another dependent variable of the research is tactical skills. It is stated that in order to perform at a high level in competitive sports, the athlete must have advanced tactical skills along with technical and physiological parameters (Helsen, & Starkes, 1999; Nougier, & Rossi, 1999; Williams, & Ford, 2013). Tactical skills are seen in anticipation sports where the athletes compete against the opponent in the same action area during the game. While trying to reach the goal by entering the field of the opposing team, the players also have to adapt to the complex and rapidly changing game conditions. In this sense, tactical skill, which is a cognitive skill, refers to the ability of players to adapt to the flow of the game and the circulation of the ball by performing the right movements at the right time in anticipation sports (basketball, handball, football, ice hockey, etc.) (Elferink-Gemser et al., 2004; Grehaigne & Godbout, 1995).

The level of creativity and tactical skills of the players can be very effective in terms of winning the game in the face of various environmental factors and variability in the areas where sportive performance is exhibited. Accordingly, the fact that the players are experienced in offensive games such as basketball, handball and football, where original solutions and tactical skills come to the fore, increases the applicability of these two variables. Thus, players' capacity to cope with unexpected situations can increase (Memmert, Baker, & Bertsch, 2010). The purpose of this study is to evaluate handball player's creativity and tactical skills levels selected by their gender, sport age, national team experience and league levels. For this purpose, the relations between the creativity and tactical skills of the handball players with some variables were examined.

METHOD

Research Model

In this study, which was designed in a relational screening model, the relationships between the tactical skills and creativity levels of individuals who continue their sports life as handball players were examined. In this model, it is aimed to determine the existence and/or degree of co-variance between two or more variables (Creswell, & Creswell, 2017; Fraenkel, Wallen, & Hyun, 2012).

Participants

Participants were selected by convenient sampling method, considering easy accessibility and affordability (Gravetter & Forzano, 2012). As this study was conducted in Turkey, having a national experience in sport gives plenty of opportunities to athletes and it is an important matter. It was chosen the Super League and 1st League category for using the national team experience as a variable in this study is the assumption that these athletes are in an advantageous position in terms of social status and that might affect their cognitive skills. No limitations were determined except that the athletes participating in the research were licensed athletes in the Turkish Handball Super League and 1st League and were over the age of 18.

Research Procedure

The two of the questionnaires (Tactical Skills Questionnaire and Creativity Questionnaire for Athletes) have been uploaded to Google Forms and the link of the questionnaires had been sent to athletes by email. We reached out handball players through their team captains. An explanation

were also attached in the link about the importance of the research and athletes were informed how to fill the questionnaires.

Data Collection Tools

Tactical Skills Questionnaire for Sports (TSQ)

The Tactical Skills Questionnaire was developed by Elferink-Gemser, et al., (2004) to evaluate tactical skills in sports. Its adaptation to Turkish was made by Yarayan, Esenturk, and Ilhan (2019). The original form consists of 4 sub-dimensions and 22 items, namely Positioning and Decision Making (9 items) (α=0.89), Knowledge of Ball Movements (4 items) (α=0.75), Knowing the Opponents (5 items) (α=0.74), and Acting in Changing Situations (4 items) (α=0.72). The inventory, which has a 6-point Likert type structure, is "Very Poor" (1), "Poor" (2), "Average" (3), "Good" (4), "Very Good" (5) and "Excellent" (6) is scored in the format. High scores indicate that the tactical skills of the athlete are good. An important element of anticipation sports is possession of the ball. For this reason, the questionnaire distinguishes tactical moves with the ball from tactical moves without the ball. While the sub-dimensions of Positioning and Decision-Making in the questionnaire and Knowledge of Ball Movements are related to the skills during the attack when having the ball, the sub-dimensions of Knowing the Opponents and Acting in Changing Situations are related to the tactical skills during the defense in the off-ball game.

Conceptual Explanations of Sub-Dimensions of Tactical Skills Inventory in Sports;

Positioning and Decision Making (Attacking) (PDM): This dimension, which is related to the tactical skills to take a good position when having the ball, focuses on perceived procedural knowledge and choosing the right actions during the game (Elferink-Gemser et al., 2004).

Knowledge of Ball Movements (Attacking) (KBM): This dimension, which is related to tactical skills when the ball is in possession, perceives declarative knowledge and focuses on game knowledge (Elferink-Gemser et al., 2004).

Knowing Opponents (Defense) (KO): This dimension, which is related to the tactical skills related to the movements of the opponents in the ball game, perceives the declarative knowledge and focuses on the game knowledge (Elferink-Gemser et al., 2004).

Acting in Changing Situations (Defense) (ACS): This dimension, which is related to tactical skills related to different situations in the ball game, focuses on perceived procedural knowledge and choosing the right actions during the game (Elferink-Gemser et al., 2004).

Creativity Questionnaire for Athletes (CQA)

The Creativity Questionnaire for Athletes was developed by Gungor, et al., (2020) in Turkish. The questionnaire consists of a single sub-dimension and a total of 19 items (α=.91). During the development of the scale, it was determined that there was a high level, positive and significant relationship between the first and second application of the questionnaire as a result of test-retest reliability (r=.89, p<.01). The 5-point Likert-type questionnaire is scored as "I strongly disagree" (1), "I do not agree" (2), "I am undecided" (3), "I agree" (4) and "I totally agree" (5).

Ethical Procedure

Permission was obtained from Gazi University Ethics Committee to conduct the study. In addition, the participants signed a voluntary consent form stating that they participated in the research.

Analysis and Interpretation of the Data

Microsoft Excel and SPSS 22.0 computer program were used for the statistical analysis of the data obtained from the inventories. Normality assumptions were checked with the Kolmogorov-Smirnov test and it was determined that the data did not meet the normality assumptions. However, there is an increasing number of opinions in the related literature that normality tests are not sufficient in Likert-type scales (Hair et al., 2013; Tabachnick & Fidell, 2013). For this reason, the prominent skewness and kurtosis values for the normality assumptions were examined. In this context, the skewness and kurtosis values (-1.5, +1.5) suggested by Tabachnick & Fidell (2013) were taken into account and the distribution was found to be normal. In this direction, the T-Test was used to determine the differences between individuals' creativity and tactical skill levels according to the gender variable and national team experience. In addition, Pearson Product-Moment Correlation analysis was used to determine the relationships between the variables, and Multiple Linear Regression analysis was used to determine the power of the independent variable (Creativity) in predicting the dependent variable (Tactical Skills). The significance value was set as $p<.05$ for each test performed.

RESULTS

In the research, 137 men (52.9%) ($\overline{X}_{age}$ =2 3.90 ± 5.17) and 122 (47.1%) women ($\overline{X}_{age}$ = 24.13 ± 5.25) continuing their professional handball life in the Super League and 1st League category in the handball in Turkey were included. A total of 259 athletes participated voluntarily. In addition, the mean of years of playing handball for male athletes was determined as $\overline{X}_{y}$ear = 11.97 ± 5.60, and female athletes as $\overline{X}_{year}$ = 12.63 ± 5.37.

Table 1. Information on Descriptive Characteristics of the Participants

Variables		n	%
Gender	Male	137	52.9
	Female	122	47.1
	Total	259	100.0
League Category	Super League	129	49.8
	1st League	130	50.2
	Total	259	100.0
National Team Experience	Yes	146	56.4
	No	113	43.6
	Total	259	100.0

n: Sample size

In table 2, information on the mean, standard deviation, minimum and maximum scores obtained by the participants from both scales is presented.

Table 2. Average, Standard Deviation, Minimum and Maximum Values of the Inventories Used in the Scope of the Research

Scales	Sub-Dimensions	n	$\overline{X}$	Sd	Minimum	Maximum
TSQ	PDM	259	4.395	0.654	5.56	6.00
	KBM	259	4.312	0.519	2.25	5.00
	KO	259	4.476	0.722	2.80	6.00
	ACS	259	4.525	0.729	2.75	6.00
CQA	CQA Total	259	4.233	0.374	2.89	5.00

TSQ: Tactical Skills Questionnaire, PDM: Positioning and Decision Making, KBM: Knowledge of Ball Movements, KO: Knowing Opponents, ACS: Acting in Changing Situations, CQA: Creativity Questionnaire for Athletes, $\overline{X}$ mean, Sd: Standard deviation

In table 3, the tactical skill levels of the participants in sports are examined in terms of gender variable. It is seen that positioning and decision making (t = .482, p > .05), having knowledge about ball movements (t = -1.950, p > .05), recognizing opponents (t = .745, p > .05), acting in changing situations (t = 160, p > .05) and the total score of TSQ (t = .551, p > .05) did not show statistically significant difference. The creativity levels of the participants in sports according to the gender variable did not show statistically significant difference in the total score of CQA (t = -1.371, p > .05).

Table 3. T-Test Results of Tactical Skills and Creativity Levels by Gender Variable

Sub-Dimensions	Gender	n	$\overline{X}$	Sd	t	df	p
PDM	Male	137	4.413	.653	.482	257	.708
	Female	122	4.374	.657			
KBM	Male	137	4.253	.563	-1.950	257	.148
	Female	122	4.379	.458			
KO	Male	137	4.508	.734	.745	257	.788
	Female	122	4.441	.709			
ACS	Male	137	4.518	.789	-.160	257	.054
	Female	122	4.532	.660			
TSQ Total	Male	137	4.535	.605	.551	257	.975
	Female	122	4.494	.589			
CQA	Male	137	4.203	.398	-1.371	257	.288
	Female	122	4.267	.344			

PDM: Positioning and Decision Making, KBM: Knowledge of Ball Movements, KO: Knowing Opponents, ACS: Acting in Changing Situations, TSQ: Tactical Skills Questionnaire, CQA: Creativity Questionnaire for Athletes, t: t-value, df: degrees of freedom

In table 4, the tactical skill levels of the participants in sports were examined in terms of the league category variable. Positioning and decision making (t = -1.774, p > .05), knowing about ball movements (t = -.620, p > .05), knowing the opponents (t = -1.808, p > .831), acting in changing situations sub-dimensions (t = -2.890, p > .05) and the total score of TSQ (t = -2.257, p > .05) were not statistically significant. The creativity levels of the participants in sports according to the league category variable did not show statistically significant difference in the total score of CQA (t = -.293, p > .05).

Table 4. T-Test Results of Tactical Skills and Creativity Levels by League Category Variable

Sub-Dimensions	League Category	n	$\overline{X}$	Sd	t	df	p
PDM	Super League	129	4.323	.622	-1.774	257	.507
	1st League	130	4.466	.678			
KBM	Super League	129	4.292	.506	-.620	257	.828
	1st League	130	4.332	.533			
KO	Super League	129	4.395	.723	-1.808	257	.831
	1st League	130	4.556	.714			
ACS	Super League	129	4.395	.734	-2.890	257	.910
	1st League	130	4.653	.705			
TSQ Total	Super League	129	4.433	.588	-2.257	257	.825
	1st League	130	4.599	.596			
CQA	Super League	137	4.226	.380	-.293	257	.504
	1st League	122	4.240	.370			

PDM: Positioning and Decision Making, KBM: Knowledge of Ball Movements, KO: Knowing Opponents, ACS: Acting in Changing Situations, TSQ: Tactical Skills Questionnaire, CQA: Creativity Questionnaire for Athletes

In table 5, the tactical skill levels of the participants in sports are examined according to the variable of national team experience. Positioning and decision making ($t = 2.117$, $p > .05$), know opponents ($t = 1.083$, $p > .05$), acting in changing situations ($t = .272$, $p > .05$) sub-dimensions, and TSQ total score ($t = 1.559$, $p > .05$) did not indicate statistically significant difference. The scores obtained by the participants from the sub-dimension of having knowledge about ball movements ($t = .624$, $p < .05$) were found to be statistically significant. The creativity levels of the participants in sports according to the variable of national team experience did not show statistically significant difference in the total score of CQA ($t = 1.999$, $p > .05$).

Table 5. T-Test Results of Tactical Skills and Creativity Levels According to the Variable of National Team Experience

Sub-Dimensions	National Team Experience	n	$\overline{X}$	Sd	t	df	p
PDM	Yes	146	4.470	.623	2.117	257	.178
	No	113	4.297	.682			
KBM	Yes	146	4.330	.566	.624	257	.016*
	No	113	4.289	.453			
KO	Yes	146	4.519	.706	1.083	257	.310
	No	113	4.421	.741			
ACS	Yes	146	4.536	.728	.272	257	.361
	No	113	4.511	.734			
TSQ Total	Yes	146	4.567	.575	1.559	257	.089
	No	113	4.450	.620			
CQA	Yes	137	4.274	.396	1.999	257	.120
	No	122	4.180	.338			

PDM: Positioning and Decision Making, KBM: Knowledge of Ball Movements, KO: Knowing Opponents, ACS: Acting in Changing Situations, TSQ: Tactical Skills Questionnaire, CQA: Creativity Questionnaire for Athletes

The correlation analysis results between the tactical skill and creativity levels are analyzed according to the variable of the participants' years of playing handball in table 6, there is a positive low level correlation between the year of playing handball and PDM ($r = .214$, $p < .05$). there is a positive low level correlation between the year of playing handball and KO ($r = .181$, $p < .05$), there is a positive low level correlation between the year of playing handball and ACS ($r = .159$, $p < .05$) and there is a positive low level correlation between the year of playing handball and TSQ ($r = .212$, $p < .05$) and there is a positive low level correlation between the year of playing handball and CQA ($r = .222$, $p < .05$) and this relationship was statistically significant. Although a low level positive correlation was found between the year of playing handball and KBM ($r = .054$, $p > .05$), it was found that this relationship was not statistically significant.

Table 6. Correlation Analysis Results of Tactical Skills and Creativity by Years of Playing Handball Variable

Variable		PDM	KBM	KO	ACS	TSQ Total	CQA
Sport Age	r	.214	.054	.181	.159	.212	.222
	p	.001*	.383	.003*	.010*	.001*	.000*
	n	259	259	259	259	259	259

PDM: Positioning and Decision Making, KBM: Knowledge of Ball Movements, KO: Knowing Opponents, ACS: Acting in Changing Situations, , TSQ: Tactical Skills Questionnaire, CQA: Creativity Questionnaire for Athletes, *p < .05, r: Correlation co-efficient, p: Reliability co-efficient, n: Sample size

Findings Related to Regression Analysis

During the analysis of the data, first of all, Pearson Product-Moment Correlation analysis was conducted in order to test the relationships between the predictive variable of the research, "Creativity Questionnaire for Athletes" and the predicted variable (Sub-Dimensions of Tactical Skills Questionnaire).

There is a moderate positive correlation between creativity and PDM ($r = .549$, $p < .05$), KO ($r = .575$, $p < .05$), and ACS ($r = .471$, $p < .05$). It was found that there was a high level of positive correlation between creativity, and KBM ($r = .809$, $p < .05$). These relationships were statistically significant (Table 7). After the relationships between the variables were determined, multiple regression analysis was analyzed in the Table 8.

Table 7. Correlation Analysis Results on Creativity and Tactical Skill Levels

Sub-Dimensions of TSQ		CQA
PDM	r	.549
	p	.000*
	n	259
KBM	r	.809
	p	.000*
	n	259
KO	r	.575
	p	.000*
	n	259
ACS	r	.471
	p	.000*
	n	259

PDM: Positioning and Decision Making, KBM: Knowledge of Ball Movements, KO: Knowing Opponents, ACS: Acting in Changing Situations, CQA: Creativity Questionnaire for Athletes, *p < .05

It is seen that the multiple linear regression model established in Table 8 is significant. In this context, when the results of the analysis are examined, it is seen that the tactical skill levels of the participants in sports are not significantly predicted by the ACS sub-dimension. However, it was determined that PDM, KBM and KO sub-dimensions significantly predicted tactical skill levels in sports and explained approximately 74% of the variance ($R = .865$; $R^2 = .748$, $p < .05$). In line with this result, it can be said that the use of creativity in sports is the determinant of tactical skills.

Table 8. Multiple Linear Regression Analysis Results on the Prediction of Tactical Skills by the Level of Creativity

Predictive Variables	B	Std. Error	Beta	t	p	Tolerance	VIF
(Stable)	1.277	.111		11.547	.000*		
PDM	.087	.026	.153	3.404	.001*	.494	2.023
KBM	.483	.025	.670	19.213	.000*	.816	1.226
KO	.111	.025	.215	4.406	.000*	.419	2.387
ACS	-.002	.022	-.004	-.097	.923	.517	1.935

R=.865; R^2=.748; F=188.248; Durbin Watson=1.822; p<.05, PDM: Positioning and Decision Making, KBM: Knowledge of Ball Movements, KO: Knowing Opponents, ACS: Acting in Changing Situations, *p < .05

DISCUSSION

In the current study, the scores obtained by the handball players from the creativity and tactical skill questionnaires were examined in terms of gender, year of playing handball and league category.

As a result of the t-test analysis, it was found that the scores of the participants from the creativity and tactical skill questionnaire were not statistically significant in terms of gender variable. Based on this result, it can be interpreted that the gender difference does not have an effect on the creativity and tactical skill levels of the handball players.

The scores obtained by the participants from the TSQ according to the league category of the team in which they play handball are analyzed, although the scores obtained from all sub-dimensions are high in favor of the handball players competing in the 1st league, this difference was not found to be statistically significant. Although the scores were higher in favor of the athletes competing in the 1st League, this difference was not statistically significant. Assuming that the competition and level of competitiveness between the handball teams competing in the Super League is higher, it is expected that the tactical skills and creativity levels of the athletes competing in this league are higher. However, on the contrary, it was found that the athletes in a lower league got higher scores in TSQ and CSA, and their tactical skill levels were slightly higher than the athletes in a higher league. From this point of view, it may be that the athletes in a lower league did not evaluate themselves objectively when filling out the scales, and thus their tactical skill and creativity levels were higher than the athletes competing in the higher league.

As a result of the t-test analysis of the scores of the participants in the KBM sub-dimension of the TSQ according to the variable of having national team experience, it was determined that the difference was statistically significant in favor of the national handball players. However, there was

no statistically significant difference in the scores obtained by the handball players in other sub-dimensions (PDM, KO, ACS) of TSQ. The more successful national handball players in the KBM may be associated with their higher tactical capacity for offensive and attacking games than non-national handball players. Although there is an increase in favor of national handball players in the scores obtained from the CSA, this difference is not statistically significant.

As a result of the correlation analysis made according to the variable of the handball players' years of playing sports, according to the scores they obtained from the other sub-dimensions except for the KBM sub-dimension of TSQ; It has been determined that the high sports age of the handball players also affects the tactical skill levels positively. Likewise, it was concluded that the high sports age of the handball players positively affects their creativity levels. Memmert, Baker and Bertsc (2010) conducted an experimental study supporting the same result in their research. The increase in the time spent by the players competing in team sports played with the ball in that sport also positively affects the creative thinking skills of the athletes.

As a result of the correlation analysis made in the light of the data collected from the current research, it was concluded that as the creativity levels of the handball players increase, their tactical skill levels will also increase. Especially in offensive games (Memmert, Baker & Bertsc, 2010; Roca, & Ford, 2021), the athlete will be able to correctly fulfill the tactics given to him as long as he uses his creativity skills at the right time and place. Thus, the element of winning, which is one of the most important satisfying features of sports, will not depend on random factors, but will enable the athlete to reach the desired result by using his cognitive skills together with his physical capacity.

CONCLUSION

In the development of creativity in sports, unstructured activities applied in training are considered very important in terms of developing this cognitive feature (Kurtzberg & Amabile, 2000). As with the development of some cognitive processes, participation in various sports and physical activities plays an important role in the development of creative thinking (Dietrich, 2004; Runco; 2007; Sternberg & Lubart, 1998). According to Piaget, symbolic games seen in childhood are very important for the cognitive development of the individual. During this period, the child's playing with imaginary characters develops his/her creative thinking skills by pushing the limits of his/her cognitive capacity by physically manipulating reality by dreaming of the non-existence (Piaget, 1962).

In conclusion, we found a level of moderate relation between creativity and tactical skills of handball players. Thus, the more they play handball, the more they have creativity and tactical skills. By the years pass in handball, they become more experienced in handball, and also given tactics by coaches can be applied effectively by athletes. Today, with the development of technology, a more sedentary lifestyle has begun to be adopted. As a result of this, street sports are no longer as they used to be, irregular training programs and lack of game knowledge are seen as some factors that limit the creative thinking potential of athletes (Memmert, 2013). In addition, the necessity of complying with a predetermined plan and strategy during the competition, the fact that the athletes struggle in a strict game environment and environmental conditions can be shown among some of the obstacles to producing creative solutions.

As a suggestion, the creativity and tactical skill levels of handball players can be evaluated by using different variables such as their positions in the game for further research.

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