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Contents

KINESIOLOGY

Gaetano Altavilla, Sara Aliberti, Tiziana D'Isanto, Gaetano Raiola
A comparison between ecological-dynamic and cognitive approach to improve accuracy in basketball shot 6

Michal Bozděch, Adrián Agricola, Adam Křehký, Petr Schlegel, Jiří Zháněl
Relative age effect in elite swimmers in U14 Czech Championship 13

Rosario Ceruso, Tiziana D'Isanto, Gaetano Altavilla, Giovanni Esposito, Felice Di Domenico, Francesca D'Elia
Functional classification and performance in wheelchair basketball 23

Jan Florian, Emanuel Hurych
HIIT system programming and some practical problems of its application examined within the sample of selected Czech probands in Brno 33

Pavol Horička, Jaromír Šimonek
Relationship between motor learning and general intelligence 44

Homa Naderifar, Leila Ghanbari
Effect of Selected Corrective Exercises on Glenohumeral Rotation range of Motion in Overhead Athletes with Scapular Dyskinesis 54

Kateřina Strašilová, Petr Vajda
The Effects of Different Rest Interval Lengths on Acute Quarter-squat Performance in Female 63

SOCIAL SCIENCES

Michal Tomíček, Natalie Pelloneová
Ranking Players by DEA: An analysis of Czech and Danish football 76

Petr Scholz, Ivan Růžička
Female Spectatorship and Unsportsmanlike Conduct at Football Stadiums: Case Study from the Czech Republic 91

STUDENT SECTION

Torki Ishak, Djouadi Khaled, Hana Válková
Benefits of 6 weeks of high interval intensity training based on basic fitness variables and losing weight during the pandemic of covid-19 period. 102

Tomáš Válek, Roman Kolínský, Petr Konečný, Jiří Zháněl
Bilateral Differences in Handgrip Strength in Czech Female Tennis Players Aged 11–12 Years and Injury Prevention 113

Jakub Fikar, Tomáš Vencúrik
Relationship between speed and explosive power of lower limbs in semi-elite football players 120

KINESIOLOGY

Editors:
doc. Mgr. Martin Zvonař, Ph.D.,
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A comparison between ecological-dynamic and cognitive approach to improve accuracy in basketball shot

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Abstract

BACKGROUND *The shot is a fundamental skill in basketball that requires high accuracy, because is the tool by which players translate their team's offensive actions into points. Basketball is one of the most practiced situational sports in physical education hours in schools. However, it is still mostly teaching according to a traditional, prescriptive-based model. The aim of the study was to compare prescriptive teaching with ecological-dynamic learning for improving shooting accuracy in a group of 3rd year high school students.* METHODS *The sample is made up of 32 students (16 ± 0.72) divided into 2 groups: Group A, consisting of 16 students who were administered a training protocol based on the ecological--dynamic approach, and Group B, consisting of 16 students, who followed a cognitive approach. The undershot test was administered in and out to test the students' level of shooting accuracy. A t test for paired dependent samples and for independent samples were performed to compare two groups and to verify which of them had the greater improvement. Data were analyzed using SPSS.* RESULTS *The results were statistically significant in group A ($p < 0.05$); infact, group A had a greater improvement in shooting accuracy than group B.* CONCLUSION *The ecological-dynamic approach was able to improve accuracy in shot more than the cognitive approach in a group of high school students.*

Keywords: *teaching, learning, approach, shot, basket, physical education.*

INTRODUCTION

The shot is a fundamental skill in basketball that requires high accuracy, because is the tool by which players translate their team's offensive actions into points (Raiola & D'Isanto, 2016). It is also the most personalized fundamental because each student is different, the muscle districts change, and consequently intervene differently in the coordination of the gesture. Each student must find his own style according to his own characteristics. The procedure of teaching the shot is very important because the technical gesture must be as fluid and correct as possible. We must consider, however, the mental limits because many times the students tend to throw the ball quickly, often making mistakes. This denotes a poor ability to manage emotions. Fundamental to scoring points, shot is the fun part of this sport. The main factors involved in shooting are technical, physical and mental. We can in fact distinguish the sensitivity of the fingers in the phase of reception or collection of the ball, balance, coordination, shooting mechanics, strength, given by the thrust of the lower and upper limbs, the gaze, psychological factors such as responsibility and autonomy. We can say that the shot is a gesture of absolute precision. Basketball is a team sport where you cannot rely solely on individuality to win. You win as a team and above all by communicating between players and between coach and players. In basketball, offensive and

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defensive collaboration systems require effective communication between players and a quick and correct understanding of game situations (Altavilla & Raiola, 2015).

There are several educational messages that sport conveys through its rules (Altavilla et al., 2020; D'Elia et al., 2020; Raiola et al., 2020). Basketball is one of the most practiced situational sports in physical education hours in schools. Sports education is probably the most implemented and researched pedagogical model around the world (Farias et al., 2018). Currently, one of the most used schools is the cognitive, performance-oriented approach (Raiola, 2014; Raiola & Di Tore, 2017; Raiola & Tafuri, 2015). However, different teaching methods can be applied to improve the execution of the technical skill with respect to the place where it is verified. In fact, the ecological-dynamic approach should prevail in schools, and the cognitive approach in sports clubs. Cognitive approach follows a prescriptive teaching, in which the teacher is at the center of the action and prescribes exercises to the student with the aim of perfecting and stabilizing motor programs. The exercises can be partial, simplified or segmented (Wightman & Lintern, 1985), varied, randomized, mental training. The other kind of approach is defined as ecological-dynamic and it is based on discovery. Unlike the previous one, the action is directly available to those who act in their environment (Raiola, 2012). The motor sense system possesses self-organizing properties that make the use of a motor program unnecessary (Edelman, 1987). This approach is based on Bernstein's theory of the three degrees of freedom: freeze, release, and capitalize. Most importantly, it uses instructional practices such as peer tutoring, tutoring, brainstorming, role-play, circle time, cooperative learning, to maximize exploration (Raiola & Di Tore, 2012). The most effective active teaching methodologies are realized in a flexible learning environment that gives space to the interests of students and their experiences. Learning comes from the laboratory experience, which places the student at the center of the process, enhancing his skills and his relational experience. Even in teaching a skill, such as the shot in basketball, these methodologies in a school setting could be very functional.

However, in schools, physical education is still mostly taught according to a traditional model, based on prescriptive teaching (Raiola, 2013). Based on direct observation, it was found that a group of 3rd year high school students had difficulty with the technical act of shooting a basket. The aim of the study was to compare cognitive and ecological-dynamic approach for improving shooting accuracy in students.

Hypothesis of the study are as follow:

1. H_0 – The null hypothesis assumes that students that follow a program based on ecological-dynamic approach do not improve their accuracy in basketball shot, unlike those who follow a program based on cognitive approach.
2. H_1 – The alternative hypothesis assumes that students that follow a program based on ecological-dynamic approach improve their accuracy in basketball shot, like those who follow a program based on cognitive approach. Being that there is a notion that the ecological-dynamic approach is often a waste of time and does not lead to improvements in skill acquisition this study may change the minds of many teachers who think this way.

METHODS

Participants' characteristics

The sample is made up of 32 Italian male students (age, Mean ± standard deviation [SD] = 16 ± 0.72 years old) belonging to the 3rd years high school. Students were randomly divided into two groups: Group A, consisting of 16 students, was subjected to the ecological-dynamic approach and Group B, consisting of 16 students, to cognitive approach. The students

included had no basketball experience and scored low on the undershot test. The study adhered to ethical code of the Declaration of Helsinki and written informed consent was obtained from all participants. Data were stored and processed anonymously.

Test procedure

The undershot test (tiro da sotto), an Italian test realized by Mondoni (2000), is designed to assess the technical skills of children in the execution of the sporting gesture. The subject is placed at 1 m along the bisector of the right angle formed by the backboard and the axis of the basket perpendicular to it. He starts shooting from the side corresponding to his strong hand. Once the first shot has been made, the subject must quickly retrieve the ball, return to the starting position on the dribble and shoot again from the same side until he makes 5 baskets. At this point he moves to the other side to shoot 5 more baskets. Measure the time needed to make 10 baskets (5 on the right and 5 on the left) from the moment the subject starts shooting. Have the subject perform a test only and record it. To carry out the test, a basketball for the boys category, the basket at a regulation height (305 cm) and a stopwatch to calculate the time of the test were used. The test was proposed in entry, to verify the ability in the execution of the fundamental technique, in exit, following practical exercises.

Training protocols

Group A: ecological-dynamic approach. The exercises proposed to the students were focused on practical exercises aimed at a heuristic learning of the gesture through various strategies such as: problem solving, discovery learning, circle time. The exercises proposed during the 4 weeks following the entrance test, all took place in the gym during the 2 curricular hours of physical education per week, and lasted about 45 minutes. A detailed description of the type of activity proposed is shown in **Table 1.**

Table 1. Structure of a typical lesson using ecological-dynamic approach.

Phase 1: Autonomous research of the solution (problem solving)	We made the students freely execute the basket shot without giving any information, seeing how the boys tried to execute it according to their previous experiences. The students will perform the gesture independently, they will test themselves and we will intervene only to give suggestions to improve the execution or any feedback of reinforcement in order to make the student understand the adequacy of his execution.
Phase 2: Altering time and game parameters and cooperative learning	We have structured drills in such a way as to bring the students indirectly closer to the model of the technical gesture, implementing changes to the environment in order to make them more likely to succeed according to different strategies: • We shoot the basket • We use balls of different sizes • We use balls of different weights The activities were carried out in small groups or in groups of two, cooperatively.
Phase 3: Circle time	It is not a real exercise, but it is a fundamental part for the children who, gathering in groups in the center of the gym at the end of the hour of physical education, discuss the results obtained in the execution of the exercises and their experience in practicing them. Circle time develops life skills, especially interpersonal skills.

Group B: cognitive approach. On the other hand, the exercises proposed for the second group included a prescriptive teaching of the technical gesture, in particular focused on the varied exercise. Therefore, the students have performed more movements belonging to the same class, going to perform the same technical gesture (shooting basket) through multiple executive variants of the

same generalized motor program. In this way, they enhanced learning because they exercised the parameterization of the technical gesture. The training sessions centered on prescriptive teaching included, according to the didactic strategy of the varied drill, the exercises shown in **Table 2.**

Table 2. Structure of a typical lesson using a cognitive approach.

Refining accuracy	The boys under instructions from the coach are placed at different distances from the basket, first at 1 meter, then 3 meters and finally 5 meters.
Variation of execution time	The teacher establishes the time within which the students must make the shot at the basket: a reduced time (1–2 seconds) will therefore lead the students to have to make the shot faster, without having the opportunity to prepare adequately for the execution of the shot; a longer time (5 seconds) will allow the students to prepare adequately before the execution and to have greater concentration at the time of execution.
Variation of shot direction	The teacher will place marks on the floor from which the children must shoot at the basket explaining in detail to the child how to make the shot towards that direction indicated by him.
The type of exercise is always focused on the continuous repetition of the motor gesture.	

STATISTICAL ANALYSIS

After verifying normality of the data with Shapiro Wilk Test and homogeneity of variances with Levene test, a t-test for independent samples was performed to compare the two groups, A and b, before and after 4 weeks, to verify if there was an improvement in accuracy thanks to the two metodological approach, ecological-dinamic and cognitive, and a t-test for paired samples to verify the improvements of each group. Statistical significance was set at $P \leq 0.05$. To qualitatively interpret the magnitude of differences, effect sizes (d) and associated 95% confidence intervals (95%CI) were classified as small (0.2–0.5), moderate (0.5–0.8) and large (>0.8) (Cohen, 1988). Data analyzes were performed using Statistical Package for Social Science software (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY).

RESULTS

Before starting the experimental study, the test execution time of group A and B were very similar, so this means that they started at the same level. After 4 weeks, the time to complete 10 baskets decreased in both groups, albeit more so in group A. A detailed description of undershot shot test time administered pre-post 4 weeks is shown in **Table 3.**

Table 3. Undershot test time of A and B groups

	Groups	N	Mean	Std dev.	Error std mean
Pre	A	16	69.62	10.93	2.59562
	B	16	69.81	7.67	1.91968
Post	A	16	58.68	5.37	1.34387
	B	16	65.56	7.65	1.62788

A result not statistically significant was found before starting the experimental study between group A and B (p=0.969). After 4 weeks, the result was statistically significant (p=0.003). A detailed description is shown in **Table 4.**

Table 4. T-test for independent sample

	t	df	Sign (two tails)	Difference in mean	Error std. mean	Confidence interval 95%		d (95% CIs)
						Lower	Upper	
Pre-test	0.039	30	0.969	0.12500	3.22837	–6.46822	6.71822	0.01 (0.02; 0.44)
Post-test	–3.227	30	0.003	–6.81250	2.11092	–11.12358	–2.50142	0.07 (0.01; 0.27)

Regarding the difference between pre-post each group the result was statistically significant in group A (p=0.002) but not in group B (p=0.117). A detailed description is shown in **Table 5.**

Table 5. T-test for paired samples

		Mean	St. dev	Error st. mean	Confidence interval 95%		t	gl	Sign. (two tails)	d (95% CIs)
					Lower	Upper				
A	Pre-post test	11.25000	12.24473	3.06118	4.72525	17.7747	3.67	15	0.002	0.91 (0.12; 0.98)
B	Pre-post test	4.31250	7.40017	1.85004	0.36923	8.25577	2.33	15	0.117	0.41 (0.01; 0.59)

DISCUSSION

The results show that in group A, that followed an ecological-dynamic approach, there was a significant improvement in the accuracy of the basketball shot, in fact, students decreased the time in which they performed the test, which consisted of shooting the ball 10 times in the basket. Also in group B, that followed a cognitive approach there was an improvement in accuracy, but it was not considered significant by statistics. Both methodologies proved to be effective, however group A, which followed lessons based on the ecological-dynamic approach, had a significantly greater improvement than the group that followed lessons based on the cognitive approach. Possible explanations for the results obtained can refer to the fact that, especially in school contexts, leaving students free to explore all the possibilities of movement and execution of gestures can bring many advantages over the cognitive approach, which is, however, used mainly in sports contexts where the coach conducts the activity in a highly intense and often too incisive and aggressive way.

From the national indications for the curriculum of the secondary school (Viscione et al., 2019), and in particular from those addressed to the high schools, it follows that in the second two years the action of consolidation and development of knowledge and skills of students will continue in order to improve their motor and sports training. At this age the students, also favored by the complete maturation of the frontal cognitive areas, will acquire an increasing ability to work with a critical and creative sense, with the awareness of being actors of every bodily experience lived (Raiola et al., 2015). In these years, students through the knowledge and practice of different sports activities, discover and enhance personal attitudes, skills and preferences by acquiring and mastering first motor skills and then the specific sport techniques, to be used in an appropriate and controlled way. In our case, students practiced improving shooting accuracy in the discipline of basketball. On the one hand, problem solving, cooperative learning, circle time, and altering the rules of play and space were used. On the other hand, varied practice. Both

variations resulted in a significant improvement in shooting accuracy. What made the difference was motivation. The motivational climate refers to the teacher's ability to promote an adequate situational structure of the environment (Sgrò et al., 2019). The students who focused on repetition of the gesture, showed themselves bored and did not conceptualize enough. Students who used instructional practices, on the other hand, showed more motivation and working in pairs motivated each other, and therefore had greater improvements because they were not bored and practiced throughout the lesson. Therefore, to overcome the boredom elicited by repetition, it is important to focus on the instructional practices. Physical education has broad pedagogical value and should be used to its fullest extent (D'Elia, 2019; D'Elia, 2020; D'Isanto, 2016). The physical activity stimulates growth through relationship in the group (Altavilla & Di Tore, 2016) and also the educational value and the learning opportunities that occur within it (Raiola et al., 2016; Di Tore, et al., 2013). Only with the repetition of the gesture, this is not possible. For this reason, the ecological-dynamic approach is more complete at the educational level.

The study has some limitations, such as sample size and lack of reliability test. Future researchers are encouraged to compare the cognitive approach with the dynamic ecological for learning sport skills from various sports. The results of this study have important implications for teachers who believe that the ecological-dynamic approach is just fun and does not actually lead to improved technical gestures.

CONCLUSIONS

We can affirm that by following the guidelines of the ecological-dynamic approach and focusing on a heuristic learning of the gesture we could appreciate important improvements already after four weeks, compared to the prescriptive teaching, based on the repetition of the gesture. The usefulness of the study proposed here is therefore in showing how ecological-dynamic approach has allowed children to obtain important improvements in the improvement of a technical skill on which they were initially lacking, resulting in fact more appropriate than the cognitive approach focused on prescriptive analytical strategies. This can also be explained by the fact that ecological-dynamic approach is particularly suitable for students who already have a good predisposition to the task, as in the case of the subjects analyzed in our study. Despite this, cognitive approach is certainly not a methodology to be excluded, as it has, however, brought improvements in our students, but in the case mentioned it was certainly not the most effective strategy. It is important to emphasize that there is not one methodology that is better than another (Pesce et al., 2015), but simply that we need to know all of them in order to understand which is the most relevant according to the situation, the students and the context we are dealing with.

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Relative age effect in elite swimmers in U14 Czech Championship

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Abstract

PURPOSE *The issue of the Relative Age Effect (RAE) has been studied in the theory of sports for more than 30 years. Most studies concentrate on team sports, while the area of some individual sports like swimming can be considered still underexplored.*

METHODS *The aim of our study was to verify the RAE in young elite swimmers (n = 198) who participated in Czech Republic U14 Championship (1) in male and female samples (2) according to swimming disciplines and distances (3) and performance (times in individual disciplines) between individual quartiles / semesters of birth. The analysis was performed with the use of adequate statistical (chi-square test, Kruskal-Wallis H test, Mann-Whitney U test) and effect size (effect size w index, eta-square test, effect size r index) tests.*

RESULTS *The results showed a different intensity of RAE sex-differences (male: w = 0.033; female: w = 0.006). In the division by the swimming disciplines and swimming distances, statistically significant values with large effect size were found in males in 50 m freestyle, 200 m individual medley, 100 m butterfly and 200 m butterfly. However, this did not apply for girls. Analysis of differences in performance showed a significant difference between the dependent variables (sex, distance, discipline) by different independent variables of quartile / semester of birth with large effect size only in cases of male 100 m breaststroke and female 200 m individual medley.*

CONCLUSIONS *The issue of RAE should be circulated among the coaches working with youth, athletes, sports organizations, but also parents of athletes in order to avoid the termination of actively spent time or drop-outs.*

Key words: *birthdate, performance, sport, swimming, sex, adolescence*

INTRODUCTION

In the field of sports sciences, the Relative Age Effect (RAE) term refers to the deviation of the distribution in birthdates of selected athletes from the normal distribution in the population (Delorme, Boiché & Raspaud, 2010). This means that the birthdates for a selected sample of athletes are not distributed proportionally, as are the birthdates for a corresponding segment of normal population, i.e. approximately evenly throughout the year. A higher frequency of athletes is, on the contrary, cumulated at the beginning of the selected time period (year, season), which means that athletes born at the beginning of the year/season are represented more often in the selected sample than athletes born in later months (Agricola, Zháněl & Hubáček, 2013; Lames, Augste, Dreckmann, Görsdorf & Schimanski, 2008). This fact can significantly affect the level of physical and performance preconditions in previously born athletes, especially in youth categories and, in particular, during the period of puberty, when the differences in anthropometric, resp. motor characteristics get even deeper (Cobley, Baker, Wattie & McKenna, 2009; Lames et al., 2008; Nykodým, Bozděch, Agricola & Zháněl, 2020).

In general, most studies have confirmed RAE mainly in youth categories and in top-level / elite sports (Cobley et al., 2009). The main interest of the authors of RAE studies in sports is mostly

focused on team sports, especially ice hockey (Bezuglov et al., 2020; Fumarco, Gibbs, Jarvis & Rossi, 2017; Nykodým et al., 2020) and soccer (Götze & Hoppe, 2020; Li et al., 2020; Roberts et al., 2020). However, we can find numerous RAE studies also in some individual sports, for instance in tennis (Moreira, Lopes, Faria & Albuquerque, 2017; Ulbricht, Fernandez-Fernandez, Mendez-Villanueva & Ferrauti, 2015; Wendling & Mills, 2018) and skiing (Bjerke, Lorås, Vorland & Pedersen, 2020; Müller, Gonaus, Perner, Müller & Raschner, 2017; Steidl-Müller, Hildebrandt, Raschner & Müller, 2019). On the other hand, we record only a small number of RAE studies in some (mainly individual) sports including swimming. Nevertheless, we can state from the conclusions of available studies that the existence of RAE has been proven in most cases in elite junior male and female swimmers, similarly as in other sports (Baker, Schorer & Cobley 2010; Cobley et al., 2009; Lames et al., 2008). We know from the conclusions of various studies that the occurrence of RAE in swimming is less frequent in girls / females than in boys/males (Baker et al., 2010; Cobley et al., 2009; Romann, Rössler, Javet & Faude, 2018) and the approximate age of 12–13 can be marked as the period of its strongest influence; later the RAE effect gradually and irregularly weakens, it may disappear completely, or so called reverse RAE may appear (Cobley et al., 2018, 2019). However, this does not mean that the relatively older swimmers achieve better specific performance (time in a given discipline) than their relatively younger peers (Costa et al., 2013). Based on the assessment through effect size tests, we can state that RAE is more pronounced with a higher level of performance, especially in the categories of 13–15 years (Cobley et al., 2019). Some studies have demonstrated RAE also in senior categories (Ferreira et al., 2017), which is usually the result of drop-out of swimmers already in junior categories and age bias environment.

As mentioned above, we still do not find a sufficient number of studies in some sports to analyse the issue of RAE in individual disciplines, age categories or performance levels which prevents a comprehensive understanding of RAE in the specific sport.

Since the conclusions of our detailed literary research imply that one of these sports is also swimming, we decided to turn our attention to this problem. The aim of our study was to find whether there existed any RAE: (1) in male and female participants of 2019 Czech swimming Championship in the U14 category, (2) in the division according to swimming disciplines and distances (3) and in relation to the performance between individual quartiles or semesters of birth, based on the times achieved in individual disciplines.

METHODS

Participants

The participants of the presented descriptive research were swimmers (male n = 94; female n = 104) who participated in the Czech U14 Summer Masters Swimming Championship in Zlín (50 m pool) in 2019. Czech Masters Swimming Championship are organized by the Czech Swimming Federation (ČSPS) according to the valid rules of the FINA international swimming federation, adjusted for the situation of the Czech Republic. The condition of qualification is participation at regional Championship; for long distance swimming, at long-distance swimming regional pupil Championship, eventually participation in the Czech Long-Distance Swimming Cup (hereinafter referred to as qualifying races). At the Czech Masters Swimming Championship, the swimmers can compete only in the disciplines in which they have raced in qualifying races; and only in six disciplines. A maximum of 32 swimmers can participate in 50 m, 100 m, 200 m and 400 m disciplines; maximum of 24 swimmers in 800 m and 1500 m. Admission of a competitor to the race depends on qualifying time; the number of swimmers from one club is not limited.

Procedures

Research variables (n = 26) consisted of 5 swimming disciplines (freestyle [FS], backstroke [BAS], butterfly [BF], breaststroke [BRS], individual medley [IM] and 6 different distances (50 m, 100 m, 200 m, 400 m, 800 m, 1500 m) by sex (male, female). As a categorical variable we chose, with regard to our research objective, dates of birth divided by quarters (Q_i) into Q_1 (January through March), Q_2 (April through June), Q_3 (July through September) and Q_4 (October through December), see Table 1–3, or divided by semesters (S_i) into S_1 (January through June) and S_2 (July through December), see Table 4.

Statistical analysis

Research data were analysed using adequate methods of descriptive (absolute and relative frequency, median, lower and upper quartile) as well as inference (chi-square test, Kruskal-Wallis H test and Mann-Whitney U test) statistics and effect size tests (effect size w index, eta-square test and effect size r index). Chi-square goodness of fit test (χ^2) was used to verify the differences between the expected and observed birthdate distributions. The expected distribution was determined by days in Q_i: Q_1 = 90/365.25 (24.6%); Q_2 = 91/365.25 (24.9%); Q_3 = 92/365.25 (25.2%); Q_4 = 92/365.25 (25.2%). Threshold values for small (w = 0.10), medium (w = 0.30), large (w = 0.50) effect were used to assess the effect size (ES) w index (Cohen, 1988). The significance of the differences between the independent variable (Q_i) and dependent variables (sex, swimming styles, and race distance) was assessed using Kruskal-Wallis H test and eta-squared effect size test (η^2), together with 95 % confidence interval (CI). The threshold values for η^2 (Cohen, 1988) are small (η^2 = 0.01), medium (η^2 = 0.06) and large (η^2 = 0.14) effects. Mann-Whitney U test was used in case if independent variables (Q_i) contained less than 5 swimmers; in these cases, we chose semesters (S_i) instead of the Q_i independent variables. To assess effect size, we used effect size r index for Mann-Whitney U test, which can be interpreted as a small (r = 0.10), medium (r = 0.30), or large (r = 0.50) effect (Cohen, 1988). All the values of ES indexes (w, η^2, r) smaller than small effect were marked as trivial (Cohen, 1988) and we transformed them into the Common Language Effect Size, (CLES), for their better interpretability and generalizability (Cohen, 1988; Dunlap, Cortina, Vaslow, & Burke, 1996; McGraw & Wong, 1992). Statistical calculations were performed using licensed IBM SPSS Statistics for Windows software (IBM Corp, Armonk, New York, USA, v. 25.0). The threshold at α = 0.05 was chosen as the level of statistical significance.

RESULTS

Table 1 contains the results of an analysis of birthdate distribution and the evaluation of RAE for the whole research group and its effect on sex. Table 2 further includes analyses of birthdate distribution and an assessment of the level of RAE effect for individual research variables, performed with the use of test in terms of statistical significance and magnitude of effect size. The following Table 3 and 4, however, do not give the numbers of frequencies as in the case of Table 1 and 2, but the final times of the competitors [MM:SS.SS]. This made it possible to verify the presumption whether the relatively older swimmers performed better, in the form of better time, because of their biological advantage.

Table 1. Differences between the Expected and Observed Distribution of Swimmers' Birthdate

Sex	Birthdate quarters				n	χ^2	p	W
	Q_1 (%)	Q_2 (%)	Q_3 (%)	Q_4 (%)				
Male	35 (37.23)	22 (23.40)	22 (23.40)	15 (15.96)	94 (100%)	9.846	0.020	0.033
Female	28 (26.92)	27 (25.96)	25 (24.04)	24 (23.08)	104 (100%)	0.385	0.943	0.006
Total	63 (31.82)	49 (24.75)	47 (23.74)	39 (19.70)	198 (100%)	6.600	0.086	0.013

Note: $Q_{1–4}$: quarter of birth; χ^2: chi-square goodness of fit test; w: effect size w index (Cohen's w)

Table 2. Differences between the Expected and Observed Distribution of Swimmers' Birthdates in Sex, Distance and Discipline

Sex	Distance	Discipline	Birthdate quarters				n	χ^2	p	w
			Q_1 (%)	Q_2 (%)	Q_3 (%)	Q_4 (%)				
M	50	FS	14 (45.16)	8 (25.81)	8 (25.81)	1 (3.23)	31 (100%)	10.625	0.014	0.585
M	100	FS	14 (43.75)	7 (21.88)	7 (21.88)	4 (12.50)	32 (100%)	6.750	0.080	0.459
M	100	BAS	11 (34.38)	8 (25.00)	7 (21.88)	6 (18.75)	32 (100%)	1.750	0.626	0.234
M	100	BF	16 (50.00)	11 (34.38)	4 (12.50)	1 (3.13)	32 (100%)	17.250	0.001	0.734
M	100	BRS	8 (34.78)	4 (17.39)	7 (30.43)	4 (17.39)	23 (100%)	2.167	0.539	0.307
M	200	FS	10 (31.25)	5 (15.63)	10 (31.25)	7 (21.88)	32 (100%)	2.250	0.522	0.265
M	200	BF	13 (40.63)	11 (34.38)	6 (18.75)	2 (6.25)	32 (100%)	9.250	0.026	0.538
M	200	IM	13 (40.63)	7 (21.88)	10 (31.25)	2 (6.25)	32 (100%)	8.250	0.041	0.508
M	200	BAS	11 (34.38)	6 (18.75)	6 (18.75)	9 (28.13)	32 (100%)	2.250	0.522	0.265
M	200	BRS	10 (31.25)	9 (28.13)	9 (28.13)	4 (12.50)	32 (100%)	2.750	0.432	0.293
M	400	FS	13 (40.63)	6 (18.75)	5 (15.63)	8 (25.00)	32 (100%)	4.750	0.191	0.385
M	400	IM	9 (29.03)	10 (32.26)	7 (22.58)	5 (16.13)	31 (100%)	1.875	0.600	0.246
M	1500	FS	6 (26.09)	6 (26.09)	4 (17.39)	7 (30.43)	23 (100%)	0.833	0.841	0.190
F	50	FS	9 (28.13)	11 (34.38)	7 (21.88)	5 (15.63)	32 (100%)	2.500	0.475	0.280
F	100	FS	11 (34.38)	8 (25.00)	9 (28.13)	4 (12.50)	32 (100%)	3.250	0.355	0.319
F	100	BAS	10 (31.25)	11 (34.38)	7 (21.88)	4 (12.50)	32 (100%)	3.750	0.290	0.342
F	100	BF	11 (34.38)	7 (21.88)	3 (9.38)	11 (34.38)	32 (100%)	5.500	0.139	0.415
F	100	BRS	7 (21.88)	7 (21.88)	9 (28.13)	9 (28.13)	32 (100%)	0.500	0.919	0.125
F	200	FS	11 (34.38)	7 (21.88)	8 (25.00)	6 (18.75)	32 (100%)	1.750	0.626	0.234
F	200	BF	8 (25.00)	10 (31.25)	3 (9.38)	11 (34.38)	32 (100%)	4.750	0.191	0.385
F	200	IM	7 (21.88)	9 (28.13)	8 (25.00)	8 (25.00)	32 (100%)	0.250	0.969	0.088
F	200	BAS	11 (34.38)	8 (25.00)	8 (25.00)	5 (15.63)	32 (100%)	2.250	0.522	0.265
F	200	BRS	7 (21.88)	6 (18.75)	11 (34.38)	8 (25.00)	32 (100%)	1.750	0.626	0.234
F	400	FS	11 (34.38)	7 (21.88)	10 (31.25)	4 (12.50)	32 (100%)	3.750	0.290	0.342
F	400	IM	7 (21.88)	9 (28.13)	9 (28.13)	7 (21.88)	32 (100%)	0.500	0.919	0.125
F	800	FS	6 (25.00)	5 (20.83)	6 (25.00)	7 (29.17)	24 (100%)	0.333	0.954	0.118

Note: M: male; F: female; FS: freestyle; BAS: backstroke; BF: butterfly; BRS: breaststroke; IM: individual medley; $Q_{1–4}$: quarter of birth; χ^2: chi-square goodness of fit test; w: effect size w index (Cohen's w)

Table 3. Differences between Swimmers' Time according to Quarters of Birthdate in Sex, Discipline and Distance

Sex	Distance	Discipline	Time [MM:SS.SS]				n	H	p	η^2 (95 % CI)
			Q_1 [med (x_{25}-x_{75})]	Q_2 [med (x_{25}-x_{75})]	Q_3 [med (x_{25}-x_{75})]	Q_4 [med (x_{25}-x_{75})]				
M	100	BAS	1:11.09 (1:07:27–1:12.26)	1:11.07 (1:06.11–1:12.47)	1:08:00 (1:06:00–1:15:04)	1:10:03 (1:09:03–1:12:47)	32	0.306	0.959	0.096 (0.000–0.254)
M	200	FS	2:12.90 (2:10.20–2:16.60)	2:10.0 (2:04.7–2:11.6)	2:12.8 (02:09.8–2:15.2)	2:13.40 (2:10.50–2:17.00)	32	4.101	0.251	0.039 (0.000–0.150)
M	200	BAS	2:30.00 (02:26.00–02:36.00)	2:30.00 (2:22.00–2:40.00)	2:33.00 (2:21.00–2:40.00)	2:31.00 (2:28.00–2:37.00)	32	0.236	0.972	0.099 (0.000–0.259)
M	400	FS	4:42.00 (4:35.5–4:47.5)	4:37.00 (4:30.00–4:39.20)	4:33.00 (4:33.00–4:41.50)	4:43.50 (4:33.70–4:48.80)	32	5.931	0.115	0.105 (0.000–0.267)
M	400	IM	5:18.00 (5:11.50–05:36.50)	5:30.50 (5:17.50–5:42.30)	5:18.00 (5:09.00–5:28.00)	5:37.00 (5:16.50–5:43.69)	31	3.928	0.269	0.034 (0.000–0.137)
F	50	FS	0:29.00 (0:28.00–0:30.00)	0:30.00 (0:29.00–0:30.00)	0:29.00 (0:28.00–0:30.00)	0:30.00 (0:29.00–0:30.00)	32	0.903	0.825	0.075 (0.000–0.222)
F	100	BRS	1:23.00 (1:20.00–1:26.00)	1:23.00 (1:17.00–1:26.00)	1:22.00 (1:16.00–1:26.50)	1:22.00 (1:20.50–1:26.50)	32	0.225	0.973	0.099 (0.000–0.259)
F	200	FS	2:22.00 (2:16.00–2:27.00)	2:24.00 (2:21.00–2:24.00)	2:23.50 (2:17.80–2:27.80)	2:22.00 (2:20.50–2:25.80)	32	0.742	0.863	0.081 (0.000–0.232)
F	200	IM	2:35.00 (2:34.00–2:42.00)	2:41.00 (2:39.00–2:45.00)	0:02:36 (0:02:35–0:02:40)	0:02:41 (0:02:37–0:02:47)	32	6.973	0.073	0.142 (0.000–0.314)
F	200	BAS	2:40.00 (2:33.00–2:46.00)	2:39.00 (2:38.00–2:39.80)	2:39.00 (2:34.50–2:43.00)	2:43.00 (2:38.00–2:47.00)	32	2.336	0.506	0.024 (0.000–0.105)
F	200	BRS	3:04.00 (2:55.00–03:07.00)	2:58.00 (02:49.00–03:02.00)	2:58.00 (2:53.00–3:03.00)	03:05.00 (2:54.00–3:08.00)	32	3.250	0.355	0.009 (0.000–0.016)
F	400	IM	5:37.00 (5:22.00–5:59.00)	5:50.00 (5:40.00–5:56.50)	5:35.00 (5:26.50–5:46.00)	5:50.00 (5:46.00–5:59.00)	32	6.759	0.080	0.134 (0.000–0.305)
F	800	FS	10:13.00 (09:47.50–10:28.30)	10:32.00 (10:07.00–10:48.00)	10:00.00 (9:51.00–10:36.00)	10:32.00 (10:24.00–10:36.00)	24	4.121	0.249	0.040 (0.000–0.157)

Note: M: male; F: female; FS: freestyle; BAS: backstroke; BF: butterfly; BRS: breaststroke; IM: individual medley; Med: median; x_{25}: lower quartile, x_{75}: upper quartile; $Q_{1-4:}$ quarter of birth; H: Kruskal-Wallis H test; η^2: Eta-square test; CI: confidence interval

Although the Table 1 shows a gradual decrease in the number of both absolute and relative frequencies from Q_1 to Q_4 in all the above given variables (male, female, total), which indicates the existence of RAE, we calculated – assessing the values of chi-square goodness of fit test – that comparing the occurrence of expected and observed birthdate (in Q_i) showed a statistically significant deviation from the birthdate distribution only in male sample (χ^2 (3) = 9.846, p = 0.020, w = 0.033, ES = trivial).

In terms of assessing the effect size w index values, we can conclude that the influence of birthdate showed in male (w = 0.033, CLES = 0.51) as well as in female swimmers (w = 0.006, CLES = 0.50) a trivial effect (w_{diff} = 0.027). Which are the smallest differences of ES values, and therefore the most homogenous effect in our study.

Since, in terms of statistical significance, different levels of RAE effect were found between the sexes, it was important to find whether and how this RAE effect would be reflected also in the division by disciplines and distances (Table 2), or by swimmers' performance (Table 3 and 4).

The chi-square goodness of fit test was calculated comparing the occurrence of expected and observed birth dates (in Q_i). Uneven distribution of the dates of birth – i.e. the existence of RAE – was demonstrated in male swimmers using statistical significance in 4 of 13 cases (30.77 %;

2times in BF, once in FS and IM). In female swimmers, we found statistically insignificant differences in birthdate frequency, so in this case we rejected the existence of RAE.

The values of ES w index in male swimmers ranged from small (w = 0.190, CLES = 0.51) to large (w = 0.734, CLES = 0.61) effect (w_{diff} = 0.544) in 13 swimming disciplines, which is the largest difference of ES values in our study, and thus the most heterogeneous effect. More precisely, we found a large effect in two disciplines (15.38 %; FS and BF), medium effect in five disciplines (38.46 %; 2times in FS and once in BRS, BF and IM), small effect in 6 disciplines (46.15 %; 3times in FS, 2times in BAS, once in BRS) and trivial effect in two disciplines (15.38 %; FS and BF).

In female swimmers, the values of ES w index ranged from trivial (w = 0.088, CLES = 0.51) to medium (w = 0.415, CLES = 0.57) effect (w_{diff} = 0.327). More strictly, we found a medium effect in five disciplines (38.46%; 2times in FS and BF and once in BAS), small effect in seven disciplines (53.85 %; 2times in FS and BRS, once in BAS) and trivial effect in one discipline (7.69 %; IM).

After assessing the existence of RAE (Table 1 and 2), we were interested in whether there existed performance differences (times achieved in individual disciplines) between quartiles (Q_i) in individual swimming disciplines. In this case, there was not a statistically significant difference between the dependent variables (sex, distance, style). This means that there was not any statistical difference in swim time between swimmers born in different Q_i. Which can be interpreted that there is no difference between relatively older and younger swimmers in performance; not even in the groups where we confirmed the effect of RAE (Table 2). The values of ES η^2 index in male swimmers in 5 swimming disciplines reached medium (η^2 = 0.034 – 0.105, CLES = 0.56 – 0.61) effect (η^2_{diff} = 0.071). These are more homogenous ES values than in swimmers in Table 2.

In female swimmers, we found in 8 disciplines the values of ES η^2 index ranging from trivial (η^2 = 0.009, CLES = 0.53) to large (η^2 = 0.142, CLES = 0.62) effect (η^2_{diff} = 0.133), which were more homogenous results than in the case of female swimmers from Table 2. We found, more precisely, a large effect in one discipline (12.50 %; IM), medium effect in 4 disciplines (50.00 %; 2times in FS, once in BRS and IM), small effect in two disciplines (25.00 %; BAS and FS) and trivial effect in one discipline (12.5 %; BRS). As some research variables did not meet the conditions of Kruskal-Wallis H test (more than 5 swimmers in group [Q_i]), the following Table 4 contains the results of Mann-Whitney U test, which we used to assess the categorial variable of birth semester (S_i) instead of birth quartile (Q_i).

The results of Mann-Whitney U test in male swimmers showed that the difference between the achieved times for S_1 and S_2 variables were statistically significant in two cases (BF and BRS, both on 100 m distance); once in case of girls (100 m BAS). In other cases, we did not prove any differences between times.

ES index r values in male swimmers in 8 swimming disciplines reached small (r = 0.116, CLES = 0.54) to large (r = 0.576, CLES = 0.70) effect (r_{diff} = 0.460). We found – more precisely – a large effect in one discipline (12.50 %; BRS), medium effect in three disciplines (37.50 %; BF, BRS and FS) and small effect in 4 disciplines (50.00 %; 2times in FS and once in BF and IM). ES r index values in female swimmers in 5 swimming disciplines reached trivial (r = 0.060, CLES = 0.52) to medium (r = 0.351, CLES = 0.61) effect (r_{diff} = 0.291). We found – more precisely – a medium effect in one discipline (20.00 %; BAS), small effect in two disciplines (40.00 %; FS and BF) and trivial effect also in two disciplines (40.00 %; BF and FS).

DISCUSSION

Based on the results of the presented study, we cannot describe the RAE influence in the examined group as unambiguous because the level of its effect depends very much on the nature of dependent variable. Similar conclusions were reached also by Buhre and Tschernij (2018) due to

Table 4. Differences between Swimmers' Time according to Semesters of Birthdate in Different Sexes, Distances and Disciplines

Sex	Distance	Discipline	Time [MM:SS.SS]		n_{s1}/n_{s2}	U	p	r
			S_1 [Med (x_{25}-x_{75})]	S_2 [Med (x_{25}-x_{75})]				
M	50	FS	0:28.10 (0:26.90–0:28.30)	0:27.30 (0:27.10–0:27.80)	22/9	79.0	0.384	0.156
M	100	FS	1:01.00 (0:59.00–1:02.00)	1:01.00 (1:00.00–1:02.00)	21/11	99.0	0.513	0.116
M	100	BF	1:09.10 (1:06.20–1:12.10)	1:04.30 (1:01.70–1:07.60)	27/5	25.5	0.029	0.385
M	100	BRS	1:11.50 (1:09.50–1:12.70)	1:14.00 (1:13.00–1:16.00)	12/11	21.5	0.006	0.576
M	200	BF	2:40.5 (2:33.30–2:52.50)	2:30.00 (2:22.30–3:00.00)	24/8	72.0	0.296	0.185
M	200	IM	2:28.30 (2:27.00–2:33.52)	2:28.30 (2:25.00–2:31.00)	20/12	103.0	0.507	0.117
M	200	BRS	2:52.00 (2:42.00–2:59.00)	2:56.00 (2:48.50–3:06.00)	19/13	73.5	0.055	0.340
M	1500	FS	18:46.50 (18:15.30–19:12.70)	18:18.00 (17:53.00–18:44.00)	12/11	40.0	0.109	0.334
F	100	FS	1:05.00 (1:03.00–0:01:06)	1:06.00 (1:03.00–1:07.00)	19/13	96.0	0.291	0.186
F	100	BAS	1:13.00 (1:11.00–1:16.00)	1:15.00 (1:14.00–1:17.00)	21/11	65.5	0.047	0.351
F	100	BF	1:15.00 (1:11.00–1:19.00)	1:17.00 (1:14.00–1:18.00)	18/14	117.0	0.732	0.060
F	200	BF	2:51.50 (2:47.00–3:00.30)	2:55.00 (2:53.00–3:01.00)	18/14	93.0	0.209	0.222
F	400	FS	5:01.50 (4:55.50–5:05.20)	5:01.50 (4:55.00–5:07.50)	18/14	117.5	0.747	0.057

Note: M: male; F: female; FS: freestyle; BAS: backstroke; BF: butterfly; BRS: breaststroke; IM: individual medley; Med: median; x_{25}: lower quartile; x_{75}: upper quartile; S_i: semester of birth; U: Mann-Whitney U test; r: effect size r index; CI: confidence interval

inconclusive evidence of RAE occurrence in elite Swedish swimmers. Although there are significantly less academic studies dealing with RAE issue in female/girls than number of studies dealing with male/boys, it is clear – despite this disparity – that the level of RAE in female/girl sample is lower (or none) than in the case of males/boys, which is also valid in all comparable sports (Cobley et al., 2009; Smith, Weir, Till, Romann & Cobley, 2018). We reached similar conclusions as well for our research group in most of the examined variables, like Cobley et al. (2018) in the group of Australian swimmers or Costa et al. (2013) in Portuguese swimmers. Most common reasoning explaining this trend is a lower competition in the membership base (so the coaches cannot give preference to the temporarily biologically more mature girls) and earlier completion of the adolescence process in girls in comparison with boys (Baxter-Jones, Helms, Maffulli, Baines-Preece & Preece, 1995). The only conclusion we found that the RAE was higher in female swimmers than in the group of males was in Ferreira et al. (2017) study, where the authors had found a larger and statistically significant RAE effect in the group of female Olympic swimmers, but a statistically insignificant RAE effect in the male group. The authors of this study did not find any other relationship between birthdates (in Q_i) and winning medals or distribution of

athletes by continents (with the exception of Asia). These findings confirm the hypothesis that the RAE effect is most evident during adolescence and then gradually and irregularly weakens (Cobley et al., 2018; Ulbricht et al., 2015). However, we can find examples when RAE is also evident in Swimming Masters age categories, which is usually caused by a progressive increase of the RAE influence during each decade of life (Medic, Young, Starkes, Weir & Grove, 2009) and thus a possible drop-out of relatively younger athletes in junior categories, where each subsequent age category created a stronger environment of age bias because of the departure of relatively younger athletes.

During our extensive literary research, we had not found a study which would deal with the effect of RAE in various disciplines (n = 6), distances (n = 6) and sex (male, female), which – in our case – consisted of a total of 26 different research variables. If we compare our results with Australian U16 swimmers (Cobley et al., 2018), we find that the ES values of our research group were comparable (small ES) 2times for the same variables (male 200 m breaststroke, female 50 m freestyle); 3times we found higher ES values (male 400 m freestyle, male 100 m breaststroke, female 400 m freestyle) and 3-times significantly higher ES values (male 50 m freestyle, female 200 m breaststroke, female 200 m breaststroke). These differences in ES values ranged from small-large to trivial-medium ES. Also in comparison with Abbott et al. (2020), our results in female swimmers in a similar age category (U16) reached higher ES values in 100 m as well as 200 m breaststroke (trivial-small ES). However, the differences disappeared when comparing ES with the group of TOP 25 % female swimmers (small-small ES).

As Cobley et al. (2018) monitored the effect of RAE in several age categories (U13 to U19), we can state, based on their results, that the most obvious effect of RAE was in younger swimmers and its intensity both in boys and girls gradually and irregularly decreased. We can conclude then that the period with the greatest RAE influence is about the age of 12. Similar conclusions were reached also by Costa et al. (2013) for elite Portugal swimmers. One explanation of this phenomenon may be that swimmers' growth curve indicates swimmers as early matures, compared to other young gymnastic, soccer, and tennis athletes (Baxter-Jones et al., 1995).

CONCLUSIONS

Our recommendation for practice are similar to the recommendations of other authors (Baker et al., 2010; Cobley et al., 2009, 2018; Smith et al., 2018), i.e. focus on the prevention of the struggles of late-born children and the protection from possible discontinuation of active spending of leisure time. Awareness of RAE issues should be spread among the coaches working with (not only talented) youth athletes themselves (e.g. in the form of workshops), representatives of sports organizations (who can modify the sports system), but also parents of athletes. This should be spread along with the emphasis on the information that relatively older individuals have only a temporary biological advantage, which does not guarantee them an excellent performance after the completion of the process of adolescence. This way, the drop-out of relatively younger athletes at the beginning of their adolescence process should be reduced (first wave of drop-out caused by RAE) as well as the drop-out of relatively older athletes after the period of adolescence who, in turn, lost the temporary biological advantage resulting from their date of birth (second wave of drop-out caused by RAE).

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STUDIA SPORTIVA 2022/1

Functional classification and performance in wheelchair basketball

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Abstract

Wheelchair basketball players are classified into four classes based on the International Wheelchair Basketball Federation competition system. The aim of this study was to investigate whether the IWBF functional classification for wheelchair basketball was related to different performance field-based tests. Forty wheelchair basketball athletes took part in the study. The players carried out five field tests, three of which were quantitative, related to the three conditional skills (strength, endurance and speed test) and two of the qualitative type (accuracy and shooting ability tests). Pearson's correlation was performed to analyse the correlation between the score obtained from functional classification and the results of the wheelchair performance tests. The IWBF class was not correlated ($p < 0.05$) with any of the tests performed. Players with even major injuries, in their best wheelchair set-up, even achieved better times than upper-class players; therefore, the disability factor in these tests is not an index that determines performance disadvantage. The study shows that the functional classification does not affect the qualitative-quantitative performance, so the disabled athlete with a lower score is not disadvantaged in basketball.

***Keywords*:** Functional classification, Wheelchair basketball, Disability, Inclusive education

INTRODUCTION

Wheelchair basketball is a sport characterised by the complexity of individual and team technical-tactical choices, which reproduce in all respects of a basketball match for non-disabled people (Altavilla & Raiola, 2015). It is a situational sport, where players must be able to immediately predict what will happen in a particular area of the pitch (spatial anticipation of the movement) and when the event will occur (time anticipation) (Altavilla & Raiola, 2019). In this way, the action can be organised in advance and carried out at the right time (Altavilla & Raiola, 2014). It is also a team sport, so communication can be a fundamental component to understanding one's teammates (D'Elia et al., 2020; Raiola et al., 2015). Non-verbal communication is essential because it allows athletes to communicate without the opponent listening to their strategies (Raiola, 2015; Raiola & D'Isanto, 2016).

Regarding the quantitative aspects in wheelchair sports (fencing, basketball, tennis, athletics), high average values of VO2max were detected on athletes, corresponding to average intensities equal to 70% of VO2max (Boccia et al., 2019). The maximum values of VO2max and heart rate recorded on the court in wheelchair basketball are similar to the values measured in the laboratory (Yanci et al., 2015). In the high-level disabled athlete, to ensure an adequate evaluation, clinical and functional, it would be advisable to perform an integrated cardiopulmonary exercise test (Coutts & Mackenzie, 1995). The standard reference values of VO2max in people with paraplegia are around 20–25 ml/ kg/ min for sedentary and 30–40 ml/kg/min or higher for trained athletes (Castagna et al., 2008; Hutzler, 1993). The metabolic commitment is mixed due to the succession of actions that can last even minutes, given the immediate succession of a

defensive action after the offensive one (Gaetano et al., 2016). As for the conditional skills used in wheelchair basketball, the athlete needs a level of strength that allows them to develop agility and speed adequately (Di Domenico et al., 2019). The qualitative aspects are very similar to basketball for the non-disabled, except for some variations in the execution of technical gestures and the regulation (Altavilla et al., 2020). Wheelchair basketball players show differences in the movement of the trunk and arms in the execution of technical gestures due to the residual motor possibilities that differentiate the players of the various classes (Cascone et al., 2020).

For each level of disability, particular biomechanical situations are created: some muscles are indispensable for a given movement, and many others are useful [20]. Wheelchair basketball was the first Paralympic sport to use functional classification (Boccia et al., 2019; Pivik et al., 2002). The classification system of the International Wheelchair Basketball Federation (IWBF) was introduced in 1984. For the first time, the classification strictly linked to medical diagnosis and assessment on the couch was abandoned, introducing technical assessment of the sporting gesture directly on the competition field (Cassese & Raiola, 2017). Currently, the classification criteria derive from a summary that considers both the evaluation of a physician and a technician (Morgulec-Adamowicz et al., 2011; Vanlandewijck et al., 1995). This summary of the judge determines the functional evaluation. The classification system of the IWBF is constantly evolving and is based on the observation of the residual functional abilities demonstrated by the players on the field. The number of classes currently in use for wheelchair basketball is 4, from 1 to 4 and 4 other intermediate classes: 1.5–2.5–3.5–4.5 (when it is difficult to place the player in the four classes or when special situations arise). The lowest classes are assigned to players with greater disabilities and reduced physical abilities (Vanlandewijck et al., 1995). Higher classes are assigned to players with minimal loss of functional skills. In the major competitions established by IWBF, the limit that a team must respect is the score of 14, or 14.5, the sum derived from the total score of the five players on the field (Gil et al., 2015; Vanlandewijck et al., 1995). Consequently, it is interesting to know if the classification as mentioned above also reflects the functional performance of wheelchair athletes while they are practising their sport. In this respect, to our knowledge, only a few studies have attempted to identify the relationship between the functional IWBF classification and performance. We hypothesised that there would be a correlation between the different levels of the classification and the performance in a wide range of field-based tests.

The aim of this study was to investigate whether the IWBF functional classification for wheelchair basketball was related to performance in short- (strength, speed and technical skills) and long-duration (endurance) field tests.

MATERIALS AND METHODS

Participants

Forty male wheelchair basketball players (Age=33.30 ± 8.01 years) from teams competing in Serie B participated in this study. All of them conducted three training sessions and played one match every week. Written informed consent was received from all players after submission of the experimental design and potential risks of the study. They were classified according to the Classification Committee of the IWBF as: class 2 (n=10), class 3 (n=10), class 4 (n=10) and class 4.5 (n=10). Thus, players were grouped into categories (classes) from 2.0 (being the player with the least physical functions) to 4.5 (being the player with the most physical functions). This classification was the players' "playing points", and at any given time in a game, the five players on the court must not exceed a total of 14 playing points. Each player had to pass a medical examination to determine his class to play. The classifiers carried out this examination.

Study Design

The authors declare that the procedures were followed according to the regulations established by the Clinical Research and Ethics Committee and to the Helsinki Declaration of the World Medical Association. The study was carried out over two weeks, where different tests were carried out in different sessions. These tests are easier to execute and interpret, and they also mimic more closely the actions and the movements of the training sessions and games, representing the performance of the athletes in a more exact way. They are the most used to evaluate the qualitative and quantitative performance of wheelchair basketball (Gil et al., 2015). The first quantitative test used was that of strength, where participants had to throw a 5 kg medicine ball as far as possible (De Groot et al., 2012) (Figure 1). The distance was measured in meters. Each participant made three attempts, and the best was used for further analysis.

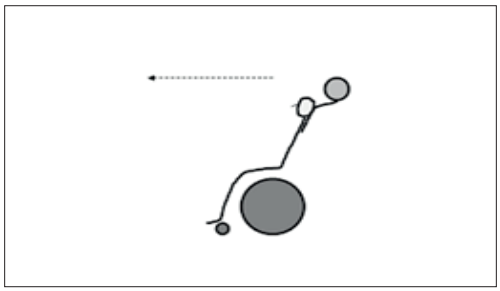

Figure 1. Strength test

The workouts performed before the execution of the test to improve strength were:

- Multiple workout stations with constant load and number of repetitions. For example, 3 series of 10 repetitions at 70% of the maximum load, with a variation of the load level and a constant number of repetitions; or 10 repetitions at 50% of the load, with constant intensity and variation in the number of repetitions.
- Pyramid training: progressive decrease or increase in the load level and inversely proportional relationship between the number of repetitions and the intensity of the load. Load intensity between 60% and 100%; repetitions between 1 and 8; sets of 5 to 10 per exercise.
- Circuit Training: technical-conditional circuits with and without tools, with or without the ball.

The second quantitative test performed was that of speed. It consisted of sprinting over 20 meters starting from the baseline. Performance was measured using electronic timing lights positioned at 5 m and 20 m and placed 0.4 m above the ground with an accuracy of ±0.001 s. The starting position of the players was 0.5 m before the first timing light. The test was performed three times with 2 min of recovery in between. The best result was used for further analysis.

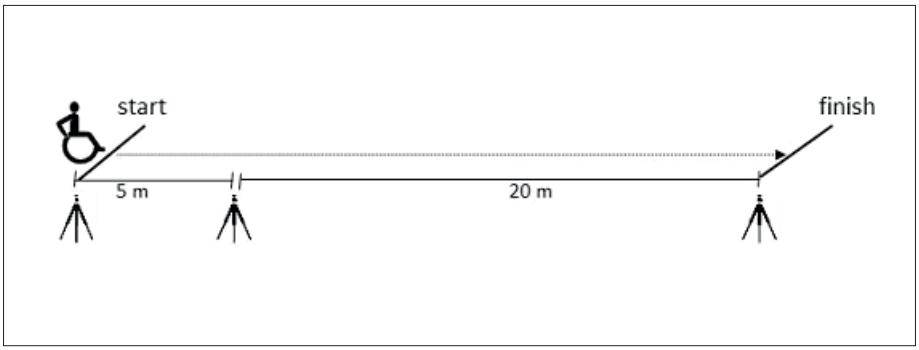

Figure 2. Speed test

The workouts were aimed at improving the speed of action with and without the ball, the reaction speed, deciding in the shortest possible time the most effective action among all possible. The last test used to analyse the quantitative aspects was the endurance test. Level 1 version of the Yo-Yo test was completed according to previously described methods (Invernizzi et al., 2020). Due to the differences between running and propelling the wheelchair, the distance covered in the shuttle run was reduced to 10 m (Figure 3). The number of laps completed for 2 minutes were counted for the set time.

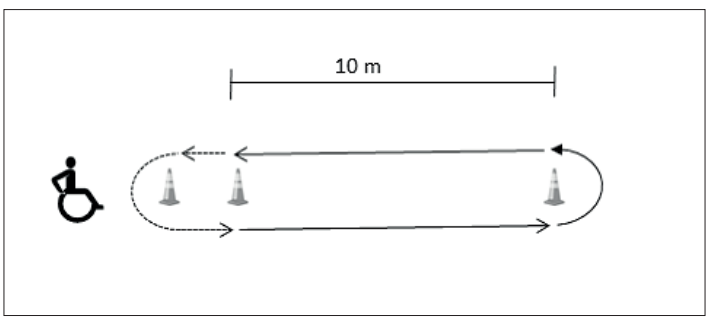

Figure 3. Endurance test

Circuits characterised by situational exercises were used to train endurance, with high demands on speed and precision of movement. There were two main objectives:
– perform the motor task even in case of fatigue. In 60 seconds of work, perform 30–40 repetitions. Recovery time: 30–45".
– work at a fast pace for 1 minute with 15 seconds of rest.

On the other hand, the accuracy-test and the shooting ability test were carried out among the qualitative tests. In the accuracy test, the player was required to shoot from an initial distance of 8m towards a target (30x30cm square) placed 1.20 m above the ground. The player could gradually advance until he was able to shoot from a maximum distance of 4 m. The overall score was added by assigning 1 point for each basket made from 4 m and 2 points from 8 m. The test lasted 2 minutes. The second qualitative test performed was the shooting skill test. Starting from the free-throw line, all successful throws have been added up for a time of 2 minutes.

Statistical Analysis

The normality of data was tested using the Shapiro–Wilk test. As the data followed a normal distribution, parametric tests were used for further analysis. To analyse the correlation between different variables the Pearson's correlation was performed. Statistical analyses of the data were performed using the Statistical Package for Social Sciences software (IBM SPSS Statistics for Windows, version 25.0. Armonk, NY).

RESULTS

Concerning the athletes with a functional classification of 2.0, the best result obtained in the strength test, i.e., throwing the ball weight by 3kg, was 5.4 m; the worst throw was 3.3 m. In the speed test, the fastest player was the one who covered the 20 meters in 2.89 seconds; the slowest was the one who covered 20 meters in 5.01 seconds. In the endurance test, the best result was 21 laps; the worst was 7 laps. The best result of accuracy was 69, while the worse was 23. The best result in the shooting ability test was 26 baskets; the worst was 11. A detailed description is shown in Table 1.

Table 1. Results of the tests performed by the athletes with the functional classification of 2.0.

Athletes	Functional classification	Strength test [m]	Speed test [s]	Endurance test [laps]	Accuracy test	Shooting ability test
1	2	4.3	3.75	8	36	16
2	2	3.3	3.60	11	23	18
3	2	5.0	4.25	10	27	15
4	2	3.8	4.83	12	30	11
5	2	4.7	3.21	8	32	26
6	2	4.5	4.59	21	23	25
7	2	5.4	3.63	20	69	18
8	2	4.9	2.89	7	23	16
9	2	5.3	3.23	8	41	18
10	2	4.9	5.01	20	47	21
Mean ± SD		4.6 ± 0.6	3.8 ± 0.7	12.5 ± 5.6	35.1 ± 14.4	18.4 ± 4.5

Regarding the athletes with a functional classification of 3.0, the best result obtained in the strength test was 6.9 m; the worst throw was 2.9 m. In the speed test, the fastest player was the one who covered the 20 meters in 2.98 seconds; the slowest was the one who covered 20 meters in 6.01 seconds. In the endurance test, the best result was 26 laps; the worst was 14 laps. The best result of accuracy was 57, while the worse was 28. The best result in the shooting ability test was 27 baskets; the worst was 11. A detailed description is shown in Table 2.

Table 2. Results of tests performed by athletes with the functional classification of 3.0

Athletes	Functional classification	Strength test [m]	Speed test [s]	Endurance test [laps]	Accuracy test	Shooting ability test
1	3	4.3	3.75	18	49	13
2	3	4.3	4.73	19	46	17
3	3	6.9	3.53	26	28	15
4	3	5.5	5.19	19	30	24
5	3	4.0	4.01	20	57	16
6	3	5.7	5.23	22	36	27
7	3	2.9	6.01	14	37	11
8	3	4.3	4.73	19	48	17
9	3	7.0	2.98	22	48	28
10	3	6.1	5.27	18	40	25
Mean ± SD		5.1 ± 1.3	4.5 ± 0.9	19.7 ± 3.1	41.9 ± 9.2	19.3 ± 6.1

In the athletes with a functional classification of 4 (Table 3), the best result obtained in the strength test was 9.3 m; the worst throw was 4 m. In the speed test, the fastest player was the one who covered the 20 meters in 2.98 seconds; the slowest was the one who covered 20 meters in 5.27 seconds. In the endurance test, the best result was 26 laps; the worst was 15 laps. The best result of accuracy was 61, while the worse was 33. The best result in the shooting ability test was 28 baskets; the worst was 15. A detailed description is shown in Table 3.

Table 3. Results of tests performed by athletes with the functional classification of 4.0

Athletes	Functional classification	Strength test [m]	Speed test [s]	Endurance test [laps]	Accuracy test	Shooting ability test
1	4	6.1	5.27	18	37	25
2	4	9.3	3.60	23	33	27
3	4	4.3	4.73	19	33	17
4	4	6.9	3.53	26	37	15
5	4	5.5	5.19	19	50	24
6	4	4.0	4.01	20	22	26
7	4	5.7	5.23	22	43	17
8	4	4.7	3.52	16	61	19
9	4	4.0	2.98	15	33	28
10	4	4.1	5.27	18	47	15
Mean ± SD		5.4 ± 1.6	4.3 ± 0.8	19.6 ± 3.3	39.6 ± 10.9	21.3 ± 5.1

Finally, regarding the athletes with a functional classification of 4.5, the best result obtained in the strength test was 6.9 m; the worst throw was 3.9 m. In the speed test, the fastest player was the one who covered the 20 meters in 2.89 seconds; the slowest was the one who covered 20 meters in 5.27 seconds. In the endurance test, the best result was 26 laps; the worst was 8 laps. The best result of accuracy was 67, while the worse was 27. The best result in the shooting ability test was 27 baskets; the worst was 15. A detailed description is shown in Table 4.

Table 4. Results of tests performed by athletes with functional classification of 4.5

Athletes	Functional classification	Strength test [m]	Speed test [s]	Endurance test [laps]	Accuracy test	Shooting ability test
1	4,5	3,9	2,89	9	64	25
2	4,5	6,1	5,27	18	47	25
3	4,5	4,3	3,23	8	67	27
4	4,5	4,9	5,01	26	39	23
5	4,5	4,3	4,73	19	53	17
6	4,5	6,9	3,53	12	27	15
7	4,5	5,5	5,19	19	50	24
8	4,5	4,0	4,01	11	32	26
9	4,5	5,0	4,25	19	38	21
10	4,5	6,8	4,83	18	56	15
Mean ± SD		5.17 ± 1.1	4.2 ± 0.8	15.9 ± 5.6	47.3 ± 13.2	21.8 ± 4.5

Pearson's test found no significant correlation between IWBF and wheelchair performance tests. A detailed description is shown in Table 5.

Table 5. Correlations amongst IWBF and wheelchair performance tests.

	Functional Classification	Strength test	Speed test	Endurance test	Accuracy test	Shooting ability test
Pearson Correlation	1	0.207	0.146	0.274	0.295	0.272
Sig. (2-tailed)		0.200	0.370	0.087	0.064	0.090
N	40	40	40	40	40	40
Mean ± SD		5.08 ±1.2	4.2±0.8	16.9±5.3	40.9±12.4	20.2±5.1

DISCUSSION

From the results obtained, we can summarise by stating that there are no significant correlations between the score obtained from functional classification and the results of the wheelchair performance tests in basketball. In the present study, we analysed the relationship among the IWBF classification with various field-based tests designed to measure speed, accuracy, technique, strength, power and endurance performance in a team of wheelchair male basketball players. From Table 5, no significant correlation was found between IWBF and wheelchair performance tests. Players with a high rating (≥3.0 points) were expected to perform better than players with a low rating (≤2.5 points), but this didn't happen. More precisely, amputee players were expected to benefit from a privileged state of muscle function over athletes with spinal paralysis (Molik et al., 2010), but this did not happen. Players with even severe injuries, in their wheelchair performance, even scored better times than upper-class players; therefore, the disability factor in this test is not an index determining the performance disadvantage. Regarding the correlation between the results of the strength test carried out and the score class of the players, we note a small increase in strength from athletes with ratings 2 to 4. At the same time, between 4 and 4.5, there is a slight

decrease (not significant from a statistical point of view). We justify this result because the pelvic stability on the wheelchair allows ample executive possibilities of throwing from the two-handed / head position. For this reason, each player has reached high levels of strength training in the specific muscles of the upper limbs, chest, upper back and abdominals, specifically for each scoring class (D'Elia et al., 2020; D'Elia et al., 2020). For the data obtained in the speed test, the correlation is not significantly relevant, i.e., there is no correlation between "the shortest time" and the various "score classes". We would have expected that amputee players would benefit from a privileged state of muscle function over those with spinal paralysis, but this did not happen. Players with even major injuries, in their best wheelchair set-up, even achieved better times than upper-class players; therefore, the "disability factor" in this test is not an index that determines performance disadvantage. From the data obtained from the endurance test, we observe that although slight, there is a small correlation between a player's score class and technical ability. Those with a mild physical disability express better ability to drive the wheelchair. The data obtained in the accuracy test indicate that the correlation from a statistical point of view is not extremely relevant even if we observe that the trend line describes an improvement in performance as the player's classification score progresses. We expected players with higher class scores to benefit from privileged muscle function status over those with spinal paralysis; this is partly the case. According to statistics, the disability factor in this test was not an index that caused performance disadvantage. Still, again the best position on the wheelchair, which determines pelvic stability in the various scoring classes, promotes good technical execution. Finally, from the data obtained in the shooting skill test, there is no significant correlation; this underlined that in the execution of the test, the player with the least motor disability did not express a lesser technical ability in the shooting. The results of this study dispel the myth that those with a higher functional classification have an advantage in the quantitative aspects of performance. As can also be seen from the qualitative tests, there is a tendency to direct correlation for the accuracy test and shooting test. To our knowledge, only a few studies have aimed to determine the relationship between the functional classification level and sport-specific skill tests. Previous research has shown that trunk impairment impacted wheelchair propulsion, especially in acceleration from a standstill (Montella et al., 2019; Tafuri et al., 2017). Similar to our study, De Groot et al. (2012) did not find any differences between the players of a low (<4) and high (>4) IWBF classification level in short-term performance field-based tests. They observed that the participants with a higher classification class performed better; these differences were particularly significant amongst the participants of both classification ends. On the other hand, Hutzler (1993) observed a moderate correlation ($r= -0.64$, $p=0.031$) between the class and 428 m racing trails (lasting for about 2–3 min), but not the 6 min test nor the slalom test.

CONCLUSION

The study shows that the functional classification does not affect the qualitative-quantitative performance, so the disabled athlete with a lower score is not disadvantaged in sports practice. Players with even major injuries, in their best wheelchair set-up, even achieved better times than upper-class players; therefore, the disability factor in these tests is not an index that determines performance disadvantage.

Conflict of Interests

The authors declare no conflict of interest.

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STUDIA SPORTIVA 2022/1

HIIT system programming and some practical problems of its application examined within the sample of selected Czech probands in Brno

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Abstract

High Intensity Interval Training is a training method based on a combination of periods in which high--intensity load alternate with low-intensity exercise or passive rest, the so-called rest interval or inactive phase. Nowadays it is gaining more popularity among the general population and is applied in modern fitness centers. The authors found that more than 95 % sports centers organizing group lessons in Brno offer some form of HIIT ("Tabata System", especially). Changing one of the HIIT components will affect the efficiency of the whole system. This effect is demonstrable on the aerobic and anaerobic performance and the composition of body tissues. Our goal within the broad research is to find out what effect changing one variable has on the most widely used HIIT program, and we wanted to examine whether the method is suitable for recreational athletes.

The authors have made the first step in the form of pilot research described in this article, trying to design the system and applying the components in it. The experiment involved twenty deliberately selected male probands. They were randomly divided into two intervention groups of ten probands. In both intervention groups, we observed: number of repetitions performed, subjective load assessment (on the Borg scale) and heart rate. The original design of the pilot study included three training units per week for two weeks (a total of six training units). Basic multiple articulated exercises (Burpees and Jump Squats) were selected for both sets in these protocols in order to achieve key intensity for HIIT. There were some limitations of the experiment described in the article.

The result of the first pilot study was essential concerning the adequacy of the cycle settings. The authors were forced to stop the piloting after the completion of the first week due to the acute overtraining of the probands. The reason to stop the experiment is attributed to an inadequate frequency of training units in individual weeks, which we reflected in the design of the following pilot study and reduced the number to two. The authors have kept the research questions and present the results of the modified piloting below.

It can be assumed that the prolongation of the rest interval has an impact on the ability to perform repeated exercises, heart rate and subjective perception of stress in selected exercises. These results of our pilot research are also related to people's desire to get as much as possible in as little (time) as possible. The HIIT method is (in many aspects) more effective than the continuous method. Its undeniable advantage is time saving, but efficiency is "redeemed" by intensity and demanding character (proved not just in the described experiments). Where is the line between benefit sport and health--threatening sport? What is the "correct" HIIT setting/programming and what causes a change in one of the key variables? Is less sometimes more or more demanding means more effective? Respecting people's demands and desires for performance, mental fitness and physical beauty, with regard to sustainability and health above all, we will seek answers to all these questions. The first step towards finding them is the study carried out.

INTRODUCTION

High Intensity Interval Training (abbreviated as HIIT) is a training method aimed at increasing the fitness of individuals. Based on the findings of many experts, especially after 2000, HIIT can

be defined more generally as a combination of periods in which high-intensity load (load interval = LI) alternate with low-intensity exercise or passive rest, the so-called rest interval (RI) or inactive phase (Gibala et al., 2006; Helgerud et al., 2007; Laursen et al.,2002). High intensity in the active phase is key to the effectiveness of the method and has been discussed by many experts. Bacon et al. (2013) or Danielse (2013) claim that intense exercise is one that exceeds seventy-five percent of maximum heart rate. According to Tabata et al. (1996), HIIT is any interval training with short pauses and maximum load. Perry et al. (2008) also include submaximal load training. Smith (2008) defines a measure of load intensity that exceeds seventy-five percent of VO_2max (the maximum amount of oxygen your body can utilize during exercise). All the criteria mentioned above determining the degree of intensity are in principle not in conflict and are accepted by the professional and lay public. Due to the maximum or submaximal intensity, the load duration is from a few seconds to 4 minutes (Smith et al., 2008). Therefore, the method belonging to the category of developing strength endurance also belongs to the group of intensive training with short to ultra-short intervals (Kuhn, 2005; Měkota & Cuberek, 2007).

HIIT method is not a completely new one and was used even in the last century by the runners like Hannes Kolehmainen or Emil Zátopek. They abandoned so-called master classes based on a large training volume (Billat, 2001). Nowadays, it is gaining more and more popularity among the general population and is being extended to all modern fitness centers. In the Czech Republic, this trend is apparent. We carried out a content analysis of the offer provided by some selected Brno gyms. We examined and compared training lessons offered on the websites *https://www.fitnessposilovna.cz/brno*. The results of this analysis display that more than 95 % of sports centers organizing group lessons provide some form of HIIT, of which the so-called "Tabata System" is dominantly represented.

One of the reasons for this preference can be the fact that this training corresponds to the trend of "fast time" and the effort to get as much as possible in a short time. Tabata System can provide a possibility for this approach and is very popular. Even the general motive is very topical. This kind of effort goes beyond the frame of sports training and becomes a topic of reflection across disciplines (sociology, psychology, or economy). Coming back to sports training, compared to classical endurance training, the exercise time is almost half (Laursen & Jenkins, 2002). We should take the apparent popularity of this kind of exercise set to the present day as a fact and, at the same time, a stimulus for more profound research, understanding, and subsequent streamlining of the method.

Speaking about one of the main reasons for the popularity of the HIIT method for recreational athletes in the commercial sphere, it should be added that the lower time requirement does not reduce the effectiveness of the method. In a number of recent studies, higher effectiveness of the HIIT method for the development of aerobic and anaerobic capacity compared to classical continuous loading has been demonstrated, and positive adaptation changes (especially a significant increase in VO_2 max) have been confirmed. For the purposes of our research, the conclusions of extensive meta-analyses of Milanovič et al. (2015) and Ramose et al. (2015) are the most suitable. They focus not only on the aspect of performance but also on the aspect of health, which must be taken into account in the field of recreational sports.

Ramos et al. (2015) proved the comparable or higher efficacy of the HIIT on vascular function in comparison with the continuous method. The monitored variables were blood pressure, insulin sensitivity, oxidative stress, body fat, or mitochondrial biogenesis (the critical factor is coactivator PGC-1a). In Milanovič's et al. (2015) meta-analysis focused on performance indicators (specifically aerobic performance), a significant positive effect on VO_2 max was demonstrated using an intensive and endurance program compared to the control group. The central goal of the analysis was to compare the effectiveness of both microcycles (HIIT versus Continuous Endurance Training). Higher efficiency was confirmed in the HIIT model. However, at the end

of the analysis, the authors refer to a more detailed examination of intensive training (variable components) for its accurate understanding. Some inconsistencies are pointed out, especially for the variables cycle length, work/rest ratio, and intensity.

The importance of variables for HIIT programming is discussed in more detail by Laursen and Buchheit (2013), both in the context of short-term stimulus and long-term cycle. For a short-term stimulus, the variables defined in particular are the length of the exercise interval and its intensity, the length of the rest interval, the number of intervals, the choice of exercises, and the form of the inactive phase (passive rest). From a long-term perspective, it is primarily the length of the training cycle and the frequency of training units. All components act interactively (training volume versus intensity, intensity versus frequency, frequency + intensity versus cycle duration, etc.). Their composition and final structure affect the requirements for aerobic and anaerobic energy coverage, post-exercise oxygen consumption (EPOC), hormone production, demands for regeneration, and some other attributes.

The problem of HIIT programming

In the following lines, we would like to present the results of some selected studies. They demonstrate the significance and impact of variables on the overall effectiveness of the program. It was found that the extension of the working interval while maintaining the length of the rest interval leads to an increase in the consumption of anaerobic glycolytic energy depending on the volume of work that is performed for a given section. Thus, increasing the duration of the load while maintaining the intensity causes an increase in the consumption of anaerobic glycolytic energy. In comparison to one minute of running with two minutes at VO_2 max at a work/rest ratio = 1, there was a significant increase in anaerobic glycolytic energy and O_2 deficiency (≈ 25 ± 2 vs. 21 ± 2 mL/kg, ES (effect size) +2.3).

Likewise, lactate values measured after completion of the stress section were significantly higher (8.8 ± 3.6 vs. 4.8 ± 1.1 mmol/L, ES +1.7) (Vuorimaa et al., 2000). However, even a seemingly slight difference in the load interval of 15% can lead to a substantial increase in glycolytic anaerobic system requirements and increase lactate production almost twofold. This is demonstrated by the findings of the Smith study in runners with a load at 100 % VO_2 max and different load intervals of 130 and 150 seconds (Smith et al., 2003). However, entitlements to an anaerobic system, and hence oxygen debt, may be different even if the same work and rest period ratio is maintained. The difference in oxygen debt compared to 1:1 and 2:2 is 23.8 ± 1.6 vs. 20.5 ± 1.9 mlO_2/kg (Vuorimaa et al., 2000).

It is notable that lactate production is not as sensitive as oxygen debt to the change in load/rest ratio. Its concentration is lower in the active form of rest at 60–70% of VO_2max than in passive rest (in the comparative study, active rest was 180 s longer (Belcastro & Bonen, 1975). Dupont's study confirmed the lower lactate concentration when active rest was included with active rest values ranging from 40–50% VO_2max (Dupont et al., 2004).

However, active rest may cause higher activation of the glycolytic system and lower muscle oxidation, which in turn may lead to higher lactate concentration (Dupont et al., 2003, 2004; Christmass et al., 1999). However, what is evident is the sensitivity to the change in intensity. Measured lactate values at load/rest at 90/80 % VO_2max, 100/70 % VO_2max, and 110/60 % VO_2max were 9.2 ± 1.3 mmol/, 9.8 ± 1.4 mmol/L and 11.3 ± 1.3 mmol/L (Billat, 2001).

The effect of time and intensity on the anaerobic system is also confirmed by Bisciotti's (2004) study, showing that anaerobic glycotic energy increases when the load is no longer than 30 s at 110 % VO_2 max. At 100 % VO_2max, there was a significant increase in lactate (La) concentration

at a load longer than 60 s (Bisciotti et al., 2004). However, even maintaining the same load/rest ratio, significant changes in the requirements for the glycotic system can be achieved through changes in the direction and selection of the surface on which the exercise is performed. The role is played primarily by the angle of change of direction and the surface characteristics (sand versus grass) (Dellal et al., 2010; Haydar et al., 2011; Binnie et al., 2013; Buchheit et al., 2012). Choosing exercises that significantly impact the intensity of training and energy system requirements is also essential. Claims vary considerably for kettlebell HIIT versus sprint interval cycling. (Williams, B. & Kraemer, R. 2015).

Laursen & Buchheit (2013) also cite the interesting finding that a similar load on the anaerobic system occurs at 30 with maximum load or runs at 300 m and repeated 4 with sprints on a non-motorized treadmill or repeated treadmill sprints of longer 6s separated by 17s pause.

The length of the rest period is of equal importance in terms of affecting the adaptation to the load. Increasing the rest period will allow for a repeat performance with at least partially supplemented acid bases and larger phosphocreatine stocks (PCr) which affects greater production of mechanical work and increases the use of the anaerobic system, hence the aerobic system and EPOC. This is demonstrated, for example, by an athlete study where lactate production was increased from 13.3 ± 2.2 to 15.1 ± 1.7 mmol/L (ES +0.9) due to an increase in rest period of 130 % (Buchheit et al., 2009). According to Rusk et al. (1993), rest periods for interval training should be longer than the 90s. The oxygen debt occurs at the beginning of the exercise, and the anaerobic system is fully loaded.

Summary of the problem and the aims of the research

The above findings mainly applied to physiological processes impacting performance and hence performance. However, the side effect of the HIIT method, which is the effect on body composition and the change in the ratio of active body mass to fat, cannot be ignored. Research on Tabata has shown a marked stress caloric output, which according to Olson (2013) and Talanian et al. (2007), is due to increased resting metabolism and EPOC (increased after stress oxygen consumption due to negative energy balance and intensive work in the anaerobic range). Increased resting metabolic rate due to both aerobic and anaerobic activity was also confirmed by Bastyan (2017) in his dissertation.

Other factors that occur in metabolic processes provoked by HIIT are: increased levels of fat metabolizing enzymes (Gillette et al., 1994), then increased fat utilization due to the maintenance of the necessary glycogen level (Rozenek, 2007), and adaptive changes in skeletal muscle, increasing fat oxidation in muscles and improving glucose tolerance (Boutcher, 2011). A number of studies have confirmed the effectiveness of the HIIT method for fat burning and increased efficiency over conventional continuous training (Stoppani, 2016; Konečný, 2014; Zhang et al., 2017).

Based on the above, we can argue that HIIT is a training method based on intensity and intervals' composition. It is very popular with recreational athletes. Changing one of the components will affect the efficiency of the whole system, and the effect of the method is demonstrable on the aerobic and anaerobic performance and the composition of body tissues. Our goal within the broad research is to find out what effect changing one variable has on the most widely used HIIT program in the commercial sphere and how it will affect aerobic and anaerobic performance and body composition. Considering the high intensity of the program, we want to prove, among other things, whether the method is suitable for recreational athletes and whether more intensive equals more efficient.

To achieve the stated objective, we have made the first step in the form of pilot research described in this article, which has given us an answer to the question of how to design the system. The data has indicated what results from we might expect.

METHODS

Tables 1 and 2 show a simplified schematic of the HIIT systems that will be compared within our further research. Therefore they have been applied in the pilot research. Table 1 shows that they are the so-called Tabata system with a change of variable RI (rest interval). The table is based on theoretical knowledge. In addition, what is expected after the extension of the RI is graphically expressed, and the suggested hypothesis, which we do not yet formulate in the pilotage, will be verified within our subsequent research.

Table 1. Training protocol 1

Intervention group 1 – Training protocol 1	
1st Set	
Period of load and rest/number of rounds	LI=20s, RI = *10s*/8 laps
Load intensity	Maximum
Selected Exercise	Jump Squat
2nd Set	
Period of load and rest/number of rounds	LI=20s, RI = *10s*/8 laps
Load intensity	Maximum
Selected Exercise	Burpee
Total amount of time performed 320s. There's a pause of 120s between sets.	

Source: processed by the authors

Table 2. Training protocol 2

Intervention group 2 – Training protocol 2	
1st Set	
Period of load and rest/number of rounds	LI=20s, RI = *20s*/8 laps
Load intensity	Maximum
Selected Exercise	Jump Squat
2nd Set	
Period of load and rest/number of rounds	LI=20s, RI = *20s*/8 laps
Load intensity	Maximum
Selected Exercise	Burpee
Total amount of time performed 320s. There's a pause of 120s between sets.	

Source: processed by the authors

Hypothetical thesis:

RI increase → NoR Increase → VO_2max reduction → Lower EPOC → Less fat loss

Figure. 1. The hypothetical thesis

Goals and research issues

The central objective of the planned broad research is to determine how and if a change in the rest period affects the performance of individuals, and consequently the composition of the body. In the pilot study, monitoring the performance aspect presented the secondary parameter, and the data obtained was weighted only intuitive in this respect. The primary was to verify that the system was set up due to intensity, exercise selection, and load frequency applicable over a multi-week cycle. We can anticipate what results we might expect after applying the cycle by comparing the data collected subjectively from the Borg scale data and objectively using the Polar M400 sporttester.

To help conclude, we have set out the following two research questions (RQ):

RQ1: Will the load (measured subjectively and objectively) and the RN (number of repetitions) implemented for Protocols 1 and 2 differ?

RQ2: Is the setting of the microcycle and its frequency adequate given the intensity?

Pilot research methods

The experiment involved twenty deliberately selected male probands (recreational athletes sporting up to 120min per week) aged 25–40 years. They were randomly divided into two intervention groups of ten probands. The average age of the participants in the first intervention group was 35 years, and the standard deviation was 4.1. In the second intervention group, the average age of participants was 34 years, and the standard deviation was 4.4. The participants' BMI (body mass index) ranged from 19 to 25. In this experimental mixed pre-research exercise, load and perception were assessed using the Borg scale (Table 3) and the sporttester Polar M400. In both intervention groups, following the application of Protocols 1 and 2, we observed the following variables: number of repetitions performed (RN), subjective load assessment on the Borg scale, and heart rate (HR). We then compared the data. The original design of the pilot study included three training units (TU) per week (Monday, Wednesday, and Friday) for two weeks (a total of six training units with a regeneration delay of 1–2 days). The start of the work intervals was preceded by a 15-minute warm-up focusing on activation of core and significant strained muscle parts, increased ventilation, and heart rate. A cool down and static stretching followed the finish. Basic multiple articulated exercises (Burpees and Jump Squats) were selected for both sets in these protocols in order to achieve key intensity for HIIT.

The main limitations of the experiment are the low number of probands for drawing more general conclusions. The measured heart rate does not depend on the actual HR max that we would obtain with a laboratory test but on the application of Polar. Also, BMI has some limitations, such as non-reflecting age, body composition (location or amount of body fat), or health (high value does not necessarily mean overweight or obesity). However, at this stage of the research and because of the following planned steps, we consider the data source and its value acceptable. The most significant risk was possible overtraining or injury due to the high workload and the inability of probands to continue the experiment.

Table 3 shows HR grades and perceived exertions. All probands were briefed on the scale and identification of each stage before the experiment began. The values were written on pre-prepared forms immediately after the load was completed.

Table 3. Heart rates and perceived extersions

Degrees	Heart rate (% of maximum)	Perceived effort
1.	60–70 %	very little effort
2.	70–72,5 %	little effort
3.	72,5–75 %	moderate effort
4.	75–80 %	greater effort
5.	80–85 %	great effort
6.	85–90 %	high effort
7.	90–94 %	very high effort
8.	94–97,5 %	extremely great effort
9.	97,5–100 %	near maximum effort
10.	100 %	exhaustion

Source: Čechovská, Dobrý (2008); (translated by the authors)

RESULTS

The result of the first pilot study was essential for us, despite the inevitability to discontinue the experiment, for further action. It gave us the answer to the key question related to the adequacy of the cycle settings.

We had to stop the piloting after the completion of the first week because of the acute overtraining of the probands. In the first intervention group, at the beginning of the second week, five probands reported an inability to continue the experiment, which is fifty percent of the sample. In the second intervention group, four probands were unable to continue. The reasons given were subjectively perceived insufficient time to regenerate between training units, back pain, and general exhaustion. Continuous readings on the Borg scale and the ability to perform in the active phase of repetitions for selected exercises also indicated a halt in piloting. In the first intervention group, the median on the Borg scale was level ten (two degrees higher than after the completion of the first training unit) after completing the third training session. The number of repetitions performed decreased by an average of twenty percent, even for the second intervention group, where the median was level eight on the Borg scale after completing the third training unit (two degrees higher than after the completion of the third first training unit). The heart rate ranged from submaximal to maximal, which is expected for this type of training, and did not fluctuate significantly.

The first experiment results within the pilot study did not give us an answer to RQ1 from which to draw a partial conclusion, but they did respond reliably to RQ2.

The reason for the need to stop the experiment is attributed to an inadequate frequency of training units in individual weeks, which we reflected in the design of the following pilot study and reduced the number to two (Monday and Thursday), extending the microcycle by a week so that the number of training units is the same as in the first experiment. So the piloting took three weeks. We have kept the research questions and presented the modified piloting results below.

Table 4 shows the median values in the repeat counts performed for the selected exercises, the assessment of subjectively perceived exertion after completion of the training according to

the Borg scale, the heart rate, percentage of maximal heart rate, and standard deviations (STD) for the first protocol. To determine the data given, the maxHR values for every proband were obtained from the formula 220-age=MaxHR.

Table 4. The median values for Training protocol 1

	Number of repetitions (NoR) Jump Squat/ Burpee	Evaluation on the Borg Scale	HR (measured)/% of maxHR
TU1	14/6	8	170/92
TU2	14/5	9	175/95
TU3	15/6	8	170/92
TU4	15/5	8	170/92
TU5	16/6	7	165/90
TU6	16/5	8	165/90
STD	0,89/0,54	0,63	3,76/1,83

Source: processed by the authors

Table 5 shows the median values in the repeat counts performed for the selected exercises, the assessment of subjectively perceived exertion after completing the Borg scale training, the heart rate, percentage of maximal heart rate, and standard deviations (STD) for the second protocol.

Table 5. The median values for Training protocol 2

	Number of repetitions (NoR) Jump Squat/ Burpee	Evaluation on the Borg Scale	HR (measured)/ % of max HR
TU1	18/8	6	155/84
TU2	18/8	7	160/87
TU3	19/8	6	155/84
TU4	20/8	6	160/87
TU5	21/9	5	150/82
TU6	20/9	6	150/82
STD	1,21/0,52	0,63	4,47/2,25

Source: processed by the authors

DISCUSSION

Based on the data obtained from the pilot study, several partial conclusions can be drawn, and the research questions identified can be answered. Although the experiment has some limitations, which we mention in the section on methodology, we consider the implementation and completion of the experiment beneficial or even necessary for the subsequent extended research. The findings of the pilot study and the answers to the research questions are as follows:

In the experiment and planned follow-up research, we examine if and to what extent a change in the selected variable (RI) affects the effectiveness of the microcycle. Based on the measured data following the application of Protocols 1 and 2, it can be assumed that efficacy will be affected. Differences are evident for all endpoints (number of repetitions performed, subjectively perceived load intensity, and HR). Changes in these, directly and indirectly, affect the energy coverage mode and the aerobic to anaerobic system involvement ratio, after EPOC oxygen stress consumption,

VO2 maximum, change in body composition, regeneration requirements, hormonal changes, and more mentioned in the theoretical part of the article. Efficacy differences in changes in aerobic and anaerobic capacity and changes in body composition will be further investigated in the framework of future research. For the time being, it can be assumed that the prolongation of the rest interval impacts the ability to perform repeated exercises, heart rate, and subjective perception of stress in selected exercises, thus also answering the first identified research question of secondary importance for the time being.

Although these assumptions will need to be confirmed or disputed in more extensive work, the data obtained indicate that the research intent set out by us is correct. After changing one of the variables, the differences in effectiveness will be confirmed with further consensus. However, the primary objective of the experiment was to verify that the application of the system is actual and that the research is feasible. We found that completing three training units per week is unsustainable for the general population. It appears adequate to use two training doses per week with a minimum of 48 hours to eliminate acute fatigue.

After reducing the training doses to two of the results, we conclude that completing the planned eight-week cycle is realistic. This position is also indicated by a tendency to decrease or stagnation in heart rate, subjectively perceived load, and the number of repetitions performed in the last week of the experiment, which may be due to partial load adjustment. Variables will have to be further monitored, results in follow-up research verified. However, based on piloting, it can be concluded that the application of training reports is possible at the frequency of two doses per week and risky or impossible at the frequency of three. This is also the answer to the crucial second research question. Due to the complexity of HIIT, we consider that a pilot study will be necessary, and we believe that the experiment conducted by us will serve other researchers.

CONCLUSIONS

Finally, we return to the initial claim of people's desire to get as much as possible in as little (time) as possible in an attempt to give it short shrift and answer the meaning of our investigation if it exists. The HIIT method is even more effective than the continuous method, as confirmed in many studies. Its undeniable advantage is time-saving, but efficiency is "redeemed" by the intensity and demanding character, as evidenced, among other things, by the results of our experiments. Where is the line between benefit sport and health-threatening sport? What is the "correct" HIIT setting/programming, and what causes a change in one of the key variables? Is less sometimes more or more demanding means more effective? Respecting people's demands and desires for performance, mental fitness, and physical beauty, concerning sustainability and health above all, we will seek answers to all these questions. The first step toward finding them is the study carried out.

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Relationship between motor learning and general intelligence

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Abstract

AIM: The aim of the research was to find out the differences in the level of motor learning (ML) and general intelligence (IQ). The research sample included 120 boys and girls of primary school and grammar school aged 12–17 years and the subsequent identification of a possible relationship between the two indicators. METHODS: 120 students Elementary school (ES) and Secondary Grammar School (SGS) took part in testing the level of motor learning and intelligence (n = 120). We evaluated the level of ML in boys and girls in the demonstration of learned gymnastic elements. We used the intelligence test to determine the level of general intelligence [1]. RESULTS: The results did not show significant differences in the level of motor learning and intelligence between the genders in either age category. Correlation analysis confirmed a significant relationship between ML and IQ excluding the gender factor (r = –0.276). When gender was taken into account, the relationship was seen only in boys (r = –0.293). We note that we found a lower rate of ML in students with a higher level of intelligence. CONCLUSION: We assume the continuity of certain mental and motor processes, which is called motor intelligence. The results of our research did not show significant differences in the level of ML and IQ in both genders. Boys slightly dominated in ML, girls in IQ. This difference decreases with increasing age.

Keywords: *general intelligence; motor skills learning; school physical education; self-perception.*

INTRODUCTION

Man as a human being is born to move and learns how to move effectively throughout life. From the didactic point of view, the acquisition (learning) of specifically focused movements and their improvement becomes a characteristic feature of learning. In that sense, the term 'motor learning' ('ML') is generally used in the field of sport and physical education. Motor learning covers a wide range of human activities and, with its results, plays an important role in the ontogenetic development of the individual. Of course, the primary credit for motor expression is motor skills. According to Fridland (2017); Levy (2017) the standard description of learned motor manifestations formed only by motor abilities cannot be given in such a simplified way. According to them, motor control is rather intelligent throughout. Conceptually, Guadagnoli & Lee (2004) consider motor expression to be the result of two variables – skill level and task difficulty.

Motor learning is the process of transforming sensory inputs into subsequent motor outputs (Stanley & Krakauer, 2013). It is a complex process that does not take place in isolation, but with the participation of many objective and subjective factors. This process is not directly observable due to its complexity, but its products – i.e. skills are observable (Schmidt,1991). Diagnosis of the learning process is problematic because these abilities cannot be quantified very much (Velenský, 2008).

Every motor skill is the product of a long and often strenuous process of acquiring a whole range of stimuli. Learning complex motor behaviors like riding a bicycle or swinging a golf club is based on acquiring neural representations of the mechanical requirements of movement (e.g., coordinating muscle forces to control the club; Mattar & Gribble, 2005). Here we provide evidence that mechanisms matching observation and action facilitate motor learning.

Gandolfo et al. (1996) investigated how human subjects adapt to forces perturbing the motion of their ams. They found that this kind of learning is based on the capacity of the central nervous system (CNS) to predict and therefore to cancel externally applied perturbing forces. If the actual sensory feedback differs from the predicted one, the resulting prediction error is controlled by the ML by updating the internal model (Donchin, et al., 2012).

It is generally assumed that the motor cortex is the basis for acquiring and performing motor skills. have confirmed the role of the brain, resp. cortical-basal ganglia circuits in motion control (Woolley & Kao, 2015). To understand the role of the cerebellum in motor control, it is helpful to consider neuroanatomical evidence showing that distinct regions of the cerebellum are concerned with specific motor functions, giving rise to concept of "compartments" of motor functions within the cerebellum (Konczak & Timmann, 2007; Paulin, 1993).

In the study of motor learning control, we encounter questions of the functioning of the neuromuscular system, its activation and coordination of muscles and limbs involved in the performance of motor skills, which Magill & Anderson (2014) unify with the term – motor control. It includes the whole system of perceptual factors – perception of oneself and the environment, maturation, motivation, social motives, anxiety, stress and other forms of tension involved in interacting with classmates and the teacher. In the theory of motor learning we also find the term – working memory. The concept of working memory assumes that a limited capacity system temporarily stores information and thereby supports human thought processes (Baddeley, 2003). One prevalent model of working memory comprises three components: a central executive, a verbal storage system called the phonological loop, and a visual storage system called the visuospatial sketchpad.. When realizing the movement itself, the visual model is compared with the planned movement. We observe this phenomenon e.g. at the high jumper. He visualizes his movement in advance (comparison with the model) and only then executes it by the executive body (Pollock & Lee, 1992). However, a prerequisite for correlation analysis is an understanding of the determining factors. While infants acquire skills through imitation and trial and error, we follow the rules in formal teaching. In supervised motor learning, where the desired movement pattern is given in task-oriented coordinates, one of the most essential and difficult problems is how to convert the error signal calculated in the task space into that of the motor command space (Kawato, 1990). From a conceptual point of view at ML, we also encounter behavioral theories that understand motor skills as a consequence of the manifestation of the entire spectrum of mental processes. Ivry (1994) considers psychological processes to be factors that allow past experience to be used to improve motor behavior. According to Wolpert et al. Wolpert, Ghahramani & Flanagan, (2001), learning involves changes in behavior that result from interaction with the environment. It has also been shown that information on the high level and form of movements can also be obtained by observing others (Petrosini, 2003). However, these processes are not sufficiently clarified in terms of motor learning in sport.

At present, the role of cognitive processes in motion control is also not sufficiently stressed. The important role of perception as a factor that has a significant influence on the time characteristics of the realization of the movement and thus on its overall quality is not emphasized (Horička, Šimonek & Paška, 2020). Current research confirms evidence of some correlations between basic categories of motor and cognitive abilities, including complex motor skills and higher order cognitive abilities (Ramakrishnan, 2018; Van der Fels, 2015).

Taking a broader view of the position of cognition in the procedural side of movement, we must also consider the role of intelligence and a common center of control of these processes – the nervous system. Intelligence is a form of mental organization, and the largest form of management of cognitive structures. It integrates forms of behavior and thus a large number of specific skills (speed of processes, attention, etc.; Piaget (1964).

METHODS

Study Design

120 students Elementary school (ES) and Secondary Grammar School (SGS) (15 boys and 15 girls from each form) took part in testing the level of motor learning and intelligence (n = 120). Until the beginning of the research, pupils and students did not complete the thematic unit of gymnastics with selected gymnastic elements, which formed the content of the ML test. The monitored group for comparing the level of motor learning and intelligence were pupils of the 6th form (decimal age DA=11.78 y.), 7th form (DA=12.96 y.), 1st form (DA=15.94 y.) and 2nd form of Secondary Grammar School in Nitra, Slovakia (DA=16.85 y.; Table 1). All research participants confirmed in writing their consent to their inclusion in the research and to the processing of personal data in accordance with the EU GDPR Regulation.

Table 1. Basic somatometric indicators

Grade	Decimal age /years	Body height/cm		Body weight/kg	
		boys	girls	boys	girls
6th ES	11.78	151	154.3	41.8	44.2
7th ES	12.96	160.2	156.6	47.8	46.3
1st SGS	15.94	173.1	165.8	62.8	54
2nd SGS	16.85	176.4	168.7	70.9	55.3
$\bar{x}$	14.38	165.2	161.4	55.8	50

Explanatory notes: ES – Elementary school, SGS – Secondary Grammar School

In 3 practice classes, students performed a methodical series of exercises, exercises to master individual positions, and finally followed the combination of individual activities to demonstrate the whole movement. After each training lesson (n = 3 / 45'), we evaluated the level of ML in boys and girls in the demonstration of learned gymnastic elements using a grade from 1 to 5, with grade 1 corresponding to the best grade and grade 5 to the worst. The gymnastic element of the pupils of the 6th form was a roll forward to the crotch stand, for the pupils of the 7th form it was a roll back to the crotch stand, for the students of the 1st form of high school it was a stand on the head and for the 2nd form students it was a cart-wheel. Assessment was performed independently by 2 qualified P.E. teachers.

Testing procedure

We used the intelligence test to determine the level of general intelligence [1]. It consists of 2 intelligence tests, each with 20 questions. The time limit is 20 min. to develop one test, immediately followed by another test with the same number of questions and the same time limit. The resulting score was the sum of the correct answers from both tests. The level of motor learning was evaluated using the method of professional assessment. To obtain the necessary material for the solution, we used anthropometric measurements, observation method, expert assessment.

Statistical methods

The normality of the primary data was determined using the Shapiro-Wilk test, the degree of statistical significance by the Mann-Whitney test, and the magnitude of the differences by the Effect size method. A non-parametric Spearman correlation coefficient rs (correlation analysis)

was used to determine the dependence of the quantitative features. Statistical processing of primary data were carried out using the Software IBM SPSS (version 24).

RESULTS

The basic characteristics of the position are given in tab. 2. At the ML level, we observe relative stability and a slight decrease in values for middle-school students (girls: 1.95 › 1.89 ML level), similarly for boys (2.24 › 2.19 ML level). Subsequently, in older school age, this ability is dynamized in both sexes, the level of ML reaches the value of $ML\bar{x}_b = 2.51$ in boys, and 2.42 in girls. Overall, we evaluate the level of ML in boys ($ML\bar{x}_b = 2.33$) higher than in girls ($ML\bar{x}_g = 2.08$), the difference decreases with increasing age (Figure 1). When evaluating the material significance of the differences, we state the dominance of boys, especially in the 7th grade of primary school (Cohen's d = 2.14).

The difference between the genders was small (p = ⟨0.19 – 0.81⟩) and statistically insignificant. The hypothesis that the performance dominance of boys over girls is also reflected in ML has not been confirmed in any age category. This statement is also supported by the values of materiality of differences (Effect size) d = ⟨0.046 – 0.24⟩. Since the null hypothesis H0 and also the small effect size were confirmed, we can say with certainty that we did not notice any differences between the samples (Table 2).

Table 2. ML level in the sample of students

Motor learning	6th form ES		7th form ES		1st form SGS		2nd form SGS	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Mean	2.24	1.95	2.19	1.89	2.33	2.06	2.5	2.42
Std. Error	0.16	0.11	0.17	0.16	0.18	0.15	0.23	0.12
Median	2.3	2	2	2	2.3	2	2.7	2.3
Std. Deviation	0.64	0.43	0.67	0.63	0.71	0.59	0.88	0.47
Minimum	1	1.3	1.3	1	1	1	1	1.7
Maximum	3.3	2.7	3.3	3	3,3	3	3.7	3.3
Sum	33.6	29.2	32.8	28.3	35	30.9	37.5	36.3
Sig. (2-tailed)	0.187		0.267		0.285		0.806	
Sign.	p>0.05		p>0.05		p>0.05		p>0.05	
Cohen's d	0.24*		0.21*		0.20*		0.046*	

Explanatory notes: ES – Elementary school, SGS – Secondary Grammar School, * – small Effect size

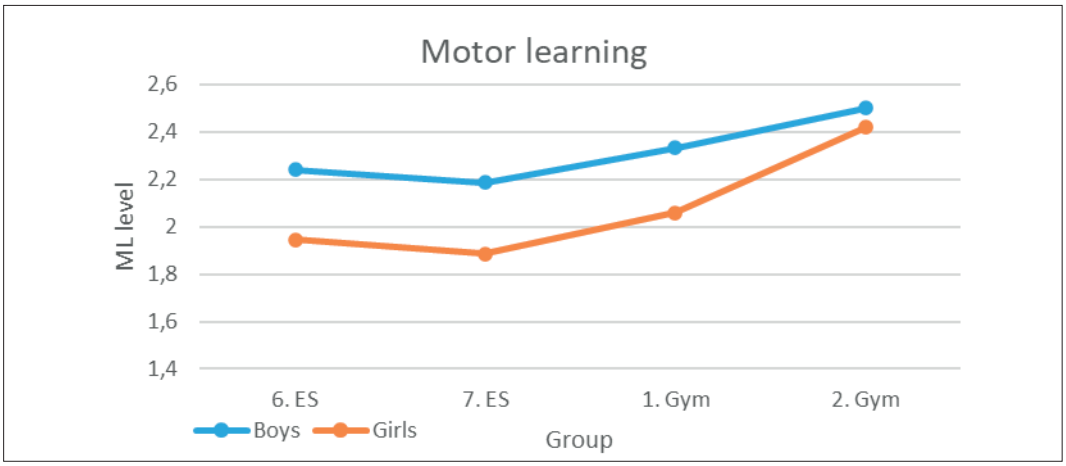

Figure 1. Motor learning level – boys vs girls

When evaluating the level of intelligence with respect to gender, on the contrary, we state a slight predominance of girls ($I\bar{x}_g$ = 112.75) over boys ($I\bar{x}_b$ = 112). In both sexes, from 12 years to 17 years of age, the IQ value increases continuously from the level of 107.1 to 116.4 points (boys) and from the value of 108.2 to 116.7 points (girls). This finding proves that intelligence is not dependent on gender. Gender differences in IQ levels decrease with age. Table 3 shows the values of descriptive statistics and the significance of differences – IQ in the monitored samples (Figure 2).

Also in the case of IQ analysis in relation to gender, no statistically significant difference was found between boys and girls p = ⟨0.089 – 0.935⟩. The statement is also supported by low values of Effect size – Cohen's d = ⟨–0.31 – 0.064⟩.

Differences in IQ levels were smaller between boys and girls than in the case of ML, but the fact that both indicators were measured in different units should be taken into account.

Table 3. IQ level in the sample of students

Intelligence	6th form ES		7th form ES		1st form SGS		2nd form SGS	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Mean	107.1	108.2	109	112.1	114.9	113.9	116.4	116.7
Std. Error	1.26	1.40	1.38	1.04	1.73	1.62	1.48	1.70
Median	107	108	108	113	115	114	118	118
Std. Deviation	4.89	5.41	5.35	4.03	6.71	6.29	5.76	6.62
Minimum	98	98	102	105	103	105	105	105
Maximum	115	117	119	119	127	125	124	127
Sum	1606	1623	1635	1682	1723	1709	1746	1750
Count	15	15	15	15	15	15	15	15
Sig. (2-tailed)	0.539 p>0.05		0.089 p>0.05		0.713 p>0.05		0.935 p>0.05	
Cohen's d	–0.11*		–0.31*		0.064*		0.011*	

Explanatory notes: ES – Elementary school, SGS – Secondary Grammar School; * – small Effect size

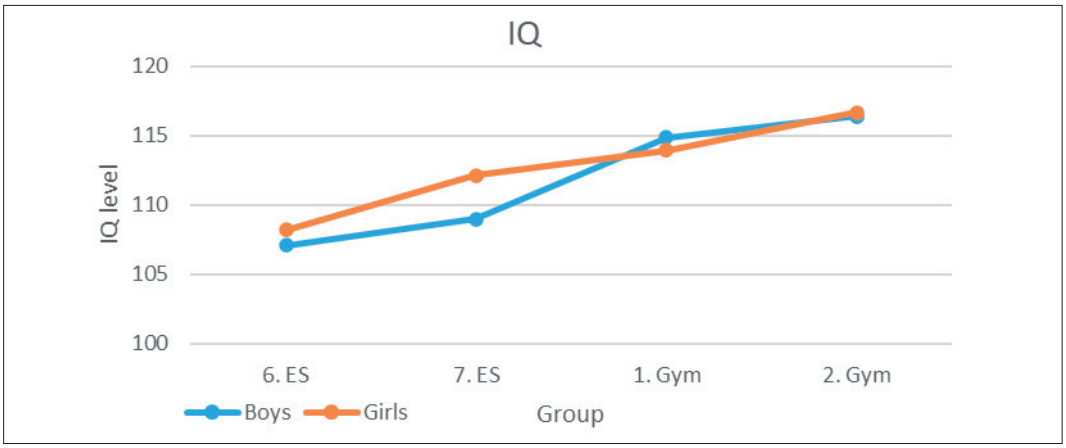

Figure 2. IQ level – boys vs girls

The subject of the correlation analysis was first to assess the existence and extent of a possible relationship between the factors of intelligence and motor learning regardless of the gender, and with regard to gender. The relationship between the two indicators was confirmed with the exclusion of the gender factor (r_s = – 0.276, sig. <0.1+ Table 4), whereas the tightness of the relationship is high. Taking into account the gender of the probands, the relationship was confirmed in the monitored indicators only in boys (r_s = – 0.293, sig. <0.5), in girls, a significant relationship was not confirmed (r_s = – 0.202, sig. >0.1; Table 5). Due to the extent of the monitored group (n = 120), a weak dependence with a value of r_s <0.3 may be statistically significant. We therefore evaluate the degree of dependence between the variables as relatively low.

Table 4. Correlation between Motor learning and Intelligence

			Motor Learning	General Intelligence
Spearman's rho	ML	Correlation Coefficient	1.000	0.276**
		Sig. (2-tailed)	.	0.002
	GI	Correlation Coefficient	–0.276**	1.000
		Sig. (2-tailed)	0.002	.
		N	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5. Correlation between Motor learning and Intelligence with regard to gender

			Boys_ML	Boys_IQ	Girls_ML	Girls_IQ
Spearman's rho	Boys_ML	Correlation Coefficient	1.000	–0.293*	0.185	–0.127
		Sig. (2-tailed)	.	0.023	0.158	0.335
	Boys_IQ	Correlation Coefficient	–0.293*	1.000	0.045	0.382**
		Sig. (2-tailed)	0.023	.	0.731	0.003
	Girls_ML	Correlation Coefficient	0.185	0.045	1.000	–0.202
		Sig. (2-tailed)	0.158	0.731	.	0.122
	Girls_IQ	Correlation Coefficient	–0.127	0.382**	–0.202	1.000
		Sig. (2-tailed)	0.335	0.003	0.122	.

*. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed).

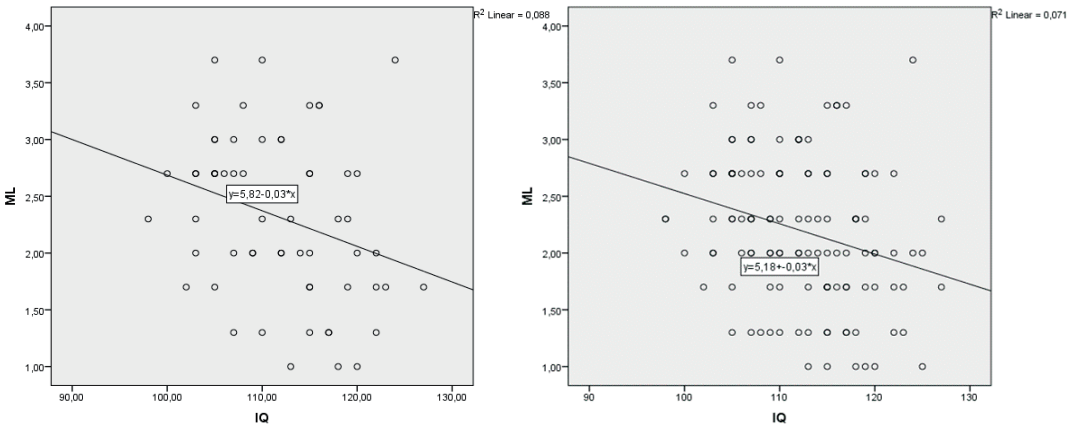

Figure. 3. Relationship between ML and Intelligence level (boys and girls)

The negative polarity of correlation coefficients and their distribution indicates the antagonistic relationship of the observed indicators. The level of motor learning decreases with increasing intelligence in both genders, but we must interpret this relationship very carefully, especially in relation to the statistical degree of the relationship between these factors (Figure 3).

In the analysis of the factor in relation to gender, no significant relationship was found in the case of boys or girls. (ML r_s = – 0.163, sig.>0.5; IQ r_s = 0.071, sig.>0.5; table 6). Thus, the observed factors are not dependent on gender, but are probably determined by other factors. The overall difference in the level and dynamics of the development of ML and IQ with respect to age is confirmed by the degree and polarity of the material significance of the differences (Effect size; d_{ML} = 1.08; d_{IQ} = –0.46).

Table 6. Correlation between Motor learning and Intelligence

Correlations			ML	gender	IQ	gender
Spearman's rho	ML factor	Correlation Coefficient	1.000	–0.163	1	0.071
		Sig. (2-tailed)		0.075		0.44
	Gender factor	Correlation Coefficient	–0.163	1.000	0.071	1.000
		Sig. (2-tailed)	0.075		0.44	
	N		120		120	
	Gender		boys / girls		boys / girls	
	Effect size / Cohen's d		1.08		–0.46	

DISCUSSION

Based on the hypothesis of the dominance of boys in terms of the pace of motor learning in a selected group of school population of boys and girls, the differences in favor of boys were not confirmed in any of the monitored age categories. Higher values were recorded in boys, but the differences were not statistically significant (p = ⟨0.19 – 0.81⟩). In both genders, the dynamics of ML are similar, but not ascending. In the 7th year, the ES even declines slightly. The gender gap gradually decreases with increasing age. The intervals of ML values were in boys $\bar{x}$ = ⟨2.19 – 2.51⟩, in girls $\bar{x}$ = ⟨1.89 – 2.42⟩.

When assessing the level of IQ, the tendencies are different in terms of gender. At the age of 11–13 years, girls $\bar{x}$ = ⟨IQg 108.2 vs IQb 107.1⟩ slightly dominate, at the beginning of adolescence at the age of 15 again boys $\bar{x}$ = ⟨IQb 114.9 vs IQg 113.9⟩ and at the age At 17 years, the differences are at least $\bar{x}$ = ⟨IQb 116.4 vs IQg 116.7⟩. The differences are also statistically insignificant in the case of IQ. The relationship analysis showed high relationship between the parameters ML and IQ with the exclusion of the gender factor (rs = – 0.276, sig. <0.1), taking into account the gender confirmed the relationship between the parameters only in boys (rs = – 0.293, sig. <0.5). We interpret the rate of motor learning in boys and girls as the IQ values decrease with increasing IQ values, and we assume that this relationship will be more pronounced at extreme IQ values. It is different from motor skills, it is limited by the cultural and social environment, while the process of motor learning is determined by teaching methods and didactics. Our results confirm that more than intellectual abilities, the pace of acquiring abilities and skills is limited by the procedural side of teaching.

CONCLUSION

Following the above facts about the theory of motor control and our findings, we assume the continuity of certain mental and motor processes, which Berendsen et al. [3] call motor intelligence. This relationship has been confirmed in many studies. Planinsec & Pisot [20] present the findings that adolescents with average intelligence performed motor coordination tasks more effectively than adolescents with below-average intelligence. Similarly, Smits-Engelsman & Hill [26, 28] found that individuals with lower measured IQs were more likely to show poorer motor performance than individuals with higher measured IQs. Păunescu et al. [17] found statistically significant correlation (r=0.76; n=40; p<0.001) between general intelligence and motoric intelligence specific to combat sports, in a group of subjects who do not practice performance sports. Students with higher level of general intelligence also prove superior motoric abilities within the process of motor skills development.

The results of our research did not show significant differences in the level of ML and IQ in both genders. Boys slightly dominated in ML, girls in IQ in accordance with Ramakrishnan [23], this difference decreases with increasing age. Thus, motor ontogenesis probably proceeds at a different rate than mental in relation to gender. There was also no relevant relationship between the ML level and general IQ. It was confirmed only in the group of boys, but only to a small extent. This fact could be caused by several factors: the age and performance structure of the sample, the validity of the diagnostic procedure, inappropriate time interval of training of the evaluated element, the type of intelligence detected, or even insufficient motivation. Our findings are in line with the research results by Cushing [4] who did not find any relevant relationship between motor educability (Iowa-Brace Test) and mental maturity (California test) on a sample of female school populationu (5th grade). However, the dynamic social development of mankind relativizes these results nowadays.

We consider it necessary to clarify the nature of the possible relationship of these properties in a broader context in order to improve the quality of motor learning. It is necessary to abandon the claim that skills are soulless or merely physical. On the contrary, we argue that movement is a manifestation of the association of motor functions and cognitive processes, the cultivation of which in the process of learning skills must take place simultaneously. Finally, learning is the only fast enough mechanism that allows us to cope with new tasks that are specified by societal tasks. Finally, the "learn to learn" competence is also one of the 8 key competences for lifelong learning [24].

Conflict of interest

The authors declare no conflicts of interest. We certify that no party having a direct interest in the results of the research supporting this article has or will confer a benefit on us or on any organization with which we are associated.

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Effect of Selected Corrective Exercises on Glenohumeral Rotation range of Motion in Overhead Athletes with Scapular Dyskinesis

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Abstract

In overhead Athletes, performing the repetitive and high intensity throwing activities causes to reduce the Glenohumeral internal rotation range of motion (GIR ROM) in dominant shoulder and Scapular Dyskinesis (SD). These factors may make the shoulder predispose to injury. The purpose of this study was to investigate the effect of eight weeks of selected exercises protocol on the Glenohumeral Rotation ROM and SD in overhead athletes. The present study is a descriptive study that was conducted on 54 volleyball players with SD. Goniometer and Lateral scapular slide test (LSST) were used to measure the Glenohumeral Rotation ROM and SD, respectively. The experimental group participated in eight weeks of exercises. Data were analyzed using independent t-test. In the experimental group, the GIR and SD after exercises showed a significant increase (P= 0.001) and a decrease (P= 0.001), respectively; while in the control group, the changes were not significant. Therefore, the exercises protocol can lead to increase the GIR and correct the SD in overhead athletes, and it is recommended to consider it as a part of their routine exercises.

Key words*: rehabilitation protocol, internal rotation range of motion, Volleyball Players, scapular Dyskinesis*

INTRODUCTION

The shoulder is at high risk for injury during overhead sports, in particular in throwing or hitting activities, such as volleyball, baseball, tennis and handball because it faces high loads and forces during serving and smashing (Cools, Johansson, Borms, & Maenhout, 2015). The repetition of high velocity overhead throwing can change the shoulder stability – mobility relationship and ultimately lead to injury (Shimpi et al., 2015). A 'shoulder at risk' in the throwing athletes, is the asymptomatic shoulder with a deficit of varying degree of glenohumeral internal rotation, scapular dyskinesis or both (Burkhart, Morgan, & Kibler, 2003b). In general, three risk factors have been defined that may form the basis for recommendations for the prevention of recurrent injury: glenohumeral internal-rotation deficit (GIRD); rotator cuff strength, in particular the strength of the external rotators; and scapular dyskinesis, in particular scapular position and strength (Cools et al., 2015).

Overhead athletes' shoulders need high stability to perform throwing patterns despite having high mobility (Cools et al., 2015). This sensitive balance between mobility and stability is known as the thrower paradox. If it disturbed, may lead to injury (Shimpi et al., 2015). The movement mechanics of the throw predispose the athlete to an imbalance in the range of motion, especially

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GIRD and decrease in the strength of the Glenohumeral external rotation (GER) (Cools et al., 2015). In this regard, Shimpi et al. (2015) comparing the two groups of overhead (rocket) athletes with the control (non-rocket) group, found that in the group of overhead athletes, Glenohumeral Internal Rotation (GIR) is less and the SD is more than the non-rocket group (Shimpi et al., 2015).

The GIRD in overhead athletes is a common occurrence due to the glenohumeral arthrokinematics changes. It causes a shift in the humeral head center of rotation to an anterosuperior position on the glenoid during forwarding flexion (Harryman 2nd et al., 1990). These arthrokinematics changes cause damage to the shoulder joint structure by increasing pressure and tension forces, joint kinematic changes and interactive movements (Burkhart, Morgan, & Kibler, 2003a; W. B. Kibler, Sciascia, & Thomas, 2012).

In addition to GIRD, the SD is also important risk factors for shoulder injuries (Benjamin W Kibler, Sciascia, & Wilkes, 2012). Altered scapular motion and position have been termed SD (W. B. Kibler et al., 2013). Scapular dyskinesis is not necessarily a pathologic term. In fact, it may be found either in asymptomatic subjects or in patients with pain in the shoulder girdle (Silva, Hartmann, de Souza Laurino, & Biló, 2010), and in overhead athletes (De Mey et al., 2013; Silva et al., 2010). Dyskinesis can affect asymptomatic subject, but it is typically observed in overhead athletes in whom it may cause a SICK syndrome (Scapular malposition, Inferior medial border prominence, Coracoid pain and malposition and dyskinesis of scapular motion), responsible for shoulder pain and functional deficit. When unrecognized and untreated, SD may cause SLAP lesions, subacromial impingement syndrome (SIS) and injuries to cuff tendons (Postacchini & Carbone, 2013). Ghanbari et al. (2019) also found in their study that there is a predictive relationship between Glenohumeral rotation ROM and SD, so that the variables of decreased IR ROM and increased ER ROM can predict SD in overhead athletes (L Ghanbari, Alizadeh, Minoonejad, & Hosseini, 2019). SD is associated with a change in the pattern of activity of the scapulothoracic muscles (Leila Ghanbari, Alizadeh, Minoonejad, & Hosseini, 2018; Ben W Kibler & McMullen, 2003). During arm abduction, the upper trapezius (UT), lower trapezius (LT) and serratus anterior (SA) result in the upward rotation and posterior tilt of the scapula as force couples (B. W. Kibler et al., 2012). Therefore, reducing the strength and activity level of the SA and LT (Cools et al., 2007) as well as delayed onset of activation of these muscles caused a change in the upward rotation and posterior tilt of scapula (Park et al., 2014). Previous studies have reported excessive activation of UT (Cools et al., 2007; Lopes, Timmons, Grover, Ciconelli, & Michener, 2015; Oliveira, Batista, Pirauá, Pitangui, & Araújo, 2013) and decreased activity of SA, LT (Cools et al., 2007), AT/LT, AT/SA in subjects with SD (Oliveira et al., 2013). These altered muscle activation patterns are associated with altered scapular kinematics, including reduced scapular upward rotation, external rotation and posterior tilt (Ludewig & Cook, 2000).

Treatment is based on rehabilitation, but not for all exercises there are sound proofs of efficacy. Some researchers were recommended performing exercises aimed at increasing the activity level of the LT (Burkhart et al., 2003a; Ben W Kibler & McMullen, 2003; Ludewig & Reynolds, 2009) and SA muscles (Cools et al., 2007) while minimizing the activity level of the UT (Cricchio & Frazer, 2011) through conducting electromyographic studies (Leila Ghanbari et al., 2018; B. W. Kibler et al., 2012; Park et al., 2014).

In addition, shoulder stretching exercises can improve posterior capsule stiffness and IR ROM (B. W. Kibler et al., 2012). Kuhn (2009) confirmed that a shoulder intervention program must focus on strengthening of the rotator cuff and periscapular muscles, joint mobilization, and posterior capsule stretching (Kuhn, 2009). The exercise program of Tang et al. (2021) also emphasized scapular stabilization exercises. The results of this study provide evidence of the effect of targeted scapular stabilization exercise in improving shoulder function and correcting scapular dyskinesis(Tang et al., 2021).

The treatment of SD described in the literature is based on exercises that increase soft tissue flexibility and ROM. Others have also suggested strengthening exercises for the periscapular muscles without overload of the hyperactive muscles (Cools et al., 2007; B. W. Kibler et al., 2012). In addition, specify studies have examined the effects of exercises protocol on overhead athletes with SD. However, there is a need for further investigation and descriptions of exercise protocol focused on SD correction and improve the GIR in overhead athletes. Thus, the purpose of this study was to describe the exercise protocol that emphasizes GR ROM and SD correction on overhead athletes. It was hypothesized that after this exercise protocol, subjects would experience improved GR ROM and SD.

MATERIALS AND METHODS

The present study is a descriptive study and the subjects consisted of 54 female volleyball players (club-level, 18–25 years old) who were selected by available method. Inclusion criteria include: female gender, having at least three years of regular sports experience in volleyball and the presence of SD, and the exclusion criteria included pain in the shoulder girdle and neck in the normal and practice conditions, history of fracture or dislocation in each shoulder girdle bones, complete rupture of shoulder girdle muscles; and history of surgery in the shoulder girdle (B. W. Kibler et al., 2012).

A total of 177 volleyball players were evaluated by an experienced physiotherapist and According to the inclusion and exclusion criteria, 54 subjects with SD were selected. Then They were divided into two groups: experimental, who participated in exercise protocol (n= 27, age= 21.59± 2.63 years old, weight: 62.48± 7.25 kg and height: 165.66± 3.58 cm) and control (n = 27, age= 22.85±2.1 years old, weight: 62.88±5.51 kg and height: 164.92±4.35 cm), who didn't participate in exercise protocol. Written consent was also obtained from all subjects.

Data measurement methods

Scapular Dyskinesis (SD): The Lateral scapular slide test (LSST), was used to investigate the SD. In this test, the distance between the inferior angle of the scapula to the corresponding spinous process in the three positions of 0, 45 and 90 degrees of shoulder abduction was measured. Each of the measurements was repeated three times in both arms and then their average was calculated (figure 1). If there was a difference of 1.5 cm or more between two the scapulae, the test was considered positive. Kibler reported the in-group reliability of this test from 0.84 to 0.88 and the out-group reliability from 0.77 to 0.85 in different aspects (Ben Kibler, 1998).

IR ROM and ER ROM: The passive rotational range of motion for the glenohumeral joint was assessed by a standard goniometer (360º, Lafayette company product). The participant lay supine on a treatment table with the legs straight and the dominant arm in 90º abduction in the coronal plane and 90º of elbow flexion with the elbow slightly off the table's edge. Maximal external and internal rotation were measured with the goniometer's axis in line with the shaft of the humerus, the stable arm perpendicular to the floor and the movable arm in line with the ulnar styloid. When measuring internal rotation, we allowed motion to occur until the spine of the scapula began to lift off the table. This defined the maximal value for internal rotation. The movement reaches its endpoint when the coracoid tends to move against the palpating thumb. For external rotation, the fixating hand is placed gently over the shoulder top, and the shoulder is moved into

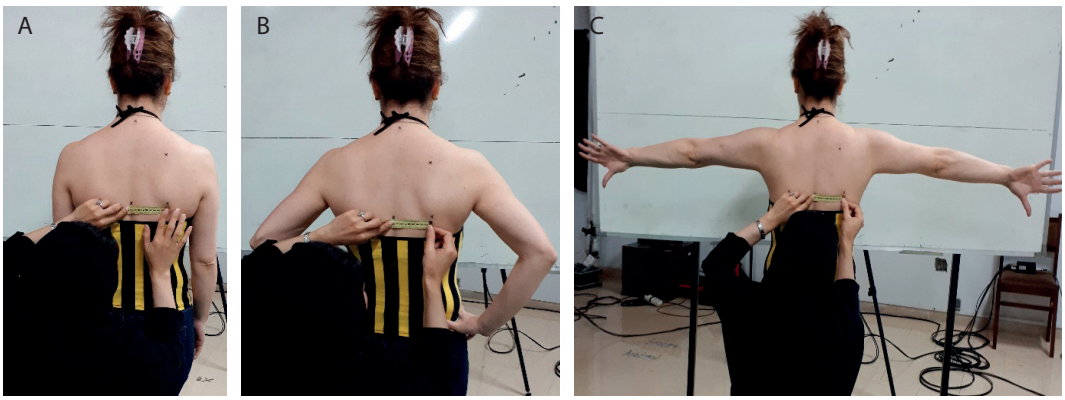

Figure 1. Lateral scapular slide test. A) both arms at the sides in glenohumeral joint neutral. B) with hands on hips and with thumbs posterior. C) with arms abducted 90 degrees with full shoulder internal rotation

external rotation, aligning the goniometer with the forearm (Cools et al., 2015). In addition, the measurements were performed in the dominant hand of the subjects.

Exercise program: The protocol used included the exercise protocol of Moura et al. 2016 (Table 1), which was performed by the experimental group to repeat three sessions of exercise per week with moderate intensity for eight weeks. The training protocol consisted of three stages. Phase 1 consisted ROM and periscapular muscular strengthening training, Phase 2 focused on periscapular muscular strengthening and initiation of sensory motor training and phase 3 on advanced sensory motor training. All exercises were dosed at 3 sets of 15 repetitions throughout the protocol, and this intermediate dosage was chosen in order to focus on muscular strength and endurance (Moura, Monteiro, Lucareli, & Fukuda, 2016). The rest between each set was gradually reduced until the end of the period. Activity intensity was monitored using the Borg scale PRE (Borg, 1998) and OMNI resistance exercise scale (Colado et al., 2012). The Borg scale is a numerical scale that ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion" (Borg, 1998). When measured, a number is chosen from the following scale by an individual that best describes their level of exertion during physical activity; and according to OMNI-resistance exercise scale, by increasing the separation between the hands gripping the elastic band, the intensity decreases.

Table 1. Selected exercise protocol

Phase 1 (week 1&2)	Phase 2 (week 3–5)	Phase 3 (week 6–8)
Sleeper stretch (60°, 90°, 120°)	Sleeper stretch (60°, 90°, 120°)	
Sitting, arms in neutral position, pull their shoulder blades back and down	Punch with dumbbells	Standard push-up plus with the Swiss ball
Punch exercise	One-hand push-up plus exercise	Modified prone Cobra on Swiss ball with dumbbells
Wall push-up plus exercise	Modified prone Cobra with dumbbells	Prone horizontal abduction exercise on the Swiss ball with dumbbells
Modified prone Cobra	Prone horizontal abduction exercise	Prone V-raise exercise on the Swiss ball with dumbbells
	Prone V-raise exercise	Low row exercise with theraband
	Prone row	Rotator cuff exercise with theraband
	Rotator cuff exercise	

1-sample K-S statistical test was used to check the normality of data distribution. According to the normality of data distribution, Independent t-test was used to compare the mean variables of IR, ER and SD between the experimental and control groups before and after exercise. Analysis was performed with IBM SPSS statistics version 22 and $\alpha < 0.05$ was considered.

RESULTS

The demographic information of the samples is presented in Table 2.

Table 2. The Demographic Characteristics of the Two Groups[a]

Variable	Groups	Mean±SD	P-Value
Age (year)	Experimental	21.59±2.63	0.163
	Control	22.85±2.1	
Height (cm)	Experimental	165.66±3.58	0.511
	Control	164.92±4.35	
Weight(kg)	Experimental	62.48±7.25	0.110
	Control	62.88±5.51	

[a]Values are expressed as mean ± SD and analyzed by 1-sample K-S test.

1-sample K-S statistical test was used to evaluate the normality of data distribution. Regarding that the sig factor is greater than 0.05 in all variables, the data distribution is normal. The results of Independent t-tests indicated that there was no significant difference between the two groups in terms of height, weight, age (table 2), IR ROM, ER ROM and SD (table 3) and the two groups were homogeneous ($P < 0.05$).

Table 3. Mean and SEM of IR, ER and SD and the Changes Between Two Groups[a]

Variable	Time	Experimental	Control	p-value
Internal rotation range of motion (degrees)	Pre	46.59±4.90	47.18±10.37	0.628
	Post	52.74±5.18	47.66±5.00	0.001*
External rotation range of motion (degrees)	Pre	97.07±10.37	95.03±9.18	0.890
	Post	95.77±10.14	95.77±9.22	0.628
Scapular Dyskinesis (cm)	Pre	1.80±0.32	1.75±0.30	0.653
	Post	1.60±0.25	1.75±0.28	0.001*

[a] Values are expressed as mean ± SEM and analyzed by IR, ER and SD t-test.

Independent t-test was used to compare the mean variables of IR, ER and SD between the experimental and control groups before and after exercise (Table 3). Table 3 presents the pre- and post-mean, SEM of the IR, ER and SD between the two groups. The IR increased significantly after eight weeks of exercises in the experimental group (P= 0.001), whereas there was no significant increase in the control group (P= 0.628). The SD decreased significantly in the experimental (p= 0.001), while the changes in ER were not significant.

DISCUSSION

Results of the study showed that the exercises protocol significantly increased the IR ROM and significantly reduced the SD of the mentioned athletes. It can also reduce the ER ROM, although this reduction was not significant.

The repetitive overhead motions which usually involve excessive ER with a maximally abducted position (cocking phase) and the subsequent phases of acceleration/deceleration and follow-through place a high amount of stress on the static and dynamic stabilizers of the shoulder, including the rotator cuff, joint capsule, and labrum. This repetitive overuse load will ultimately lead to a failure in these structures to absorb arm energy, predisposing them to injury, which generates pain and posterior shoulder tightness (Borsa, Laudner, & Sauers, 2008). Posterior inferior capsular and rotator-cuff tightness have been suggested as the main contributing factors to the loss of GIR for most athletes (Lintner, Mayol, Uzodinma, Jones, & Labossiere, 2007).

In the present study, GIR in the experimental group increased significantly after exercise (IR_{pre}= 46.59±4.90, IR_{post}= 52.74±5.18, P= 0.001). Stretching has been proposed as an effective approach for the management of GIRD, restoring shoulder ROM, and reducing the incidence of shoulder injury and muscle soreness (Burkhart et al., 2003a; W. Kibler & Chandler, 2003). Burkhart et al. (2003) and Launder at al. (2008) examined the effect of the Sleeper Stretch on GROM and found that the sleeper stretch group improved significantly in IR compared to the control stretching group (Burkhart et al., 2003a; Laudner, Sipes, & Wilson, 2008). Moura et al. (2016) presented a rehabilitation training program to amateur athletes with SD to reduce subacromial pain, increase ROM, periscapular muscular strengthening, and SA activation. The authors also attributed the increase in ROM to the posterior capsule structures stretching (sleeper stretch) (Moura et al., 2016). In the present study, it seems that the increase in IR is due to the stretching (sleeper stretch) of the posterior shoulder structures. This finding confirms the reports of other authors who attribute this deficiency in the IR ROM to joint capsule stiffness disturbance and SD (3, 37, 47). Sajadi et al. (2019) also reported a significant increase in GIR in swimmers with SD following the training protocol of Moura et al. (2016) According to the results of this study, performing sleeper stretching at three angles of 60, 90 and 120 degrees increased the GIR in swim-

mers with SD (Sajadi, Alizadeh, Barati, & Minoonejad, 2019). The results of a systematic review study suggest that the rehabilitation program for subjects with shoulder dysfunction should focus on periscapular muscular strengthening and rotator cuff, joint mobilization techniques, and posterior capsule stretching (Kuhn, 2009).

Another finding of this study was a significant reduction in SD in the experimental group following eight weeks of exercises (SD_{pre}= 1.80±0.32, SD_{post}= 1.60±0.25, P= 0.001*). Due to relationship of GIRD in the incidence of SD (L Ghanbari et al., 2019; Ben W Kibler & McMullen, 2003), performing corrective exercises by increasing IR ROM can reduce the rate of SD. In their study, Kibler et.al cited the posterior capsule stiffness as one of the causes of SD and recommended stretching and flexibility exercises to treat it (Ben W Kibler & McMullen, 2003). According to studies, in overhead athletes with GIRD, the protracted scapula was associated with SD, and increasing IR deficiency lead to increase the rate of SD (Borich et al., 2006; Thomas, Swanik, Swanik, & Kelly, 2010). In interpreting the relationship between GROM and SD, it can be stated that during the Follow through phase of the throw, the scapula helps to release energy by protracted on the chest (Thomas, Swanik, Swanik, & Kelly IV, 2010; Thomas, Swanik, Swanik, & Kelly, 2010). In case of IR deficiency, protracting the scapula increases in order to compensate the IR deficiency and also to maintain the overhead acceleration. At this time, this constant pressure causes soft tissue adaptation and weakness in the scapular stabilizers (Shimpi et al., 2015; Thomas, Swanik, Swanik, & Kelly IV, 2010; Thomas, Swanik, Swanik, & Kelly, 2010). Therefore, the scapula cannot provide a stable surface to support the rotator cuff muscles. This reduces its efficiency and increases the pressure on the dominance shoulder static structures (Cools et al., 2015). Thus, the rotator cuff pushes the scapula outward rather than putting pressure on the head of humerus in the glenoid fossa, causing further external protrusion and rotation of the scapula, altering the scapulohumeral rhythm, and disrupting the scapular movement (W. B. Kibler et al., 2013). According to the explanations provided, the relationship between the shoulder rotation ROM and SD was well explained. Therefore, it seems that increasing the shoulder rotation ROM was one of the reasons for reducing the SD in the subjects.

On the other hand, SD is associated with muscle imbalance (Ben W Kibler & McMullen, 2003). According to a study by Seitz et al. (2015). Athletes with SD had less upward rotation of scapula and GER, and weaker LT muscles than athletes without SD. Weakness of SA and LT strengthening was associated with lack of upward rotation of scapula (Seitz, McClelland, Jones, Jean, & Kardouni, 2015). Also, due to the importance of the SA role in the stability of the scapula, its disorder and imbalance in each of the SA, UT, LT muscles can change the natural three-dimensional movement of the scapula and its asymmetry (Ludewig & Cook, 2000). While pointing out that the asymmetry of the scapula (Ben Kibler, 1998) and its abnormal movement can be referred to as SD (B. W. Kibler et al., 2012; W. B. Kibler et al., 2013), many researchers have recommended targeted exercises by conducting electromyographic studies and with regard to the prevalence of imbalance in scapulothoracic muscle activation and also the presence of muscle imbalance in the force couples of UT with LT and SA in patients with SD (B. W. Kibler et al., 2012; Park et al., 2014). Therefore, in shoulder rehabilitation exercises, the focus should be on increasing the SA and LT activity (Pirauá et al., 2014), reducing the UT activity (Cools et al., 2007; B. W. Kibler et al., 2012), reducing the ratio of UT to SA, ratio of UT to LT and the ratio of UT to middle trapezius and strengthen the rotator cuff muscles (Cricchio & Frazer, 2011). Exercises such as Push-up plus, dynamic hug and punch are recommended, which can also amplify the SA muscle via production of the largest electrical signal (Pirauá et al., 2014). As Moura et.al commented on interpreting the results of their study, one of the reasons for the decrease in the symptoms of SD can be attributed to the increased level of SA muscle activity following participation in the rehabilitation exercise protocol (Moura et al., 2016). This finding is consistent with the view of some authors that the

SA is an important muscle that participates in three scapular movements during arm elevation and also usually decreases in activity during shoulder injuries (B. W. Kibler et al., 2012; Ludewig & Reynolds, 2009). Therefore, it can be stated that one of the reasons for the reduction of SD in the subjects of the present study was as a result of sensory motor training of the present training protocol. It is suggested to study the effect of the present protocol on the strength of shoulder rotator cuff muscles and electromyographic activity of scapulothoracic muscles in athletes with SD in other studies. Also, among the limitations of the present study is the lack of control over the effect of other protocol exercises on variables related to SD such as the strength of shoulder rotators and periscapular muscular activity.

CONCLUSION

According to the results of the study, the exercises protocol of the present study, responds well in volleyball players with SD, so that caused a significant increase in the GIR and a decrease in SD in volleyball players. It is recommended to consider it as a part of their routine exercises.

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STUDIA SPORTIVA 2022/1

The Effects of Different Rest Interval Lengths on Acute Quarter-squat Performance in Female

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Abstract

Inclusion of resistance training in the athletic preparation of young athletes is associated with increased time and personal demands. This study compared the effect of different rest interval (RI) lengths on quarter-squat performance in two age groups. Sixteen girls (age 12.20 ± 0.55) and 16 women (age 23.13 ± 2.23) performed three series of 10 quarter squats (10 repetition maximum [RM] load) with different RI times (1 min, 2 min, 3 min) between the three series. Each participant was randomly tested under all the RI conditions. The number of successful repetitions, power and speed were recorded for each set using by FitroDyne device. The women completed significantly less repetitions in the third set than in the first set for the 2-min and 1-min RIs (9.38 ± 1.54, p = .05 and 8.44 ± 2.42; p = .003, respectively). There was observed a significant decrease in mean power and speed in the 3-min RI between the first and second set and in the 1-min RI between the first and third sets. No significant differences in numbers of completed repetitions and mean power were evident in girls for any RI condition, but there was a significant decrease in mean velocity in the 2-min RI between the first and second sets in this group. These results show that recommendations for adults may be not suitable for girls; the girls' performance in three sets of 10 quarter squats was less affected by RI than the women's performance.

Key words: *Age, Exercise, Fatigue, Number of repetitions, Recovery, Resistance training*

INTRODUCTION

Studies have provided evidence that resistance training (RT) is a safe and effective method for enhancing athletes' muscular strength, power, and endurance (Benjamin & Glow, 2003; Faigenbaum et al., 2003, 2008; Guy & Micheli, 2001; Hernandez et al., 2020; Malina, 2006; Ratel, 2011) and improving athletic performance (Faigenbaum et al., 2016). The effect of RT is similar for adults and children (Haff et al., 2016). Previous research has shown that RT (2–3 times per week) can increase bone mineral density and improve body composition (Faigenbaum et al., 2003; McGuigan et al., 2009; Shaibi et al., 2006); and lower blood pressure (Winett & Carpinelli, 2001). Moreover, it has been found that RT can reduce the risk of injuries in other sports and recreational activities for young athletes (Council on Sports Medicine and Fitness, 2008; Faigenbaum et al., 2003; Zatsiorsky & Kraemer, 2006). Well-designed RT programs (sufficient warm-up, proper technique, progressive loading, supervision by a qualified professional, etc.) can instill a lifelong positive sports habit in children (Zatsiorsky & Kraemer, 2006), and it has a positive effect on children's psychological health, especially their self-confidence and self-efficacy (Schranz et al., 2013).

However, RT alone does not provide optimal gains in performance. A systematically structured program is needed to achieve maximum results (Faigenbaum et al., 2008). The main program variables include exercise selection, training volume, training intensity, movement velocity, and

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rest interval (RI) length (Grgic et al., 2018). RI length should be selected based on training intensity, training goals, the athlete's fitness level or the targeted energy system (De Salles et al., 2009; Ratamess et al., 2007). In adults, the RI length between multiple sets appears to be a significant factor that impacts many variables, such as the metabolic and hormonal response (Faigenbaum et al., 2008; Ratamess et al., 2007, 2012) and the immune cell acute response (Ratamess et al., 2012). RI length also affects acute power output (Faigenbaum et al., 2008; Ratamess et al., 2007, 2012) and the performance of subsequent sets (Faigenbaum et al., 2008; Ratamess et al., 2007), muscular strength improvements (Faigenbaum et al., 2008; Ratamess et al., 2007), and changes in post-resistance exercise creatine kinase concentrations (Ratamess et al., 2012). Previous studies suggested differences in recovery speed and a lower force output between sets at different RI lengths (De Salles et al., 2009; Iglesias-Soler et al., 2012; Ratamess et al., 2012). Kraemer described the differences in the total number of repetitions in three consecutive sets of 10 repetition maximum (RM) loads on leg press and bench press exercises. At an RI of 3 min, all highly trained athletes were able to perform 10 repetitions; at an RI of 1 min, the mean number of repetitions were: set 1=10 ± 0, set 2=8 ± 1.4, set 3=7.1 ± 3.5 (Kraemer, 1997). Different results were obtained by Richmond and Godard, who reported that an RI of 5 min was not sufficient to maintain repetitions over two consecutive sets. This result suggests that while a 3-min RI interval may be sufficient for highly-trained athletes, a 5-min RI is not satisfactory for healthy recreationally-trained men to achieve the desired performance (Richmond & Godard, 2004). There is a growing body of literature that recognizes that an RI that is too short (30 – 120 sec) between sets performed near or to muscular exhaustion causes a reduction in the number of repetitions performed in each successive set in adults. For example, Miranda et al. showed that a 1-min RI caused a significant decrease in the number of performed repetitions for all the selected exercises. The recommended length of the RI also depends on the training goal (Miranda et al., 2007). While longer RIs (i.e., at least 2–3 min) are recommended for strength and power multiple-joint exercises, shorter RI lengths (i.e., ≤ 1–2 minutes) are recommended for strength endurance (De Salles et al., 2009; Grgic et al., 2017; Ratamess et al., 2012) and single-joint exercises (De Salles et al., 2009; Grgic et al., 2017; Ratamess et al., 2007).

Previous evidence has suggested that RI recommendations that are valid for adults may not be appropriate for younger athletes (Faigenbaum et al., 2008). Children recover from physical exertion more quickly than adults, especially from high-intensity exercise (Falk et al., 2006). Faigenbaum et al. stated: "children (compared to adults) have a faster heart rate recovery, lower peak lactate concentrations, higher oxidative capacity, better acid-base regulation, and a tendency toward faster phosphocreatine resynthesis following high-intensity exercise" (Faigenbaum et al., 2008).

This is confirmed by the results reported by Zafeiridis et al., which showed that boys (age 11.4 ± 0.5 yrs.) recover faster during high-intensity 60- and 30-s intermittent anaerobic exercise in comparison to adolescents and adults. That study's research design consisted of a 30-s protocol including 18 maximal extensions and flexions of the knee joint, with a 1-min RT between sets and a 60-s protocol, including 34 maximal extensions and flexions, with a 2-min rest (Zafeiridis et al., 2005). Although some studies have addressed differences in muscle fatigue during high-intensity exercise, most of them used cycle ergometers; only a few investigated it in the context of RT (Faigenbaum et al., 2008).

Despite the differences between youth and adult athletes, recommendations for the RI length in children during different types of RT or for different RT goals are not well explored (Faigenbaum et al., 2008), especially for girls. This seems to be a serious gap in the literature because many coaches consider RT to be an essential part of a young athlete's training program (Faigenbaum et al., 2016). Thus, the present study aimed to examine the relation between age, muscular strength,

and RI duration (1 min, 2 min, 3 min) and the number of repetitions completed and strength parameters in girls and women.

MATERIAL AND METHODS

Participants

The participants in this study were allocated into two groups. In the first group, 16 physically active women (age 23.13 ± 2.23) volunteered to participate in this study. All the participants were students recruited from a local university with an RT experience ranging from 1 year to 6 years (average of 2.8 years) and they were able to perform the quarter-squat (QS) using the correct technique.

The second group consisted of 16 girls (age 12.20 ± 0.55). All the girls were synchronized swimmers competing at the national level and international level. The girls had 4–5 training sessions per week. They had no previous experience with RT. Therefore, the research protocol was preceded by 4 months of proper technique training and RT practice.

Table 1. Physical and Performance Characteristics of the Subjects

	Girls (N=16)	Women (N=16)
Age (yrs.)	12.20 ± 0.55	23.13 ± 2.23
Tanner Stage	II–III	–
Height (cm)	158.28 ± 6.58	167.84 ± 5.07
Weight (kg)	46.38 ± 4.62	67.43 ± 7.53
1RM QS (kg)	59.47 ± 10.71	100.72 ± 16.04
10RM QS (kg)	44.60 ± 8.03	75.53 ± 12.03
Relative Strength (%)	129.73 ± 26.61	150.34 ± 24.50

Tanner Stage (scale of physical development) – evaluated by parents' self-report; RM = repetition maximum; QS = quarter-squat; Relative Strength = (1RM/body mass); Values are mean ± SD

Maximum Strength Testing

In the women, the 1RM QS (knee angle of 120°) strength test was performed before the experimental sessions. The test was carried out according to the standard 1RM bilateral back squat protocol (National Strength & Conditioning Association (U.S.) & Miller, 2012). The warm-up started with 10 reps with a light load (about 50% of the expected maximum), followed by a 1-min RI. Subsequently, the athletes were instructed to perform 3–5 reps with resistance increased by 10–20%. After an RI of 2 min, the athletes were instructed to perform 2–3 reps with resistance increased by 10–20%. After an RI of 3 min, the same resistance was added, and the athletes were ordered to perform one repetition. If the athletes were successful, there was a 3-min RI and a new attempt was made with a resistance that was 10–20% higher. If the athletes were unsuccessful, a new attempt was made after a 3-min RI with a resistance that was 5–10% lower. Load increasing or decreasing was continued until the athlete was able to perform one repetition with the proper exercise technique. An athlete's personal 1RM should be reached within five attempts.

In the girls, 1RM testing was not performed with the 1RM test; rather, it was performed at the 5RM level. The 5RM level was used although the 1RM test has been shown to be safe and appropriate for healthy children (Faigenbaum et al., 2003). The 5RM level was chosen based on the high technical demands of the selected exercise and because the girls had no previous experi-

ence with RT (except 4 months of proper technique practice and RT training used in this study). The test was performed according to the following protocol. The warm-up started with 10 reps with a light load (about 50% of the expected maximum). The 1-min pause was used, and 10 reps with a resistance of 10–20% higher were performed. After 1 min, the load was again increased by 10–20% and the girls were instructed to perform five reps. If the athletes were able to perform the repetition with the proper form, there was a 2-min pause, and a new attempt was made with resistance that was 5–10% higher. If the athletes were unsuccessful, a new attempt was made after a 2-min pause with resistance that was 3–5% lower. If the proper technique was violated, the attempt was considered unsuccessful. A strength and conditioning specialist supervised all the testing procedures and an instructor-to-subject ratio of 1:1 was maintained. Each instructor had previous experience in children's strength training and understood the physical and psychological uniqueness of children. Relative strength was calculated as 1RM/weight.

All the participants were asked not to perform any strenuous RT three days before each measurement day. The adult athletes performed the 1RM test or the 5RM test in two sessions. The test always took place on the same day of the week and at the same time, with a 1-week interval due to familiarization according to the test protocol presented below. During this time, the participants' height was measured using a wall-mounted stadiometer, and body weight and body composition were measured using InBody 720.

QS Protocol

After the second maximal strength testing session a 10RM load value was determined for each athlete, based on the formula in Baechle et al. (Baechle et al., 2008). Previous experience with the calculation of 10RM (especially in girls and women who were not strength athletes, such as weightlifters, etc.) has shown that the calculated load is not accurate for some athletes. Furthermore, the value of 10RM in some young athletes appeared to be unstable on various occasions, so a control 10RM re-test was included in the present study.

All the subjects completed three protocol sessions, always in the evening with each session separated by at least 72 hours. Each protocol consisted of a general warm-up and three series with 50%, 60%, and 70% 1RM and a 10RM load control re-test (a re-test was included to achieve maximum accuracy of the 10RM load). The athletes were instructed to perform as many repetitions as possible with resistance, which should correspond to the 10RM load, according to the formula in Baechle et al. (Baechle et al., 2008). The current value of 10RM was corrected according to the number of repetitions each athlete was able to perform. A 5-min pause and three series of QS followed. The RI length was different for each session. The athletes performed each protocol using 1-min (1RI), 2-min (2RI), or 3-min (3RI) RIs (in a randomized order). The subjects were encouraged to target 10 repetitions per set. If the repetition was not performed in the full range of motion or was completed via assistance from a spotter, the repetition was not calculated.

Average Power and Speed Evaluation, Fatigue Index

The average power (AP) and average speed (AS) value for concentric phase of QS repetition was measured with a FitroDyne device (Fitronic, Bratislava, Slovakia). The AP and AS values of all the completed repetitions from the first, second, and third sets was subsequently used for statistical analysis and was directly compared. The fatigue index (FI) was calculated according to the following formula: $FI\ (\%) = [(AP_{max}\text{-}AP_{min})/AP_{max}*100]$. AP_{max} and AP_{min} represented the highest and lowest mean AP value of the group within a single set with the same RI. This was used to determine the percent decrease in performance within one set. While AP_{max} and AP_{min} did not always represent performance in the first and last repetition during the sets, the FI represents the intra-individual difference in performance within one set (for all completed repetitions).

Ethics

All the adult participants signed an informed consent in accordance with the Declaration of Helsinki and the study was approved by the research ethics committee of Masaryk University. For the children that participated in the study, informed consent was signed by their parents.

Statistical Analysis

Normality was checked using Shapiro-Wilk's test (α=0.05). Standard statistical methods were used to calculate the mean and standard deviation (SD). Friedman's test was used to analyze the effects of RI length on the number of repetitions per set, mean AP, and AS within the groups. Subsequent post hoc tests were used for pairwise comparison.

Statistical significance was set at $p \leq .05$ for the Friedman test, and pairwise comparisons were performed with a Bonferroni correction for multiple comparisons. Effect size was assessed by r (Fritz et al., 2012). All analyses were performed using SPSS statistical package (Version 25, SPSS, Inc, Chicago, IL, USA). Excel 365 software (Microsoft Corp., Redmond, WA, USA) was used for graph processing.

RESULTS

The data of completed repetition, AP and AS data during the QS sets were not normally distributed, as assessed by the Shapiro-Wilk's test ($p \leq .05$). QS repetition data for both groups are presented in Table 2 and the mean values of AP and AS for both groups (women and girls) are presented in Table 3.

Table 2. QS Repetitions in the Groups of Women and Girls with Different Types of RI.

	Set 1	Set 2	Set 3	Total	p
3-min RI					
Women	10.0 ± 0.0	10.0 ± 0.0	9.94 ± 0.25	29.94 ± 0.14	1.000
Girls	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	30.0 ± 0.0	1.000
2-min RI					
Women	10.0 ± 0.0	10.0 ± 0.0	9.38 ± 1.54	29.38 ± 0.92	0.050
Girls	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	30.0 ± 0.0	1.000
1-min RI					
Women	10.0 ± 0.0	9.19 ± 1.64	8.44 ± 2.42	27.63 ± 1.77	0.003
Girls	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	30.0 ± 0.0	1.000

Values represent mean ± SD

The numbers of completed repetitions were statistically significantly different between sets in testing session with 2-min and 1-min RIs in the group of women. Post hoc analysis did not reveal statistical differences among the sets. Statistically significant difference for AP and AS was found in the group of women in testing session with 3-min and 1-min RIs. Regarding AP performance, post hoc analysis revealed statistically significant differences between the first set (Mdn = 276.02) and the second set (Mdn = 249.22) ($p = .008$, $r = –0.53$) in testing session with 3-min RI and between the first set (Mdn = 244.99) and the third set (Mdn = 221.46) ($p = .014$, $r = –0.50$) in testing session with 1-min RI. Further, there was a significant difference in AS performance between the first set (Mdn = 0.329) and the second set (Mdn = 0.303) ($p = .014$, $r = –0.50$) in testing session with the 3-min RI and between the first set (Mdn = 0.304) and the third set (Mdn = 0.287) ($p = .040$, $r = –0.44$) in testing session with1-min RI.

Table 3. QS Average Power and Speed in the Groups of Women and Girls with Different Types of RI

Average power (W)						
	3-min RI	p	2-min RI	p	1-min RI	p
Women						
Set 1	264.23 ± 62.99		262.81 ± 69.78		251.52 ± 64.54	
Set 2	248.23 ± 64.49	0.100	256.57 ± 69.29	0.214	242.90 ± 68.52	0.015
Set 3	253.03 ± 65.96		252.21 ± 76.34		244.39 ± 72.00	
Mean	255.17 ± 64.83		257.30 ± 71.92		246.48 ± 68.31	
Girls						
Set 1	144.57± 39.98		154.02 ± 56.11		160.47 ± 49.81	
Set 2	148.89 ± 38.32	0.646	154.77 ± 52.43	0.068	159.84 ± 50.49	0.229
Set 3	144.33± 35.88		145.74 ± 50.97		163.29 ± 50.13	
Mean	145.93 ± 38.16		151.51 ± 53.37		161.20 ± 50.17	
Average velocity ($m.s^{-1}$)						
	3-min RI	p	2-min RI	p	1-min RI	P
Women						
Set 1	0.322 ± 0.050		0.320 ± 0.059		0.303 ± 0.057	
Set 2	0.302 ± 0.053	0.018	0.313 ± 0.065	0.129	0.288 ± 0.066	0.024
Set 3	0.307 ± 0.054		0.310 ± 0.077		0.285 ± 0.065	
Mean	0.310 ± 0.053		0.315 ± 0.067		0.293 ± 0.063	
Girl						
Set 1	0.305 ± 0.059		0.332 ± 0.066		0.342 ± 0.058	
Set 2	0.316 ± 0.064	0.444	0.312 ± 0.060	0.022	0.340 ± 0.057	0.229
Set 3	0.303 ± 0.059		0.314 ± 0.060		0.348 ± 0.061	
Mean	0.308 ± 0.061		0.321 ± 0.062		0.343 ± 0.059	

Values represent mean ± SD

No significant differences in numbers of completed repetitions and AP were found in girls. AS results indicated significant different values between the first set (Mdn = 0.326) and the second set (Mdn = 0.307) ($p = .040$, $r = –0.44$) in testing session with 2-min RI. The changes in AP during all three sets at different RI lengths in the girls and women is shown in Figures 1–3. While the AP is relatively balanced in all sets for all 10 repetitions for the girls, there is a visible decrease in the women.

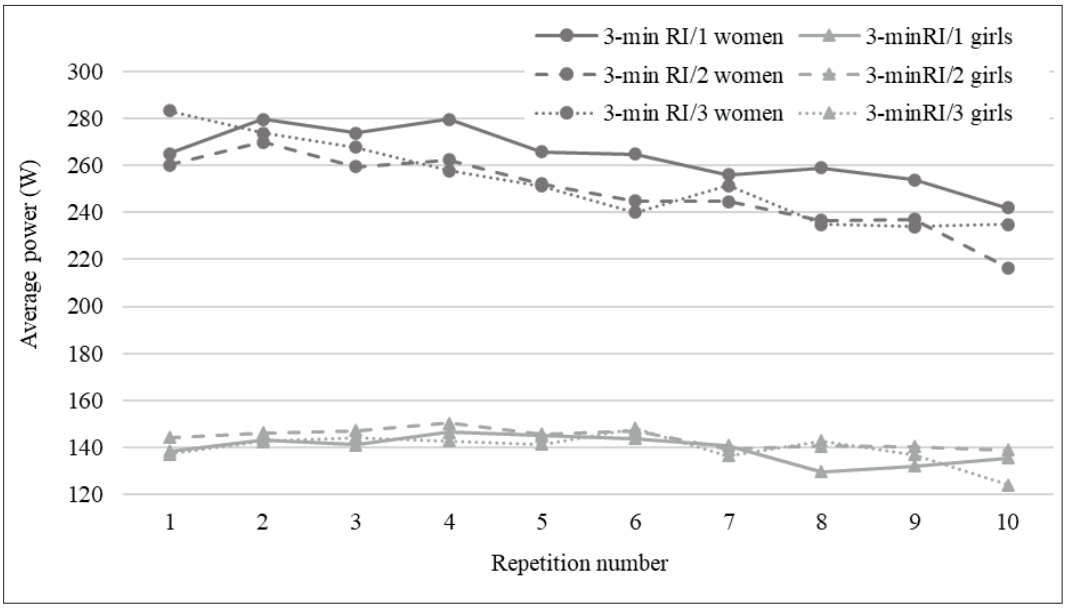

Figure 1. The mean AP data during the 3-min RI for both groups. Data depict the mean group power for each repetition.

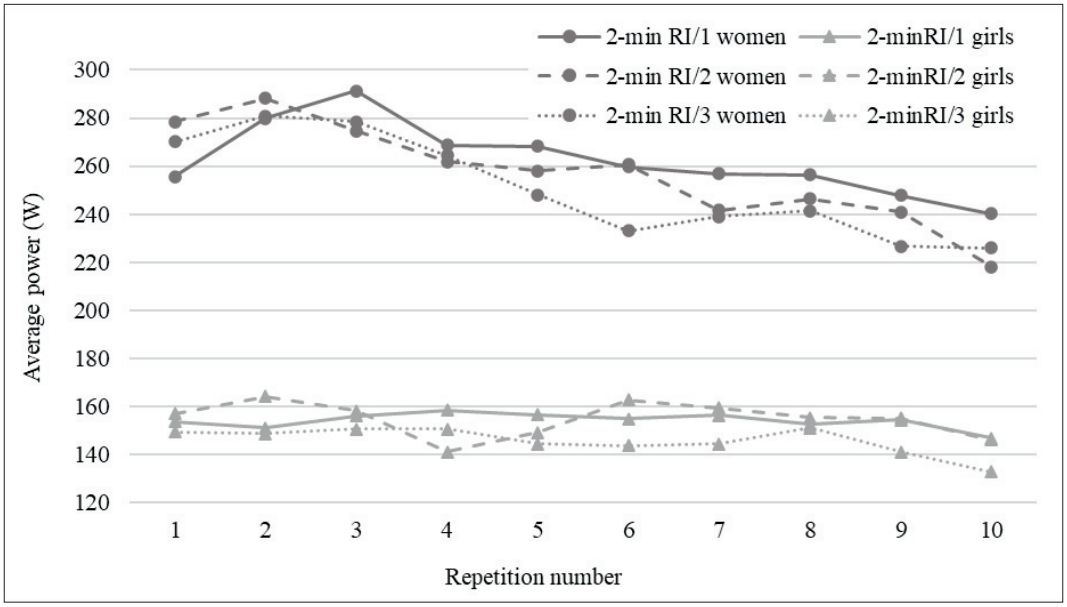

Figure 2. The mean AP data during the 2-min RI for both groups. Data depict the mean group power for each repetition.

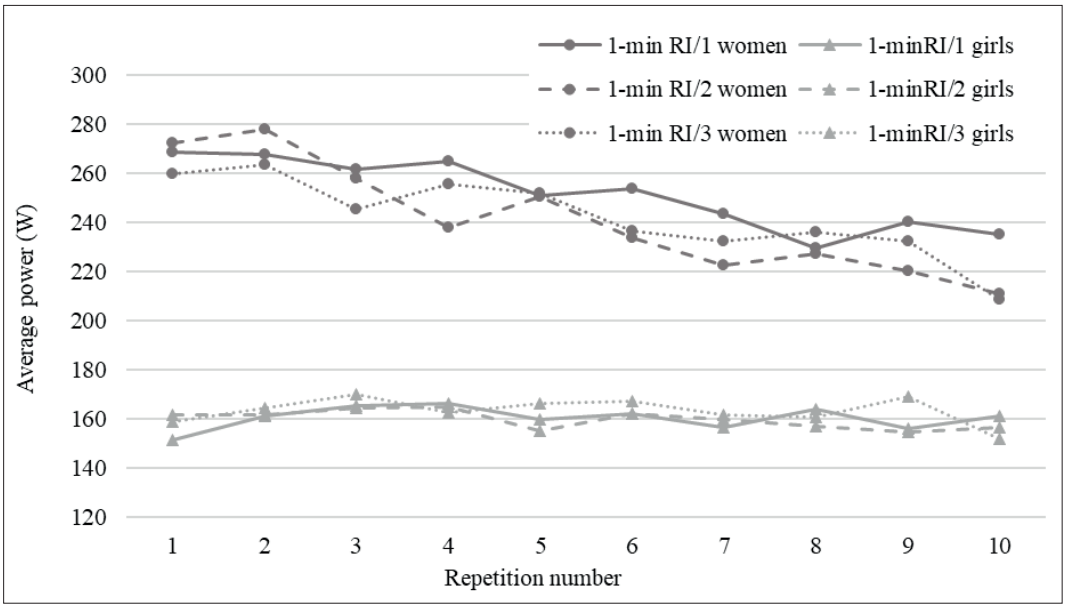

Figure 3. The mean AP data during the 1-min RI for both groups. Data depict the mean group power for each repetition.

Table 4 represents the highest and lowest mean AP values and percentage FI for the groups of women and girls during three sets with same RI lengths. As seen in Table 4, for the women, the FI (%) increases over time from the first to the third sets (except for 1-min RI between 2nd and 3rd set). The smallest increase is visible in the 3-min RI. The largest difference between the first set and the second set was achieved in the 1-min RI, but there was a decrease in the third set. This is due to the inability of some women to complete all 10 repetitions. This also affected the AP_{min} in the third set, the value of which was not as low as it was in the second set. In the third set of the 1-min RI, the initial level of AP_{max} was not restored in comparison to the previous two sets; this can be explained by the insufficient time needed to restore energy supplies. No clear trend in the decrease of AP_{max} and AP_{min} was visible in the girls, as the highest performance was sometimes achieved in the second set or the third set. Moreover, no significant decrease was visible in the FI percentage, which was lowest in the 1-min RI.

Table 4. The highest and lowest mean AP value within a single set with the same RI

	Women			Girls		
	P_{max} (W)	P_{min} (W)	Fatigue Index (%)	P_{max} (W)	P_{min} (W)	Fatigue Index (%)
3-min RI						
Set 1	297.07	228.25	23.46	162.06	115.40	29.12
Set 2	287.82	203.79	29.44	169.78	113.29	33.04
Set 3	294.68	205.51	30.78	160.58	108.61	32.69
2-min RI						
Set 1	302.36	217.91	27.53	174.20	130.04	25.79
Set 2	299.51	200.83	32.59	178.15	124.18	30.97
Set 3	297.33	190.89	36.00	170.56	118.03	31.43
1-min RI						
Set 1	288.34	203.58	29.47	179.14	132.54	25.37
Set 2	284.07	170.48	40.22	180.38	135.64	25.55
Set 3	271.48	180.33	33.02	185.11	136.12	27.84

DISCUSSION

The main finding of the study is that while the results for the women show a decrease in strength production and QS performance in connection with a change of RI length, the girls were able to produce a relatively constant performance independent of the RI lengths. In some of the parameters, changes were evident in the girls' performance between the sets. However, these changes represent unsystematic performance fluctuations without a significant decreasing trend. These results suggest that girls are able to recover faster than women from moderate-intensity resistance exercise; this finding is similar to the results in Faigenbaum et al.'s (Faigenbaum et al., 2008)) study on men and boys, which can be beneficial to all coaches and health professionals designing strength programs for children and youth (Tibana et al., 2012).

Determining a sufficient RI length is important in children not only in terms of sufficient regeneration, as seen in adults (Faigenbaum et al., 2008), but also from a training planning perspective. According to our own experience, many coaches working with youth report that the high amount of time required for RT does not allow them to include a RT program in the regular training plans of young athletes due to the low hourly allowance for training. The possibility of using a shorter RI length could save time and enable coaches to include a RT program even in sports disciplines with a low training-hours capacity.

The results of the present investigation showed that the total number of repetitions performed during three sets of the QS were significantly different in the group of women with the 2-min RI and the 1-min RI. However, the decrease in the number of completed repetitions was not as significant as that reported in previous studies (Faigenbaum et al., 2008; Miranda et al., 2007; Ratamess et al., 2007; Richmond & Godard, 2004; Willardson & Burkett, 2006). A possible explanation for this can be found in Ratemmes et al' study, which points to a lower decrease in performance in women in comparison to men (e.g., 1-min RI men: 1 set: 10.0 ± 0.0 reps, second set: 7.1 ± 2.3 reps, third set: 4.0 ± 1.7 reps; e.g., 1-min RI women: 1 set: 10.0 ± 0.0 reps, second set: 9.3 ± 1.4 reps, third set: 7.7 ± 3.0 reps) (Ratamess et al., 2012).

Although previous studies have reported differences in the recovery between children and adults, many of them describe these differences in relation to high- or moderate-intensity exercises not strength performance. For example, Weinstein et al. compared performance in two upper-body Wingate Anaerobic Tests separated by either 2-min or 10-min recovery intervals in boys and men. The results showed that power decrease (mean and peak power) and blood lactate concentration were significantly lower in the boys than the men during the 2-min RI. In the 10-min RI, the differences in the performance between the boys and men in the second round were not statistically significant (Weinstein et al., 2018). Differences are mainly due to children's lower maximal power output, which puts lower demands on regeneration and allows for faster recovery (Falk et al., 2006). This is consistent with the results reported by Faigenbaum et al., who described significant age-related differences in relative strength between boys (55.7%), adolescents (68.9%), and adults (124.3%), and with the results of our research: girls' relative strength (129.73%) and women's relative strength (150.34%) (Faigenbaum et al., 2008). Nevertheless, maturation-related differences (lower relative muscle mass, lower neuro-motor recruitment), size-related factors (smaller muscle-fiber diameter, higher capillary density, shorter perfusion distance, shorter circulation distance, and faster cardio-respiratory kinetics), and metabolic characteristics (faster return of acid-base balance, lower peak of La and H+, faster CrP replenishment, lower glycolytic enzyme activity, and lower energy substrate level) may contribute to children's ability to recover more quickly than adults (Falk et al., 2006). Dipla et al. (Dipla et al., 2009) and Ratel et al (Ratel et al., 2006); mentioned similar physiological and neuromotor parameters; however, most of the studies reviewed in these works investigated men and boys. Interestingly, the results of their research suggest that while the ability to resist fatigue in prepubertal girls and boys was the same, the fatigue resistance of adult women was the same as male adolescents.

In addition to the number of repetitions, the present study also evaluated the measurement of bar speed and power during each QS repetition. This allowed us to observe a decrease in performance even in cases where the number of repetitions did not decrease. This phenomenon is also described by Faigenbaum et al. with repeated performance in the bench press exercise (Faigenbaum et al., 2008). However, the AP and AS evaluation results during the QS series showed a similar trend as the decrease in the number of repetitions across the groups. While the women's results showed a statistically significant difference in AP and AS, both for the 3-min RI and the 1-min RI, no statistically significant difference in AP was found in the girls. Interestingly, there was a slight increase in AS in the third set. The only statistically significant difference in the girls was the difference between the AS at the 2-min RI. This increase and a slight fluctuation in both the AP and AS results without a clearly visible trend in all the successive sets indicates the degree of variability in the girls' performance in general rather than the insufficient length of RI for the necessary replenishment of energy reserves.

CONCLUSION

There was no systematic decrease in the ability to produce strength associated with different RIs in the girls, both in terms of reducing the number of repetitions or a significant decrease in the power or speed during QS. Based on our results, we are unable to determine whether the reason for the small decline and fluctuating performance (within a set) is due to the girls' ability to regenerate faster, as suggested by previous research, or their inability to exert their maximum effort (the relative strength of the girls did not reach the same values as found in the women). However, this result indicates that a 1-min RI could be sufficient for RT with a 10RM load for girls that do not engage in strength training. This result may help coaches include an RT program

in the athletic preparation of children in sports with a smaller time allowance for the training or in sports that do not have RT as priority conditioning method. This could lead to a reduction in the amount of time required for strength training in children, as it is not necessary to employ the RI that is used for the adults to develop strength in children.

Acknowledgments

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SOCIAL SCIENCES

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Ranking Players by DEA: An analysis of Czech and Danish football

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Abstract

Team managers and coaches need to choose the best players. The selection relies mainly on the cost and performance of the entire team. It is a common practice that several key players contribute to the overall results of the football team. The quality of players is one of the crucial features determining the failure or success of a sports team. The present article focuses on measuring player efficiency in the Czech and Danish top football competitions during the 2015/16 to 2019/20 seasons. The presented research aims to identify the most technically efficient players, considering their position on the field. The authors used an input-oriented model of data envelopment analysis and subsequently also cluster analysis to determine the best football players. The following article may be of interest to football club managers, football analysts, economists and others interested in the business of football because it combines two methods of measuring the efficiency of football players.

Keywords: *data envelopment analysis, efficiency, performance evaluation, cluster analysis, CCR-I model*

INTRODUCTION

Football is the most popular sport in the Czech Republic and Denmark, although other sports, such as hockey and tennis, are also very popular. The football business has grown significantly over the last few decades, and football clubs have become large companies. To be profitable and thrive in the pitch, they need to improve the efficiency of their business (Pyatunina et al., 2016). The growing worldwide popularity of professional football has made the sport an expanding industry with a substantial financial turnover. The fundamental factors determining the performance of a football team include the selection of players and the team's organisation, taking into account various economic and technical constraints. Player selection has become particularly important as their salaries and transfer costs place increasing restrictions on professional football clubs, which have to select the best possible pool of players within the constraints of their budgets (Nasiri et al., 2018). In addition, the player's market value is an influential economic valuation determining not only the player's price but also various other factors. A player's market value is a score dependent on numerous factors such as the talent, popularity, skill, playing style, efficiency, etc. of a player (Singh & Lamba, 2019). Market value is the economic evaluation of a player that signifies the player's price and performance. In this context, professional football team managers should develop management practices that help clubs evaluate and select the best players to achieve two objectives simultaneously: success on the pitch and commercial performance.

Efficiency and sports are two closely related concepts. A considerable amount of professional literature has been written on sports management. The economic framework of professional sports activities relies on the work of Rottenberg (1956), Jones (1969) and Sloan (1969). Choosing players and the sports team structure represents a fundamental decision of club owners and managers in their efforts to achieve the best possible results. Obviously, the success or failure of any sports team depends primarily on the skills of its players and the organisation of their potential teams. In sports science, data envelopment analysis has been widely used in recent decades

to evaluate performance and subsequently support decision-making in various sports. Several of the studies listed below have applied data envelopment analysis (hereinafter DEA) to assess sports teams in different sports disciplines. For example, Chitnis and Vaidya (2014) and Ruiz et al. (2013) deployed the DEA method and evaluated the performance of professional tennis players in terms of the effectiveness of their game. DEA models have also been used to evaluate baseball players, for example, by Cooper et al. (2009), Chen and Johnson (2010). Other authors have applied the DEA method to evaluate golfers (Fried et al., 2004).

In addition, experts have applied parametric and non-parametric analyses to determine the performance of football teams in the last few decades. The efficiency of European professional football clubs has been evaluated by Espitia-Escuer and García-Cebrián (2004), Guzmán and Morrow (2007), Halkos and Tzeremes (2013), Pyatunina et al. (2016), among others. Djordjević et al. (2015) applied the DEA method to rate the performance of the national football team in the qualifications for the 2010 FIFA World Cup. Ribeiro and Lima (2012) employed data envelopment analysis to measure the effectiveness of Portuguese football clubs in the first league from 2002/03 to 2008/09 seasons. Despite the wide popularity of this sport, there are only a limited number of scientific studies available focusing on the statistical, economic dimensions and performance evaluation of individual players. However, only a few studies have concentrated on individual footballers when applying data envelopment analysis. An overview of authors using data envelopment analysis to evaluate player performance is summarised below.

Haas (2003) measured team and player effectiveness in Major League Soccer using data envelopment analysis (DEA). Hirotsu et al. (2012) evaluated the players' performance in Japan's top J-league soccer competition during the 2013 season using DEA. They analysed the players' on-field performance using input-oriented Banker Charnes and Cooper (BCC) and Charnes Cooper and Rhodes (CCR) models of data envelopment analysis. Hirotsu et al. (2018) selected evaluation indicators for individual football players and used data envelopment analysis to identify the player's performance characteristics. The players' on-field performance was then analysed using the DEA super-efficiency model regardless of the players' game position. In their research, Tiedemann et al. (2011) presented a model for evaluating the performance of football players in the field. Based on the data envelopment analysis, they used a non-concave metafrontier approach to estimate players' efficiency scores concerning their playing position. They applied this approach to the data set of German Premier league footballers in the 2002/03 to 2008/09 seasons. Their research included one input variable (playing time) and four output variables (goals, assists, tackle ratio and pass completion ratio) in the DEA model. The research results revealed a positive relationship between the average player efficiency score and the team's placement in the league table at the end of the season. In addition, a metafrontier approach was used to identify the optimal playing position of a football player in the team and, subsequently, quantify the increase in performance when moving to that playing position. Choosing the best players is also very important for team managers and coaches. Player selection is primarily related to the cost and performance of the team. Arabzad et al. (2013) proposed a two-stage approach to selecting and evaluating the best English Premier League football players in 2010/11. An output-oriented BCC model was used to identify the best players and evaluate chosen players. The BCC model identified 29 players as efficient. Efficient players were further sorted using the DEA ranking model. The results show that the best players are Rooney, Drogba and Tevez. Erickson and Callum (2004) used data envelopment analysis to evaluate the National Football League players. Alp (2006) applied the output-oriented CCR model and the Andersen-Petersen super-efficiency model to rank 32 goalkeepers from the 2002 World Cup. The CCR model identified 12 of the 32 goalkeepers as efficient (e.g. Oliver Kahn, Gianluigi Buffon, Iker Casillas and others). Fernández et al. (2020) analysed players' efficiency in the Spanish Soccer League for the 2009/2010 season

using a metafrontier version of data envelopment analysis methodology. In their research, they divided the sample of players into three groups according to their game position in the team. They also included specific outputs for each game position to characterise these positions better. In addition, they compared the efficiency of Spanish and foreign players and analysed the correlation between the number of efficient players per team and the points won by each team. Research has found that defenders and midfielders are more efficient than forwards. This is due to the fact that the forwards accumulate the inefficiency of midfielders, who in turn accumulate the inefficiency of the defenders. Research has found that the majority of efficient defenders and midfielders are Spanish. On the other hand, almost 60% of efficient forwards are foreigners. These forwards include, for example Lionel Messi and Cristiano Ronaldo. The correlation coefficient of 0.928 confirmed the existence of a direct relationship between the number of efficient players and the number of points won in the league. Papahristodoulou (2007) evaluated the individual performance of the forwards in the UEFA Champions League. The author warned that only forwards who scored two or more goals were evaluated due to software limitations. The DEA model identified the seven forwards who scored the most points as effective: Kaká, Cristiano Ronaldo, Ronaldo, Miccoli, Mpenza, Fowler and Giggs.

This paper proposes an approach set within the context of football players' evaluation. It focuses on the players in the top Czech and Danish football leagues playing in the 2014/15 to 2019/20 seasons. All available players have been evaluated using an input-oriented DEA model (Banker et al., 1984; Charnes et al., 1978). The first objective of the presented research is to use data envelopment analysis to identify and compare the efficient players of both football competitions under study and, subsequently, to determine whether the most valuable players of the assessed football competitions are efficient. The second objective is to apply cluster analysis to divide the set of players into compact clusters and, subsequently, determine what the individual clusters reveal about the players of the football competitions.

METHODS AND DATA

Data

Players from two top European competitions with potential similarities were selected for analysis and subsequent comparison from the football environment. They are the Czech Fortuna:Liga and the Danish 3F Superliga. These competitions are similar in terms of the same game model and similar positions in the UEFA league coefficients. Considering the data availability in both countries, the player efficiency was analysed for the 2015/16 to 2019/20 seasons. The research period was mainly limited by the data available for the Danish 3F Superliga, as the oldest available data for managed sports came from the 2015/16 season. Data from the 2013/14 season is also available for the Czech top competition; however, they were not included in the research to compare the two competitions.

The research focuses only on players who have played at least one game in a season. Players who did not play in any games can be assigned a market value, but must play in at least one game in the season to be assigned game performance statistics. For players playing for more than one club in the same season, the number of games played in the season for the clubs was the determining factor for club assignment. The player was assigned to the club for which he played more games in the season, with the number of minutes being the tie-breaker. Players on loan were assigned the club they played for in the season.

The research data used have been obtained from the official databases of both sports competitions and completed by private databases of companies from the football environment. The core

of the research data came from InStat (2020), which analyses the performance of athletes and sports teams. InStat provides match data and detailed statistics for individual players. The set is supplemented by databases of the Transfermarkt.com server (2021), the Czech Fortuna:Liga (2021), and the Danish 3F Superliga (2021). The Transfermarkt.com database was used mainly to obtain information about the market values of players in each season.

Data Envelopment Analysis

In the presented research, data envelopment analysis was used to evaluate the efficiency of individual players. The data envelopment analysis is a benchmarking tool initially developed by Farrell (1957) and further elaborated by Charnes et al. (1978). DEA is a method based on linear programming that evaluates the efficiency of production units. These units are called decision-making units (DMUs) and can include schools, hospitals, universities, banks, companies or even individuals, such as employees or players (Charnes et al., 1978). In the case of this research, DMUs are football players. The DEA compares inputs and outputs and considers whether the units under study achieved efficient or inefficient results. The best performing player in the set of DMUs is assigned a score of 100 per cent or 1. The remaining DMUs are scored between 0 to 100 per cent or equivalent between 0 and 1 relative to the score of the best performing DMU. The fundamental DEA feature is that a certain weight can be assigned to each input and output, i.e., for each DMU separately. The weights are attributed to maximising the efficiency of each DMU. It is a strong argument if a DMU is inefficient because inefficiency is achieved despite employing weights as favourable as possible to that DMU. The DEA was applied to a set of players from both competitions. For the purpose of the data envelopment analysis and a higher informative value, all players were divided by their game posts into goalkeepers, defenders, midfielders, and forwards.

The first step is to select appropriate variables for the DEA model. The market value of the player was chosen as the input variable. The output variables had to be selected based on three requirements. The first requirement was a minimum correlation within the output variables. The resulting effect could be duplicated with a high correlation of some variables. The second requirement was a high correlation of the output variables with the input variable (i.e., market value). Otherwise, the analysis would lose its informative weight. The third requirement was determining the optimal number of variables concerning the number of evaluated units (i.e., players). For example, Zhu (2014) stated that a large number of inputs and outputs compared to the number of DMUs could negatively affect the discriminatory power of the DEA. Cooper et al. (2011) introduced a rule that the number of DMUs (i.e., players) should be at least double or even triple the number of inputs and outputs. The present research has no problem in fulfilling this condition. In fact, the players' data sets are several times larger than the number of inputs and outputs.

Within the output variables for individual groups of players, factors were selected that correlate to the player's post. For forwards, mainly offensive factors were considered (goals scored, assists, shots on target, etc.). Defenders were assessed based on defensive factors (total number of challenges won, number of ball recoveries, air challenges won, etc.). A balanced mix of defensive and offensive factors was adopted for the midfielder group. Goalkeepers formed a separate group in terms of selecting outcome factors, consisting of general factors (e.g., accurate passes) and typical characteristics such as the number of shots saved, etc.

The output variables characterised by the factors for each player group are summarised in Table 1. Some output factors are common to multiple game posts. These include, for example, the number of matches played during the season, a factor that is common to all game positions. Other factors are specific to a particular group of players.

Table 1. DEA output factors (CCR-I) for individual player posts

Output factors according to the player's game post			
Goalkeepers	Defenders	Midfielders	Forwards
Matches played	Matches played	Matches played	Matches played
Short passes accurate	Goals	Goals	Goals
Medium passes accurate	Assists	Assists	Assists
Long passes accurate	Fouls suffered	Fouls suffered	Fouls suffered
Close range shots saved	Shots on target	Shots on target	Penalties scored
Mid range shots saved	Key passes accurate	Key passes accurate	Key passes accurate
Long range shots saved	Passes accurate	Passes accurate	Chances successful
	Defensive challenges won	Challenges won	Challenges won
	Offensive challenges won	Chances created	Chances created
	Air challenges won	Crosses accurate	Crosses accurate
	Dribbles successful	Dribbles successful	Dribbles successful
	Ball recoveries		Tackles successful
	Ball interceptions		
	Free ball pick ups		

In the next step, the DEA model was applied to the selected variables. The input-oriented CCR-I model was applied to both competitions, considering constant returns to scale. The input-orientation of the model was adopted given that the sports environment belongs among industries where the input variable, i.e., the market value of a player, can be influenced rather than the output variables, representing the sporting factors of individual players (Guzmán-Raja & Guzmán-Raja, 2021). In the basic input-oriented CCR model with constant returns to scale assumption, the objective function (1) is maximised under restrictive conditions (2), see e.g. Jablonský and Dlouhý (2004). The symbol x_j denotes inputs, y_i outputs, u_i is the weight of the output, v_j is the weight of the input and z is the value of the objective function.

$$z = \sum_{i=1}^{r} u_i y_{iq} \tag{1}$$

$$\sum_{i=1}^{r} u_i y_{ik} \leq \sum_{j=1}^{m} v_j x_{jk,}\ k = 1, 2, ..., n \tag{2}$$

$$\sum_{j=1}^{m} v_j x_{jq} = 1$$

$$u_i \geq \varepsilon, i = 1, 2, ... r, \varepsilon \text{ - very small non- Archimedean number } (> 0)$$
$$v_j \geq \varepsilon,\ j = 1, 2, ..., m.$$

A technical efficiency score was determined for each player; the calculations were performed using open software OSDEA-GUI (Open source DEA, 2021). The technical efficiency score obtained using the CCR-I model was termed the overall technical efficiency score.

Cluster analysis

Based on the factors derived from the data envelopment analysis method, a cluster analysis of the players of the Czech Fortuna:Liga and the Danish 3F Superliga was subsequently performed. Cluster analysis is based on the idea of sorting players into clusters so that players belonging to

the same group are more similar than players from other groups (Aggarwal & Reddy, 2014). The players were divided into clusters according to the similarity of the values of their individual characteristics. In the process of cluster analysis, the nearest neighbour technique was used (3).

$$D_{NN}(A,B) = min\{d(a; b)\} \quad (3) \qquad (3)$$

In this case, data were divided into *n* clusters, one for each observation. Then, the calculation of the minimum distance between all pairs of points that are located in different clusters was done. Two mutually closest clusters were joined together. The process of calculation of the minimum distance between all pairs and joining those mutually closest pairs was repeated until the number of clusters has been reduced to the chosen extent. The optimal number of clusters was chosen by inspecting the dendrogram created using hierarchical clustering. Cluster analysis was performed using Statgraphics Centurion 18 statistical software (Statgraphics Technologies, 2021).

RESEARCH RESULTS

Initially, the CCR-I model was applied to a set of 180 goalkeepers who had played at least one match in one of the evaluated seasons of the Czech Fortuna:Liga and the overall technical efficiency score was determined. The CCR-I model identified three goalkeepers as efficient (see Table 2). All of them had a relatively low market value (input variable). Jan Šeda and Martin Berkovec played 32 games in the 2018/19 season. Jaroslav Drobný played 18 games in the 2019/20 season. All three goalkeepers performed above average in the passing and interventions. However, none of the efficient goalkeepers was the best in any statistics. Ondřej Kolář (6 million euros) and Florin Nita (2.5 million euros) posted the highest market value. However, Ondřej Kolář and Florin Nita achieved a very low overall technical efficiency score (max 0.215 and max 0.092). Thus, according to the CCR-I model, they can be considered inefficient.

Table 2 present the efficient goalkeepers of the Danish 3F Superliga based on the CCR-I model. According to the overall technical efficiency score, Jesper Rask was the most efficient goalkeeper of the 139 goalkeepers who had played at least one game in the top Danish competition. In terms of short and medium passes, this goalkeeper was below average than the goalkeepers of the Danish highest competition but above average in long passes, especially in the statistics of saved shots. The other efficient goalkeeper was Thomas Mikkelsen, who reached the maximum long range shots saved in the 2019/20 season. He also achieved an efficient score with excellent other statistics. Kamil Grabara (5 million euros) and Frederik Ronnow (3 million euros) had the highest market value. However, both achieved a very low overall technical efficiency score and can be classified as inefficient according to the CCR-I model.

Table 2. Efficient goalkeepers of the Czech and Danish leagues according to the CCR-I model

Goalkeeper	League	Club	Season	Market value (ths. €)
Jan Šeda	CZ	FK Mladá Boleslav	2018/19	250
Martin Berkovec	CZ	MFK Karviná	2018/19	250
Jaroslav Drobný	CZ	SK Dynamo České Budějovice	2019/20	100
Jesper Rask	DK	Hobro IK	2015/16	200
Thomas Mikkelsen	DK	Lyngby Boldklub	2019/20	150

Next, the overall technical efficiency score was calculated for a group of 722 defenders who had played at least one match in any of the observed seasons of the Czech Fortuna:Liga. Only one per cent of the defenders (nine defenders in total) of the Czech Fortuna:Liga were considered efficient from the perspective of the CCR-I model. Martin Jiránek was marked as an efficient unit in two seasons (2016/17 and 2017/18). The other players (see Table 3) played a maximum of six matches per season. These were young substitute players who were gaining experience in their first seasons in professional football. Defender Radim Černický is a typical example: He played 130 minutes in four matches for the FC Slovan Liberec in the 2019/20 season and scored two assists and two shots on target.

In the Danish 3F Superliga, the CCR-I model has identified 17 efficient defenders out of a total of 593 defenders (i.e. 2.86 %). A total of 13 of these defenders played more than 15 games in a season and seven of them even more than 30 games. Bjorn Paulsen was the most versatile player in terms of relative value balance compared to other efficient defenders. He also added three goals and two assists to the highest number of won air and offensive challenges. The Danish league's market value of efficient defenders was at a higher financial level than that of the Czech defenders (see Table 3).

Table 3. Efficient defenders of the Czech and Danish leagues according to the CCR-I model

Defender	League	Club	Season	Market value (ths. €)
Tomáš Janíček	CZ	FC Fastav Zlín	2015/16	100
Martin Jiránek	CZ	1. FK Příbram	2016/17	50
Martin Jiránek	CZ	FK Dukla Praha	2017/18	50
Martin Nečas	CZ	FC Fastav Zlín	2019/20	100
Matyáš Kazda	CZ	FC Slovan Liberec	2019/20	50
Tomáš Vincour	CZ	1. FC Slovácko	2019/20	50
Lukáš Červ	CZ	SK Slavia Praha	2019/20	75
Sunday Adetunji	CZ	1. FK Příbram	2019/20	50
Radim Černický	CZ	FC Slovan Liberec	2019/20	50
Marc Pedersen	DK	SonderjyskE Fodbold	2015/16	300
Mads Justesen	DK	Hobro IK	2015/16	200
Kevin Mensah	DK	Esbjerg fB	2015/16	250
Bjorn Paulsen	DK	Esbjerg fB	2015/16	400
Thomas Hansen	DK	Hobro IK	2015/16	100
Johnny Thomsen	DK	Randers FC	2016/17	200
Peter Nymann	DK	AC Horsens	2016/17	250
Johan Absalonsen	DK	SonderjyskE Fodbold	2016/17	200
Mads Bech Sorensen	DK	AC Horsens	2016/17	150
Jakob Ahlmann	DK	Aalborg BK	2017/18	400
Kenneth Petersen	DK	Odense BK	2017/18	300
Michael Baidoo	DK	FC Midtjylland	2017/18	150
Melvin Frithzell	DK	FC Helsingor	2017/18	100
Mads Madsen	DK	Silkeborg IF	2017/18	350
Johnny Thomsen	DK	Randers FC	2018/19	200
Markus Halsti	DK	Esbjerg fB	2018/19	200
Peter Nymann	DK	AC Horsens	2018/19	200

The third group of players analysed represented the midfielders from both football competitions. In the case of the Czech Fortuna:Liga, a set of 934 midfielders was assessed. Altogether,

seven players were identified as efficient based on the CCR-I model. The analysis of the midfielders of the Czech Fortuna:Liga was influenced by Pavel Zavadil. The experienced midfielder of Zbrojovka Brno or SFC Opava achieved the efficient result of overall technical efficiency three times (in 2016/17, 2018/19, and 2019/20 seasons). Pavel Zavadil managed to transform his market value into selected game statistics efficiently. In the 2019/20 season, besides Pavel Zavadil, three other players were marked as efficient. They comprised young talents of individual teams who had played no more than one half of the season. More information can be found in Table 4. It can be expected that they will appear more frequently on Czech (or world) pitches in the future, as in the case of Pavel Zavadil, one of the group's four 40-year-olds. The highest market value was attributed to Tomáš Souček (12 million euros), who was, however, identified as an inefficient unit according to the CCR-I model.

In the case of the Danish 3F Superliga, a pool of 836 midfielders was analysed. Altogether, six players were marked as efficient based on the CCR-I model, which is very similar to the Czech Fortuna:Liga case. The most valuable efficient midfielders in Denmark in the period under study were Kasper Risgard (33 years old), who had played for Aalborg BK, and Jonas Borring (32 years old), who had joined FC Midtjylland. Both players consistently played around thirty matches in the same season. Adnan Mohammad, the only Pakistani, became efficient in the jersey of the newcomer from Helsingor. In terms of sporting statistics, it was his best season. He participated in 28 games and excelled, especially in the accuracy of his passes and the number of balls recoveries. Lucas Ohlander also played for the same team in the same season but only participated in one match. The overall overview is shown in Table 4. The Danish league's market value of efficient midfielders reached a higher financial level than the Czech midfielders.

Table 4. Efficient midfielders of the Czech and Danish leagues according to the CCR-I model

Midfielder	League	Club	Season	Market value (ths. €)
Pavel Zavadil	CZ	FC Zbrojovka Brno	2016/17	50
Pavel Zavadil	CZ	SFC Opava	2018/19	50
Pavel Zavadil	CZ	SFC Opava	2019/20	25
Paulo Alves Paulinho	CZ	1. FK Příbram	2019/20	75
Petr Janota	CZ	1. FK Příbram	2019/20	25
Vojtěch Patrák	CZ	AC Sparta Praha	2019/20	50
Pavel Osmančík	CZ	Bohemians Praha 1905	2019/20	50
Kasper Risgard	DK	Aalborg BK	2015/16	300
Martin Mikkelsen	DK	Hobro IK	2015/16	150
Jonas Borring	DK	FC Midtjylland	2016/17	300
Adnan Mohammad	DK	FC Helsingor	2017/18	200
Magnus Westergaard	DK	Lyngby Boldklub	2017/18	50
Lucas Ohlander	DK	FC Helsingor	2017/18	50

The largest group of efficient players represented a pool of forwards of both competitions. Altogether, 18 forwards out of 327 forwards of the Czech Fortuna:Liga can be described as efficient based on the CCR-I model. Table 5 below presents the complete list. The highest number (seven in total) of the efficient players played in the last observed season (2019/20). Only three players did not play at least ten matches in their efficient season. The only player who did not score a single goal in the season was the forward Jan Kuchta at Prague Bohemians. However, he dominated in terms of challenges won per match. A pair of foreign players from Zlín, Pedro Martinez and Lamin Jawo, scored the most goals.

The CCR-I model identified a total of 13 forwards as efficient out of 298 forwards participating in the Danish 3F Superliga. Like the forwards in the Czech Fortuna:Liga, the Danish forwards scored a minimum of goals from penalty kicks. On average, the forwards in Denmark had fewer won challenges (190) than their Czech counterparts (220). On the other hand, the Danish efficient forwards scored more goals on average than the Czech players. AC Horsens had the most efficient forwards of the Danish league, all in the 2016/17 season when the club finished tenth in the regular season. The following Table 5 provides a more detailed overview of efficient Danish forwards. The Danish league's market value of efficient forwards reached the same financial level as that of Czech forwards.

Table 5. Efficient forwards of the Czech and Danish leagues according to the CCR-I model

Forward	League	Club	Season	Market value (ths. €)
Lukáš Magera	CZ	FK Mladá Boleslav	2015/16	350
Roman Bednář	CZ	1. FK Příbram	2015/16	300
Jakub Mareš	CZ	FK Dukla Praha	2015/16	400
Michael Rabušic	CZ	FC Vysočina Jihlava	2016/17	200
Milan Baroš	CZ	FC Slovan Liberec	2016/17	300
Pavel Černý	CZ	FC Hradec Králové	2016/17	175
Jean-David Beauguel	CZ	FK Dukla Praha	2016/17	200
Jan Kuchta	CZ	Bohemians Praha 1905	2016/17	150
Eric Ramirez	CZ	MFK Karviná	2017/18	150
Miroslav Slepička	CZ	1. FK Příbram	2018/19	75
David Puškáč	CZ	Bohemians Praha 1905	2018/19	150
Jiří Kladrubský	CZ	SK Dynamo České Budějovice	2019/20	200
Antonín Fantiš	CZ	FC Fastav Zlín	2019/20	300
Martin Bukata	CZ	MFK Karviná	2019/20	250
Tomáš Pilík	CZ	FK Jablonec	2019/20	200
Pedro Martinez	CZ	FC Fastav Zlín	2019/20	250
Lamin Jawo	CZ	FC Fastav Zlín	2019/20	250
Michal Papadopulos	CZ	MFK Karviná	2019/20	100
Mads Agesen	DK	Randers FC	2015/16	200
Jeppe Kjaer	DK	Lyngby Boldklub	2016/17	250
Andre Bjerregaard	DK	AC Horsens	2016/17	400
Lasse Kryger	DK	AC Horsens	2016/17	250
Kim Aabech	DK	AC Horsens	2016/17	250
Mohammed Fellah	DK	FC Nordsjaelland	2016/17	200
Mikkel Vendelbo	DK	Silkeborg IF	2016/17	150
Mustapha Bundu	DK	Aarhus GF	2016/17	300
Quincy Antipas	DK	Hobro IK	2017/18	200
Mikael Antonsson	DK	FC Copenhagen	2017/18	250
Morten Hegaard	DK	FC Helsingor	2017/18	100
Julian Kristoffersen	DK	Hobro IK	2018/19	200
Adam Jakobsen	DK	Vejle Boldklub	2018/19	100

Consecutively, the data were subjected to cluster analysis. First, a cluster analysis of goalkeepers in both evaluated football competitions was performed. As a result, the goalkeepers were divided into three clusters. Figure 1 below presents the observed factors for the goalkeepers and the course of the average values of each set.

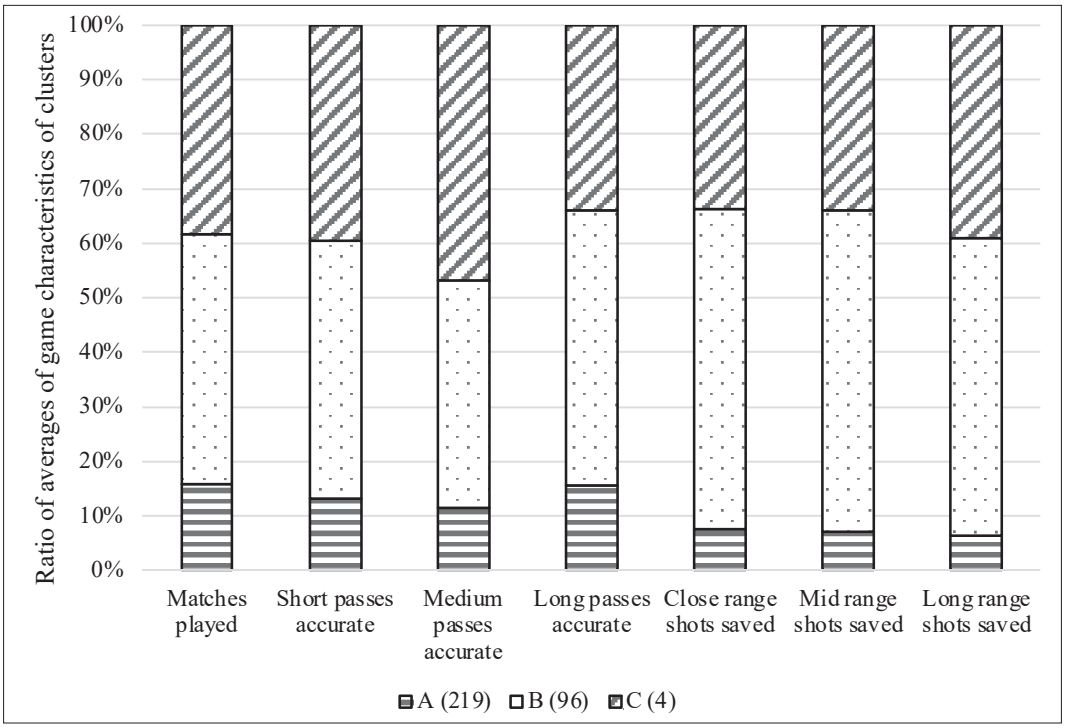

Figure 1. Cluster analysis of goalkeepers in both evaluated football competitions

Figure 1 displays data on the average sports performance of individual groups of goalkeepers. The number of goalkeepers in each group is indicated in brackets next to the group description in the chart legend. The goalkeepers of Cluster A achieved an average market value of 350,000 euros. We have observed that this most numerous group of goalkeepers is, on average, the least sport performing group compared to the other two. The second-largest group of goalkeepers is represented in Cluster B. On average, they reached a market value of 630 thousand euros. This cluster achieved a lower average weight than the most valuable group of players (Cluster C) only in the statistics of accurate medium passes. Goalkeepers Ondřej Kolář, Florin Nita and Kamil Grabara averaged a market value exceeding 4.5 million euros. In all statistics, they reached similar values as the Cluster B goalkeepers. However, based on their high market value, they should dominate the other goalkeepers of Clusters A and B in all statistics.

The same type of analysis was performed for on-field players. The selected characteristics are indicated on the horizontal axis and their frequency on the vertical. In the legend of Figure 2, the number of players in each cluster is stated in brackets. Only the characteristics of the number of games in a season are common to the goalkeeper pool. Clusters A to F are ordered by the average market value of the players. Players in the most numerous Cluster A reached an average market value of 480 thousand euros. In comparison, the players of the least numerous and simultaneously, the most valuable Cluster F reached approximately 8 million euros. Players in Clusters B to E had a market value ranging from 950 thousand to 6 million euros.

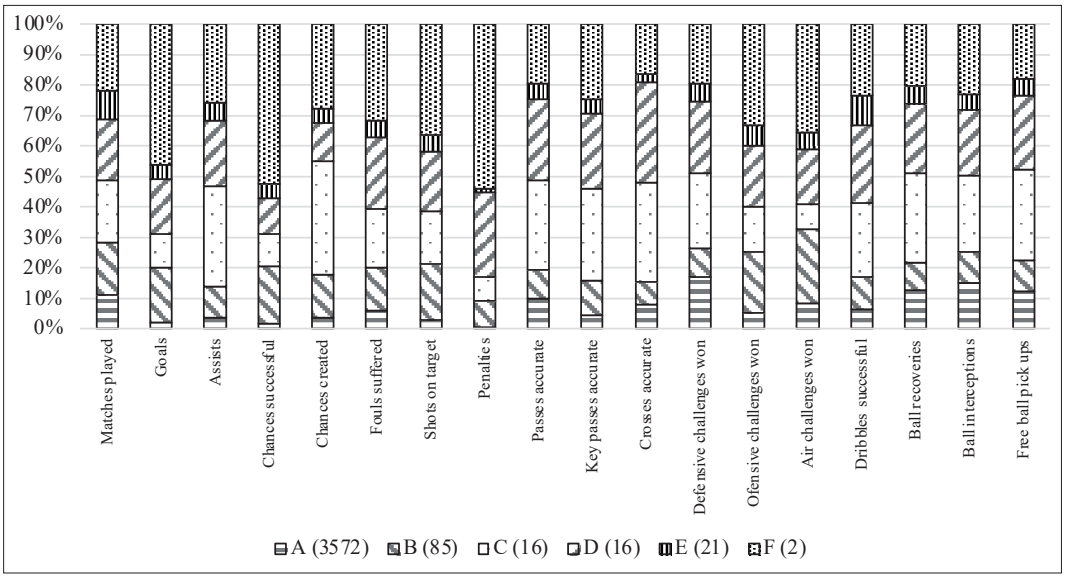

Figure 2. Cluster analysis of on-field players in both evaluated football competitions

The data shows that Cluster A is dominated primarily by defensive players (relatively high average number of defensive challenges won, balls recoveries or opponents' broken passes). They are the players with the lowest average market value among the clusters. More than 95% of all players are incorporated in Cluster A. The other five clusters contain particular groups of players. Cluster B contains offensive players who have, on average, a high number of matches played during the season, an increased number of created chances, shots on target or won offensive challenges. Compared to Clusters C to F, these players are relatively "cheap" in terms of market value, as indicated by the Transfermarkt.com server. Cluster C mainly comprise creative midfielders with a high average value of accurate passes and crosses or created chances. At the same time, the players of Cluster C have achieved a relatively high average value of successful dribbles or free ball pick ups. Players in Cluster D have reached relatively constant average values of the given characteristics compared to other clusters. This Cluster comprises an equal representation of defensive and offensive players. Clusters E and F account for the most valuable players in the group on average. Cluster F contains the most valuable players who have scored the highest number of goals, shots on target, converted penalty kicks, won offensive and air challenges, and successful chances; Cluster E includes players with high market value but low game performance. In most cases, the players in Cluster E do not reach the average values of Cluster A (players with the lowest average market value).

DISCUSSION

The presented research aimed at identifying and subsequent comparing the efficient players of the two competitions under study using data envelopment analysis; by doing so, it was possible to determine whether the most valuable players are also the most efficient. Efficient players were identified by applying the CCR-I model to both football competitions. The number of efficient players at each game position was similar in both leagues, except for one. In the case of the Danish 3F Superliga defenders, the CCR-I model, despite the smaller number of evaluated

players, marked almost twice the number of efficient players compared to the Czech Fortuna:Liga. The highest number of efficient players in both football competitions was among the forwards (31 in total). This result is in line with the widely held view that forwards are the most efficient players. This result contrasts with the result published by Tiedemann et al. (2011) and Fernández et al. (2020). These authors believe that the most efficient players should be among the defenders. Fernández et al. (2020) believes that the attack actions are initiated in to defense, continue with the midfield and just them in the opposite field. Therefore, the inefficiencies of each positions are accumulated towards the more advanced positions. Hence, the inefficiency of the defenders is moved to midfielders, which along with own inefficiency is moved to forwards. The present research also supported some correlation with this opinion. In the case of defenders, 26 players were identified as efficient by applying the CCR-I model. It represents the second-highest number of efficient units.

The most valuable players in each position were not assigned to the group of efficient players in either the Czech Fortuna:Liga or the Danish 3F Superliga, as confirmed by Alp (2006). Therefore, this can imply that the most expensive players in both competitions should have better individual game stats. The CCR-I model provides, among other things, model values of the output characteristics inefficient players should achieve in order to become efficient. Research demonstrated that the Danish league's market value of efficient defenders and midfielders was at a higher financial level than in the case of Czech defenders and midfielders. In the case of the market value of goalkeepers and forwards, there are no significant differences between the Danish and Czech leagues.

The second objective was to apply the cluster analysis to divide the player pool into compact clusters and, consecutively, determine the characteristics of each cluster. This approach can be used as a basis for further research on individual players' game positions and performance, as confirmed by studies by Mulitz (2015) and Martineau (2022). In contrast to this research, Mulitz (2015) uses cluster analysis to evaluate defenders entering the National Football League draft. The clusters are created based on the data collected at the training camp. The cluster analysis results in three defender clusters that divide defenders into offensive defenders, defensive defenders and central defenders. Martineau (2022) applied clustering to football player data in 2016 and identified nine clusters, e.g. defensive technical players, natural goalscorers, players proficient in the aerial game but less skilled during other game phases, players characterized by an ability to accelerate and to keep the ball, versatile midfield players, physical defenders etc. This research also arrived at a similar breakdown by player skill.

CONCLUSION

The main objective of the research was to outline an integrated approach to analysing and evaluating the best players in two selected European football competitions over five consecutive seasons. Although player selection is an important decision-making problem, researchers have paid little attention to this area. The main reason for conducting this research was to expand the research literature by furthering the approach for player evaluation. A two-phase method was proposed in the paper. First, the CCR-I model was used to determine the best players. The DEA methodology has the advantage of establishing benchmarks for inefficient DMUs and identifying sources of inefficiency. Cluster analysis was then used to evaluate the players, which allowed to divide the players into compact clusters. Subsequently, cluster analysis helped to determine what the clusters revealed about the players.

The methods described above focused on analysing players from two selected football competitions – the Czech Fortuna:Liga and the Danish 3F Superliga. The players of both leagues under study were arranged according to their game positions, and the most relevant game factors were determined for the individual groups. Forwards had the highest number of efficient players in both competitions. The most valuable players at the given positions were not included in the efficient players' pool. It can be interpreted that the most expensive players in both competitions should, according to the input-oriented CCR model, achieve higher performance as measured by the mentioned game statistics.

The obtained data were subjected to cluster analysis in the second part of the research. After cluster analysis, the goalkeepers' pool was divided into three clusters, with Cluster A containing more than two-thirds of all players at this position. The average market value of the goalkeepers in the first cluster was the lowest compared to the other two. Cluster B included relatively more valuable goalkeepers than Cluster A and, at the same time, the most efficient in terms of given game statistics. The last cluster, C, represented the goalkeepers with the highest market value who did not achieve the corresponding values of the game statistics. The cluster analysis was also applied to the in-field players in the second step. Cluster A contained more than 95% of players, primarily defensive players (defenders and defensive midfielders); the players in the group can be characterised as cheap and reasonably efficient. Cluster B included combat offensive players with a relatively high average number of shots per goal per season. Cluster C involved players with high average values of accurate passes and crosses. Cluster D players achieved consistent and relatively high average values for all given characteristics. In this perspective, they constitute versatile players. Cluster E players can be characterized as "overpriced". Their average market value is high, not matching game statistics. On the other hand, players from Cluster F attained even higher market values than those from Cluster E; however, their average values of individual statistics were relatively high, and they achieved the best results in some of them (e.g., number of goals scored, successful chances, successful penalty kicks, etc.).

Given football clubs' current economic and financial situation, it is increasingly important to know how efficiently a club uses its resources. Efficiency analysis is used to calculate the performance scores of the players and also to determine the lack of aspects and the amount of lack of the inefficient players. The proposed approach is appropriate when there is a large amount of data with different criteria and alternatives. The inputs and outputs can be changed according to the research needs, allowing managers or coaches to find out additional player characteristics. The DEA methodology has the advantage of establishing benchmarks for inefficient DMUs and identifying sources of inefficiency. The methodology and empirical approach adopted and drafted in this paper can illustrate the potential of individual player efficiency assessment as a valuable tool to support decision-making in team sports management. The results obtained from the model show that scientific decision support can bring positive returns to club owners, managers and the whole team and facilitate its success. Future studies may consider multi-period models (such as WDEA or Malmquist index) or applying the proposed approach to player selection in other team sports.

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STUDIA SPORTIVA 2022/1

Female Spectatorship and Unsportsmanlike Conduct at Football Stadiums: Case Study from the Czech Republic

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Abstract

Football is the most popular team sport in the world. It is entertainment, primarily for men, but nowadays, it can be said that the number of women at football stadiums is steadily increasing. Given the long history of spectator sports events consumption, it is not a surprising fact that there have also been serious manifestations of spectator aggression. The paper aims to analyze the relationship between women visitors' verbal and other expressions of their violent behavior on an example of SK Slavia Prague football club. Primary data were collected by a questionnaire survey mainly at the Eden stadium and other selected Czech football stadiums in 2015/16 and 2016/17 seasons. A total of 120 respondents (aged 25.01 ± 10.20 years old) participated in this research, and all of the respondents were attending the matches in a stand of home team supporters. We state that there are correlations between women visitors' verbal and other expressions of their violent behavior; e.g., the surveyed respondents had no experience with demolishing stadiums and other riots. The respondents also consider it to be the most serious activity at 82.58%. The racism display noted similar results. We state that the results are adequate for women visitors.

***Key words**: football, negative phenomena, women, questionnaire, violence*

INTRODUCTION

Football has become a social and sporting phenomenon, especially in the last few decades, entering the distinctive scene of mass culture as an attractive form of spectator experience. The European Championship semi-final match in France (2016) between Iceland and England was watched by 99.8% of the adult population of Iceland. The World Cup in Russia (2018) was watched by more than 3.5 billion viewers, more than half of the world's population aged four and over. In this context, the dynamic interrelationships between sport and society are reflected, bringing issues such as the widening gap between recreational leisure sport and elite high-performance sport. In particular, passive spectator consumption of sport has taken on a mass character in recent decades. This corresponds to a situation in which the majority of the population does not actively participate in sport and their contact with sport is only in the form of spectatorship. Thus, passive spectator consumption of sport fills the leisure time of a significant part of the population regardless of national borders or socio-cultural formations (Slepička et al., 2010).

On the other hand, we have to state that football fan behavior has been a significant cause for concern throughout Europe, especially in Germany, the Netherlands, Italy, Belgium, and the United Kingdom. Substantial disturbances at football matches have also been witnessed in the Czech Republic, Greece, Denmark, Austria, and Eastern Europe (Frosdick & Marsh, 2005). In recent years, the issue of football hooliganism has become the subject of intense media, political and academic interest. Unfortunately, frequently ignorance and misunderstanding of football hooliganism determine preview on it. It is essential to distinguish hooligans from other people

who are interested only in football and watch football matches. This study is related to some previous interpretations of investigations concerning Slavia Prague football visitors. Some authors identify three major groups: football spectators, football fans, and football hooligans (Mareš et al., 2004). However, a more frequently used form of categorization distinguishes fans from supporters/ultras (Antonowicz et al., 2020; Doidge & Lieser, 2018; Hodges, 2016; Kossakowski et al., 2018; Scholz, 2016; Yusoff, 2016). Football offers a show full of physical clashes of opponents with distinctive features of aggression and primarily attacking the audience's emotions (Slepička, 1990). The researchers carried out on the Czechoslovak Socialist Republic/Czech Republic territory in the 1990s and the beginning of the new millennium did not distinguish the audience in various sports, let alone individual visitors to football matches. The term spectator was incorrectly used for all visitors. Alternatively, there was only a division into fans, spectators, and problematic spectators. We have to say that such a division is insufficient. It is crucial to distinguish, e.g., hooligans from other people interested only in football and watch football matches. At the beginning of the new millennium, the academic community began to distinguish individual visitors. In this context, it is possible to use the most common division and identify four major groups: inactive spectators, football fans, supporters, and hooligans (Sekot & Smolík, 2009). Each group is characteristic and has its specificities. To better understand the negative phenomena, it is desirable to know which persons occur at football stadiums and how they behave.

a) Inactive (objective) spectators. In this group, there are four subgroups: (1) irregular visitors of the football matches; frequently is a special type of fashion and snobbery, (2) fans of the other clubs, not teams that are currently playing a football match, (3) observers, coaches or other football players from other clubs, and (4), women (especially older ages), who attend the match as the accompanying persons of her partners. Heitmeyer & Peter (1998) characterize this type of spectator "consumer-oriented fan." They sit in the stand or seeks a quiet spot on the terraces and wants to see a good football game. Mareš et al. (2004) state that they are passive observers of the game, not affected by the two teams' rivalry, and thus the game looks absolutely neutral. They are not interested only in football matches, but they visit other sports games and other sports. Often, they are not identified with a particular club and donot wear its symbols, such as a scarf, jersey, cap, etc. The spectator is not always present at the football stadiums, but the football match watches via the internet, television, etc.

b) Classical football fans ("normal"). These are the individuals who attend football games. They regularly have a relationship with their club, often because the stadium is located relatively close to their residence. A fan has certain expectations for the development of the match, identifies with the team, and therefore takes its success, or lack of it, personally. Football is usually the only popular sport for a football fan. Fans' identification is presented mainly by clothing, jerseys, club scarves, caps, T-shirts, flags, badges, etc. The football fan has been characterized by division into "we" (supporters club) and "they" (fans of other clubs; Slepička, 1990). A football-oriented fan attends every match and decks out in his team's colors (Heitmeyer & Peter, 1998). These fans can be found mostly on the main grandstands and sometimes even be swayed by the loud cheering and support, sometimes with racist overtones. We note that this group of spectators is usually not involved in other manifestations of spectator violence, except for throwing random objects on a pitch.

c) Supporters (ultras). This is a highly homogeneous group of fans who strive for the most spectacular development of the match while avoiding direct conflict, violence, and vandalism. They are bearers of choreography in the game, supporting the use of fireworks, banners, and singing (Sekot, 2013). They greatly enjoy every game and are interested in club life. We can find them behind the goals (ends) on the side stands during the match, designed chiefly for standing. Almost every fan is dressed in the club jersey, T-shirts, or owns at least a scarf of his favorite team.

d) Hooligans (rowdies). The term hooligan was coined in the 1890s as an alternative to a ruffian. Now readily applied to the wild and unruly football fan of the 1960s, the term and the on-screen images of undisciplined toughs rekindled a Victorian-style moral panic vocalized by the Conservative Party and fanned by the press (Frosdick & Marsh, 2005). Football hooligans come together in small groups mainly consisting of young, militantly oriented supporters. They come to football stadiums and their surroundings with the primary objective cause conflict or fighting with other similar groups opposing teams. These groups (gangs) have their own names, which are defined against unorganized groups and other groups. Some of these parts are very well organized and do not unite only club rivalry and hatred of the enemy groups, but also political, racial, religious, national, regional, or social motives. Hooligans, unlike fans, often do not identify with a football club but only with their group (Mareš et al., 2004).

Although it is primarily a male pastime, female fans can also be found at football stadiums and are proud of it (Ben-Porat, 2009). The omission of female fans could result from their much smaller presence in stadiums and the fact that male scientists are more interested in fandom research (Jakubowska et al., 2020). In 2019, the Women's World Cup was attended by an average of almost 22,000 people and watched on television by almost a billion people worldwide. Nowadays, we can state that the number of women in football stadiums is constantly increasing, and female fans support their team even in outdoor matches. There is a proof. In 2022, a world record has been broken in women's football when 91,553 fans turned up to watch Barcelona beat Real Madrid at Camp Nou. The previous record was 90,185 for the 1999 World Cup final where the US and China faced off (Thomson, 2022). Some clubs provide women with better prices for match tickets, and in the case of an outdoor match, women do not pay for transportation (Yusoff, 2017). If a woman is knowledgeable and understands football, she is more respected among men and can contribute to an intelligent conversation. On the other hand, in the identical situation, a female fan may feel uncomfortable as some fans will let her know that as a woman, she can never understand football (Berg et al., 2014; Sveinson & Hoeber, 2016). Some female fans are dressed in jerseys or wear scarves and in rare cases use the colors of their favorite team on their face to indicate who they are rooting for. Some women wear tight-fitting clothes at football matches and have to face sexist innuendos afterwards (Sveinson & Hoeber, 2015). In the Czech Republic, football matches are mainly attended by men, but the number of women is gradually increasing – 9% of women in the 1990s (Slepička, 1990), 19% of women a decade later (Slepička et al., 2010) and 20% of women nowadays (Scholz, 2018). Approximately 19% of women attend football matches in England (Pope, 2012). On the other hand, we have to state that women's football strives to build a stable platform in terms of fan interest. However, while an increase in gate receipts can help its long-term sustainability, there is limited proof in the academic literature on the factors influencing spectator demand in women's football (Valenti et al., 2020). Pope (2012) divides female fans into two groups, namely (1) passionate, enthusiastic fans and (2) cool fans. The first group includes female fans who attend every match of their team, engage in cheering at the stadium, use the internet to get information from the club, etc. The second group of female fans does not spend as much time watching the game or thinking about football during the week and are not as influenced by the game results. Rather, they enjoy the match in front of the TV screen or the internet.

We have to state that women are often overlooked in academic research (Pope, 2016). The process of women attending football stadiums, the so-called 'feminization' of stadiums, is a desirable process for empirical investigation from a sociological perspective (Pope, 2017). Currently, there is no research that focuses on women's unsportsmanlike behavior worldwide. If any data is available, it is not fully explored as is the case with the male population. There are many studies focusing, for example, on image issues in women's football (Harris, 2005), sports fans from a

female perspective (Sveinson & Hoeber, 2015), etc. McGee (2017) conducted research on 2,729 visitors. Many women attend all home games but do not feel safe at away games due to excessive alcohol consumption, problems with flares, smoke bombs, standing during the game, etc. Toffoletti (2017) describes and analyses female sports fans from a feminist perspective, more specifically using transnational feminism. According to the author, this perspective allows observing the diversity of female fandom and taking into account the different socio-cultural contexts in which specific categories of fans operate (ethnicity, race, sexuality, etc.).

METHODS

The aim of the paper is to analyze the behavior of women and their opinions, which are mostly related to violent behavior at selected football stadiums in the Czech Republic (mainly SK Slavia Prague). Slavia is the oldest football club in the Czech league (est. 1892) and this team has a number of championships (Özaydın, 2021). On the other hand, Slavia had struggled with financial troubles, mainly at 2013/2014 season and was only one step to be in the second league. From the season 2018/2019, Slavia won three titles in a row.

The chosen method of data collection was a questionnaire survey. Primary data was used, which was collected by questionnaire survey technique in the 2015/2016 and 2016/2017 seasons. The questionnaire contained 29 questions; some of them were scaled, where the respondent could rate on a Likert scale individual manifestations from the least serious to the most serious. The respondent had to rate each manifestation with a score, (1 – least severe manifestation and 5 – most severe). However, most of the questions were closed-ended with multiple choice. All respondents attended football matches of the club SK Slavia Prague and watched them from the area behind the goal (the Kop). This part of the stands was chosen because all groups of visitors to football matches are represented there. The stand of the stadium for the home fans and supporters is called "Tribuna Sever", with a capacity of 3,065 seats. It consists of 5 sectors each with 25 seats in 28 rows. The end is mostly filled up to 2/3rds, and sold out during matches against attractive away teams, e.g., Sparta Prague, Plzeň, Ostrava and European teams, e.g., Barcelona, Inter Milan, Dortmund, Sevilla, Chelsea, Feyenoord etc. The selection of the respondents was based on a predetermined key; e.g., seats 1, 3, 5, 7 in the first row, seats 2, 4, 6, 8 in the second row, etc. The sampling consists of 720 respondents; 592 men, 120 women and 8 respondents who did not wish to specify their gender. In this research, we focus on women only (25.01 ± 10.20 years). It was a random selection. Because it is not easy to organize empirical research in a stand, the administrators tried to behave in a user-friendly way. All the respondents were informed about the research and anonymity of the questionnaire. The respondents were willing to participate in the research and were even entertained filling out the questionnaires before the match started. Once they had answered the inquiries, each of them received a small Slavia club badge. They also had the opportunity to contact the interviewer via the email stated on the questionnaire list and inform themselves about the research results.

The paper uses quantitative research and mathematical and statistical methods, specifically correspondence analysis (CA). Using the graphic tools of the CA, it is possible to describe an association of nominal or ordinal variables and to obtain a graphic representation of a relationship in multidimensional space – it is easier to understand for the readers. The analysis provides further evidence that there are dependencies between variables. CA is a multivariate statistical technique. It is conceptually similar to principal component analysis but applies to categorical rather than continuous data. In a similar manner to principal component analysis, it provides a

means of displaying or summarizing a set of data in a two-dimensional graphical form (Zámková & Prokop, 2014).

RESULTS AND DISCUSSION

As far as the individual groups of female football visitors are concerned, we can state that in the Slavia Kop the most frequent age group was 20–26 years old, the most frequent age group of female fans was 13–19 years old, and the age range of the ultras was 34 years and older. No respondents were in the group of female hooligans. We are aware that in the article, we present only summary results for visitors; however, we believe that it is essential to state the age difference between the individual groups (Figure 1).

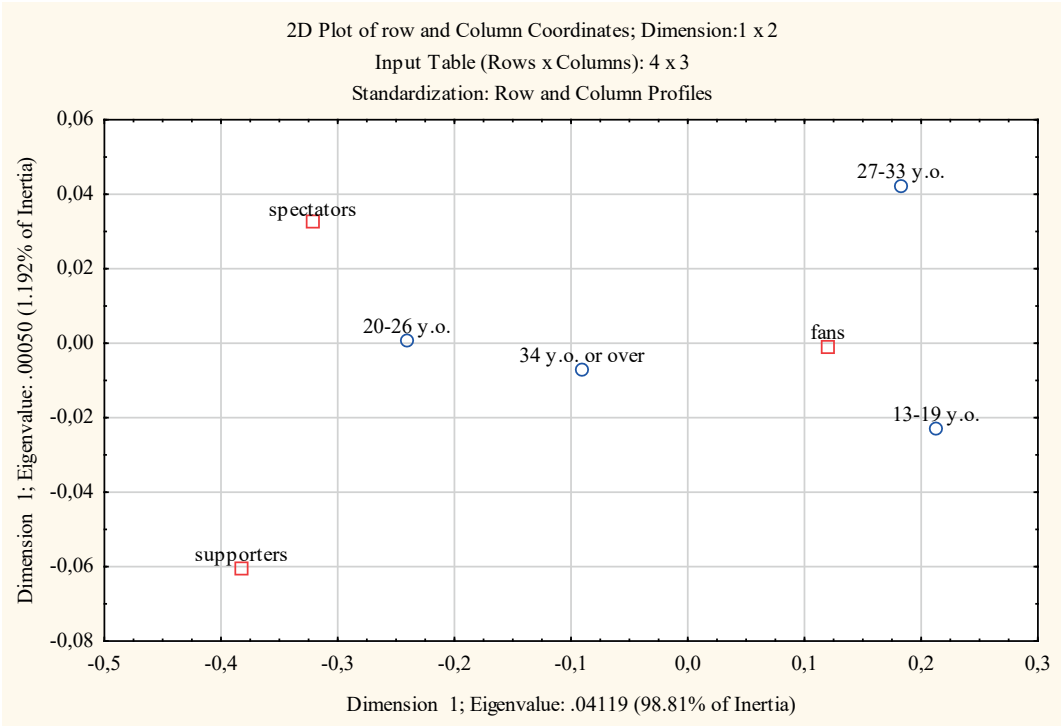

Figure 1. Age composition of each group of female respondents.

More than 3/4 of the respondents (76.67%) were single, 15.00% were married or in a registered partnership, another 5.00% were divorced. We state that the results mimic the societal situation where the current trend is to delay the consummation of marriage until later in life. More than 1/3 of the respondents (38.33%) lived with their parents. Further, more than 1/3 of the respondents (35.00%) lived with their partners or spouses, and 11.67% of the respondents lived with their children, and another 10.00% of the respondents lived alone. More than 3/4 of the respondents (80.00%) were from a complete family. An equally important fact that is often mentioned in connection with the atmosphere in football stadiums is the educational attainment mix of the female respondents. We can observe that the highest number of responses was noted for secondary education with a high school Maturita examination (35.00%). Almost 1/5 of the respondents (18.33%) had completed vocational training and obtained an apprenticeship

certificate and another 1/6 of the respondents (16.67%) had received a university diploma. More than 1/10 of the female viewers (13.33%) received only primary education. Further, 13.33% of the female respondents did not wish to give their answers. It can be noted that more than one-tenth of the female respondents did not want to indicate their educational attainment is relatively high. Nevertheless, the respondents who chose this answer were in the age range of 13–14 years, i.e., they had not yet completed compulsory schooling. Therefore, these educational characteristics should be interpreted in the light of the fact that some of the respondents were primary school students at the time of the survey. Thus, in these cases, they did not have completed education (Table 1).

Table 1. Participation in selected activities during the match (%).

marital status				
single	married		divorced	no answer
76.67	15.00		5.00	3.33
living conditions				
with parents	partner/spouse	with children	alone	no answer
38.33	35.00	11.67	10.00	4.00
education level				
elementary school	high school-Maturita examination	high school-apprenticeship certificate	university	no answer
13.33	38.34	18.33	16.67	13.33
occupation				
student	manager	waitress/bartender	clerk	others	no answer
40.00	6.67	5.00	5.00	30.00	13.33
life satisfaction				
satisfied	rather satisfied	rather dissatisfied	very dissatisfied	no answer
55.00	43.33	1.67	0.00	0.00
economic situation				
very satisfied	satisfied	rather dissatisfied	dissatisfied	no answer
26.67	35.00	10.00	10.00	18.33

Female students dominated the most common "occupation" among the respondents (40.00%). The other occupations were manager (6.67%), waitress/bartender, and clerk (identical 5.00%). More than 1/2 of the respondents (55.00%) were satisfied with their current life, and the other 43.33% were rather satisfied. Regarding the subjective assessment of their own economic situation, 35.00% of the respondents were satisfied, and another 26.67% were very satisfied. One tenth of the respondents (10.00%) was very dissatisfied; the same value was recorded for the response rather dissatisfied (Table 1).

More than 3/4 of the respondents (84.39%) never knowingly brought an object that could be used as a weapon. Only 15.61% of the female respondents reported that they sometimes brought an object that could be used as a weapon into the stadium. Focusing on objects, these were mainly knuckle dusters, pyrotechnics, folding umbrellas, or empty plastic bottles. These, when filled with water and capped, could cause injury if the object was hit.

A significantly high value (88.03%) was recorded for respondents who had never assisted with pyrotechnics. From our own experience, however, we must state that they are women who can easily carry pyrotechnics to the stadium, as their checks at the turnstiles are not so thorough (the authors attended hundreds of football matches in the Czech Republic, England, Italy, Spain,

Slovakia, and women are not given enough attention stadiums). Pyrotechnics are tucked into handbags. It is often hidden in intimate games, where the organizers are not allowed to reach.

More than 2/3 of the respondents (69.09%) occasionally used vulgar language as far as vulgarity is concerned. Vulgar expressions were mainly addressed to referees and also to the former president of the FAČR (Football Association of the Czech Republic, hereafter FAČR), the current vice-president of the FAČR, and the former chairwoman of the FAČR Central Commission of Referees.

Regarding alcohol consumption, we noted that more than 1/2 of the respondents (57.88%) did not consume alcohol mainly because they arrived at the match by motor vehicle.

As expected, we observed that all respondents (100.00%) had never participated in stadium demolition. Almost the same value (96.97%) was obtained for acts of racism. As far as, for example, racist chants are concerned, the situation is more favorable if we compare the beginning of the 1990s, when dark-skinned players started to appear in the Czech top competition. In recent years, however, dark-skinned players have started to appear much more frequently in Czech football stadiums. They have become significant reinforcements for their clubs and fan favorites (O. Doorley, A. Sima, I. Traoré, Y. Sor, etc.). For this reason, these racist chants are only sporadic, but for example the chant "jude Slavie" is always heard during the derby with Sparta. International organizations and fan groups are trying to eradicate racism from football completely through various projects and banners during matches (Table 2).

Table 2. Participation in selected activities during the match.

	always	**sometimes**	**never**
Carrying objects into the stadium with the purpose to use them as a weapon	0.00	15.61	84.39
Assisting with pyrotechnics during a football match	0.76	11.21	88.03
Vulgar language during a football match	8.94	69.09	21.97
Alcohol consumption before or during the match	15.76	26.36	57.88
	often	**sometimes**	**never**
Participation in the demolition of the stadium	0.00	0.00	100.00
Participation in racist acts	0.00	3.03	96.97
Booing at the referee during a football match	13.48	41.06	45.46
Booing at Slavia Prague during a football match	0.00	11.36	88.64
Booing at an opponent during a football match	15.00	50.91	34.09
Booing at the former president of the FAČR and other officials during the match	13.48	32.12	54.39
	yes	**no**	**–**
Running onto the pitch	8.18	91.82	
Throwing an object into the playing area	3.03	96.97	

Regarding booing, more than 1/2 of the respondents (50.91%) occasionally booed and another 15.00% of the respondents were frequently booing. The most common reasons were players lying down on the field of play, delaying playing a standard situation, and passing constant passes in their own half when the team was trying to maintain a hopeful result. Almost 1/10 of the respondents (8.18%) had the experience of running into the playing area. After the historical promotion of Slavia Prague to the Champions League (2007), most of the Kop supporters celebrated this special moment on the pitch directly with the players after the match. Only 3.03% of the respondents threw the object on the playing field. This was most often done when the head or sideline referee made an incorrect call or when celebrating an opposing player's goal in front of the home crowd. The football pitch was often littered with empty or full beer cups, soft plastic

drink bottles, small coins, strobes, smoke bombs, and lighters. We can therefore conclude that the referees' actions could, in some cases, have become the instigator of violent clashes, even in cases where they themselves acted in violation of the football rules (Table 2).

The most severe activities are considered to be stadium demolition (82.58%), racism in the stands (71.36%), physical aggression against police and organizers (61.21%), and physical aggression against fans of the opponent in the stadium (59.70%). We observe that these are serious acts and agree with the highest marks. The booing was unanimously identified as the least serious activity (73.49%). More than 1/3 of the respondents (38.94%) considered the use of pyrotechnics as the least serious problem and conversely almost 1/4 of the respondents (24.24%) rated this activity with the highest possible mark. Some respondents reported that there is a risk of burns when handling pyrotechnics, but no case of burns has been recorded so far in Slavia. We agree that some matches (Sparta Praha, Viktoria Plzeň, Baník Ostrava) had to be interrupted due to the indiscipline of some people, but after a few minutes, the matches continued. Never has a match against Slavia been abandoned due to pyrotechnics. The majority of respondents thought that pyrotechnics clearly and always belonged to football and they could not imagine football matches without them. We believe that as long as pyrotechnics are controlled (Bengals, not bangers), Czech football should not go down the path of banning them. It could pick up information about safe pyrotechnics developed in Denmark and allow their use in Czech stadiums. As far as the vulgar chanting of the whole Kop or individual vulgarisms are concerned, we can say that we have achieved approximately the same results. The vulgarisms stem from the referee's wrong verdict, delay of the game, and celebration of the opponents' goals in front of the Tribuna Sever stand. Regarding the hooligan clash outside the stadium, more than 1/3 of the respondents (42.12%) expressed that it was a very serious problem and rated it with the highest mark, i.e., 5. Some respondents were upset that the club was associated with these fights. On the other hand, 25.30% of the respondents did not find any problem in an arranged clash outside the stadium. On the other hand, if an opponent´s fan is dressed in a jersey and scarf and meets a hooligan, he may not be worried. Interviews with Slavia supporters and hooligans have confirmed that true hooligans are highly disciplined, they know what aspects of the culture are, and they will not beat up another team's supporters. For women, this rule is doubly true. Almost 1/2 of the female respondents (48.79%) believed that throwing objects (lighters, beer cups, coins, etc.) on the field was the most serious activity. Almost 1/2 of the female respondents (44.09%) perceived running onto the playing field as the most serious activity (Table 3).

Table 3. Female respondents' comments on individual activities (%).

Activities	1	2	3	4	5
firing of pyrotechnics	38.94	20.15	15.15	1.52	24.24
vulgar chants in the stand	37.42	26.36	19.54	3.03	13.64
individual vulgar expression	39.70	20.45	20.30	7.58	11.97
physical aggr. against rival fans at the stadium	0.76	8.18	1.52	29.85	59.70
physical aggr. against police and riot police	7.42	10.45	3.03	17.88	61.21
arranged hooligan fight outside the stadium	25.30	3.03	6.06	23.49	42.12
throwing object to the pitch	3.79	11.97	14.24	21.21	48.79
demolishing the stadium and other riots	0.00	1.52	6.82	9.09	82.58
racism display	3.03	1.52	6.06	18.03	71.36
booing the referee/rival players/club	73.49	12.88	11.36	1.52	0.76
pitch incursion	16.51	6.06	15.15	18.18	44.09

Note: 1 – the least serious expression; 2 – less serious; 3 – neutral; 4 – more serious; 5 – the most serious expression

However, there are several limitations in the submitted article. First, our research cannot be generalized, and no in-depth analysis was performed. We were only interested in Czech football clubs. We would like to investigate other major international football clubs in other countries and compare these data with the results of an elite Czech football club. We suppose that a comparison of other countries would be desirable. Furthermore, in our future research, we aim to investigate the implementation of preventive measures, including thorough personal examinations and football visitors if there is any correlation. Finally, we would like to focus on qualitative research to complement the quantitative findings. In our opinion, such extended results based on in-depth screening would gain significant value in affecting the international field of female fanhood issues.

CONCLUSION

The authors' interest and the fact that there is not enough up-to-date information on this issue motivated this article. The aim of this paper was to analyze the behavior of women and their opinions concerning behavior and violence in football stadiums in the Czech Republic. The research shows that the most common profile of female respondents is of single marital status (76.67%) with a high school education (38.34%) and living with a spouse (35.00%). The most common was a student (40.00%) who was satisfied with her life (55.00%) and economic situation (35.00%). We also identified that there were correlations between the verbal and other expressions of the study subjects and their violent behavior. None of the respondents participated in the destruction/demolition of the stadium and vandalism and rioting in the stadium was considered by 82.58% of the respondents as the most serious manifestation of violent behavior. The female respondents surveyed had no experience of stadium vandalism. Similar results were obtained for racism. Furthermore, 61.21% of female respondents identified police aggression and riots as the most severe activity, and almost the same value (59.70%) was noted for aggression among fans. On the other hand, 73.49% of the visitors said that booing was the least problem.

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STUDIA SPORTIVA 2022/1

Benefits of 6 weeks of high interval intensity training based on basic fitness variables and losing weight during the pandemic of covid-19 period.

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Abstract

BACKGROUND: Due to the authorization to do outdoor sports in Algeria, the government allowed the sports that do not require physical contact. The purpose of this study is to show the benefits of 06 weeks of high interval intensity training (HIIT) based on body weight movement and sprint on developing maximum oxygen consumption (VO_2max), power, maximum aerobic speed (VMA), endurance, and losing weight during the pandemic of covid-19.

METHODS: 11 persons participate in this study belonging to the fitness club in Bordj Bou Arreridj – Algeria – (age: 32.18± 8.08 year, high: 1.78 ± 0.052 cm, weight: 84.24 ± 11.25 kg, BMI: 26.50± 3.95 kg). the protocol was contained 3 session moderate intensity, pretest, 6weeks HIIT 3 sessions per week, and ensure that the heart rate is 100% during the exercise finally, post-tests.

RESULTS: similar increases ($p < 0.05$) in distance of running by (226,54m, 17.30%). And VMA it enhanced by 2.26 km/h with 17.34%. While VO_2max it's developed by 17.28% (7.92 mL/kg/min). with very large effect size (ES=1.75). In addition, the power of legs it boosted by 3.17% (6.27 cm) with small effect size (0.58). Also, results indicate decrease in weight by 2.73 with large effect size (0.87).

CONCLUSION: the outdoor exercise it seems safe to do during the pandemic of covid-19. Results highlight great effect of HIIT on enhancing (VO_2max, power, VMA, endurance, and losing weight).

Keywords: *High interval intensity training, Maximum oxygen consumption, Power, Maximum aerobic speed, Endurance, Losing weight, covid-19.*

INTRODUCTION

The world is witnessing a big pandemic these days, which is the Coronavirus. The propagation of the virus SARS-CoV-2 officially started at the beginning of December 2019 in Wuhan (China), where the first COVID-19 victim was diagnosed with a new type of coronavirus. The virus first spread over different states in China before reaching other countries. On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a pandemic, pointing to more than 1180 0 0 cases of the coronavirus illness in over 110 countries around the world (Buldú, & all 2020). COVID-19 is a respiratory virus that is transmitted by large respiratory droplets and direct contact with infected secretions (Jacob et al., 2020). On February 25, 2020, the country Algeria announced the first infection with the virus, for an Italian who had been deported to his country. And on

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March 13 record the first death. Begun, on March 19 the government has begun to take preventive measures to curb the spread of the virus as it has begun to limit the movement of citizens in some areas and leave the house except for necessity, such as the acquisition of medicine or food, and in other areas, the movement has been stopped completely, and it has also recommended social distancing, especially the elderly. And announce that the lockdown according to the practice in other countries is the best option and the great way to control the virus.

At the time of restrictions, the population was limited in social personal contacts including physical movement which was a serious negative phenomenon. This crisis affected negatively on the world of sports and on fitness, performance and energy of athletes because they can't follow their training program constantly and safely.

The negative effects of sedentary employment are intensively studied by a team from Palacký University in Olomouc from Czech Republic. The sedentary behavior is assessed from various aspects, such as the age of participants, social and geographical environment, parents influence (Frömel, Mitáš & Kerr, 2009; Mitáš, Nykodým & Frömel, 2009; Sigmundová, Sigmund, Badura, Vokáčová, Klein & Bucksch, 2017).

And this significantly decrease their level of physical activity and lots of them get some weight due to inactivity during the lockdown and there are not enough exercises on their daily routine. About 48% of physical activity and 49% energy expenditure was decreased in physiotherapy professionals and students during the lockdown period when compared to them before the lockdown period (Srivastav & all, 2020). The guidelines recommend at least 150 to 300 min per week of aerobic exercise and 2 resistance training sessions per week. Under the quarantine it could be suggested to increase to 200–400 min per week distributed among 5–7 days to compensate for the decrease in the normal daily PA levels (D Jiménez-Pavón, 2020).

Studies reported that staying home at the prolonged time might lead to sedentary behaviors, such as spending more time on sitting activities, playing games. Watching television, decreasing regular outdoor activity and exercises leads to an increased risk of chronic health conditions (Srivastav et al., 2020). Many studies suggest that exercise produces positive effects on physical fitness, mental health, and lifestyle. It is wrong to completely renounce physical activity with the aim of preventing the spread of SARS-CoV-2, it has been proven that physical activity improves the performance of our immune system and reduces cardiovascular risks (Petersen, 2020). The purpose of this study is to regain the level of fitness for the athletes by increasing their VO_2max, VMA, endurance and decreasing the weight that they gain on the pandemic. Also, trying to enhance their immune system against corona virus showed that sport can help patients in their recovery from the covid-19 (Faghy et al., 2020). The use of moderate-intensity exercise is recommended to strength the body defense against COVID-19 (Samadi, Shirvani, & Rahmati-Ahmadabad, 2020). Physical inactivity during period of COVID restriction was analyzed by Sallis et all, (2021). They studied 48 440 adults patients with a COVID-19 diagnosis from 1 January 2020 to 21 October 2020 according the data: risk hospitalisation, intensity of illness, habits of physical activity before COVID-detection (March 2015 – March 2020) with at least three exercise vital sign measurements from 19 March 2018 to 18 March 2020. "Consistently meeting physical activity guidelines was strongly associated with a reduced risk for severe COVID-19 outcomes among infected adults. We recommend efforts to promote physical activity be prioritised by public health agencies and incorporated into routine medical care." (Quot: Sallis, Young, Tartof et al., 2021, p.1.) On the bases of this knowledge, when the lockdown open, the authors tried to give help for all people around the world and specifically for the athletes. Also, the authors try to add value for the society that people can facing this new phenomenon on clever and strong way by building a program based on high interval intensity training (HIIT) and body weight (BW) for 6 weeks.

The government announced on official TVs and radio that persons should be stay active in their homes. and the top clubs proposed in their website and Facebook pages to their competitive athletes some exercise to do at home aim to keep their fitness level.

High Intensity Training (HIT) refers to a special form of brief and intense resistance training targeting maximum muscle fiber recruitment with high muscle tension, leading to temporary muscle fatigue. Since muscle fatigue with HIT is severe, this type of resistance regime requires more recovery than other weight training methods (Kunz, 2019) HIIT, also known as Interval Training (IT) or Sprint Interval Training (SIT) consists of a set number of high intensity exercises, each immediately followed by periods of recovery. The high intensity exercises can range anywhere from between 5 or 10 seconds to 5 or 10 minutes. Likewise, the periods of recovery can range in duration, too (Driver, 2013). The key of HIIT is about time and recovery in and between exercises. Also, HIIT defined as "near-maximal" efforts generally performed at an intensity less than peak VO_2 or peak power output that elicits greater than or equal to 80% peak HR (often in the range of 85%–95%) (Dun, Smith, Liu, & Olson, 2019). And what I mean with HIIT in this study is peak power and peak HR at 100% and doing each exercise as many reps as possible (all-out).

Studies showed the huge benefits of HIIT in increasing VO_2max, and the Increases in $\dot{V}O_2$max exhibited in response to different HIIT regimes are due to improvements in oxygen delivery (Astorino et al., 2017). This kind of exercise is safe and promising exercise prescription to improve cardiovascular function and metabolic capacity (Grace et al., 2018Dun et al., 2019) Dun and his colleague found that multi-system integrative physiologic adaptations in respiratory, cardiovascular, and skeletal muscle systems induced by high-intensity interval training contribute to improvements in peak VO_2. In addition, all-out HIIT can result in the same degree of improvement in maximal oxygen uptake (VO_2max) and time trial performance as traditional continuous endurance training despite a much shorter total training time (Atakan et al., 2020; (Kon & al, 2020; M.M., Y. & al., 2019. Ram et al., 2020). However previous studies concluded that HIIT has big effect in fat oxidation and losing weight (Russomando et al., 2020). Russomando and his colleagues results that HIIT has positive trends in the reduction of fat mass percentage. HIIT has several health outcomes including increases in cardiorespiratory fitness and maximal fat oxidation, up regulation of skeletal muscle proteins and markers of mitochondrial function related to oxidative phosphorylation capacity and improved body composition (M.M & al, 2019). Also, HIIT has a positive effect on effects on body mass, body fat, body composition, and physical fitness, (Batrakoulis et al., 2019). The researcher suggests that in order to guarantee HIIT effectiveness, programs should include 2–3 sessions per week, with intervals of 15–30 s and passive or active rest periods of 15–30 s. For higher volume programs, discontinuous games of up to 6 min work with 4 min rest periods for a total session time of 40 minutes can be used (Delgado-Floody, Latorre-Román, Jerez-Mayorga, Caamaño-Navarrete, & García-Pinillos, 2019). Accordingly, the aim of the present study was to highlight the benefit of 06 weeks of HIIT based on body weight movement and sprint on developing (VO_2max, power, VMA, endurance, and losing weight) during the pandemic of covid-19.

MATERIALS AND METHODS

Participant recruitment

Eleven healthy recreationally active males and some of them non-active. Belonging to the fitness club in Ghillassa Affiliated with the Sports Star Club of Karate Ghillassa in Bordj Bou Arreridj – Algeria – (age: 32.18± 8.08 year, from – up to high: 1.78± 0.052 cm, weight: 84.24± 11.25 kg, BMI: 26.50± 3.95 kg). described in the Table 1. The study based on only male be because it's voluntary participation and those males have the motive to participate. Inclusion criteria were: non-smokers, they have not any history related to cardiac respiratory function and they do not have any bone or join problem and, of course. They are not carriers of the Coronavirus to avoid transmitting the infection. And with no specific diet to follow. This data was assessed by their honor proclamation as

Table 1. Participant characteristics at the baseline.

Variables	High (cm)	Weight (kg)	Age	BMI (kg)
Mean	1.78	84.24	32.18	26.50
SD	0.052	11.25	8.08	3.95
N	11			
Sex	Meal			

Abbreviations: BMI= body mass index. Sd= standard deviation.
N= number of participants.

Study design

The experimental protocol included a familiarization procedure, week 01 moderate intensity in order to prepare the participants physically, psychologically, and physiologically. Then there are pre-tests, 6 weeks of HIIT – 3 sessions per week, and finally post-tests as described in the tables 02. According to the General Data Protection Regulation, the authors assured the participants that the results would be used solely for scientific research purposes.

Regarding the tests', training area was outdoors, away from gyms, to prevent direct interaction with surfaces and the use of the same tools by all participants, and only during the time allotted for exercise in order to comply with Covid-19 restriction regulations.

Table 2. Protocol training description

weeks	days	Kind of exercise	intensity	Total time (min)
Week 01	Sunday	Running	Moderate	20
	Tuesday	Running	Moderate	25
	Thursday	Running	moderate	30

weeks	days	Kind of exercise	HIIT time (s)	Recovery time (s)	Total time
Week 02	Sunday	Body weight movement	10	50	25
	Tuesday	sprint	10	50	20
	Thursday	Body weight movement	10	50	30
Week 03	Sunday	Body weight movement	15	45	25
	Tuesday	sprint	15	45	20
	Thursday	Body weight movement	15	45	25
Week 04	Tuesday	Body weight movement	20	40	30
	Thursday	sprint	20	120	22
	Sunday	Body weight movement	20	40	35
Week 05	Tuesday	Body weight movement	25	35	25
	Thursday	sprint	15	60	20
	Sunday	Body weight movement	25	35	30
Week 06	Tuesday	Body weight movement	30	30	25
	Thursday	sprint	10	50	17
	Sunday	Body weight movement	30	30	35
Week 07	Tuesday	Body weight movement	30	30	35
	Thursday	sprint	15	60	20
	Sunday	Body weight movement	30	30	35

Note: time of all these sessions is not including (warm-up, dynamic stretch, static stretch, cool down, time of those is separated).

Tests

Participants run for 06 minutes for the greatest possible distance they can with no stop and if someone get tired, he will complete the duration with a walk, then we record the distance.

VMA test: maximum aerobic speed

– Equipment: whistle, tape measure, timer, a wide-open space.

Ex: The first participant cut 1320 m per min. we convert this to km so (6 min = 1320m = 1.32 km) then we convert the 6 min to the hour because the result will be on km/h (6 min *10 = 1h). The mileage per kilometer is multiplied by 10 to get the total distance per hour (1.32 km*10 = 13.2 km/h). So, VMA=13,2 km/h.

VO_2max test: maximum oxygen consumption (In milliliters per minute per kilogram of body weight)

To calculate VO_2max we use this formula (VMA * 3.5 = VO_2max). Take the same previous example: (13.2 * 3.5 = 46.2). So, VO_2max = 46.2 ml/mn/kg.

Power test: Standing Broad Jump Test

– Tools: flat floor that does not expose the individual to slipping – tape measure – draws the starting line.
– Procedure: the athletes stand behind a line marked on the ground with feet slightly apart. A two-foot take-off and landing is used, with swinging of the arms and bending of the knees to provide forward drive. The participants try to jump as far as possible and as much as they can, landing on both feet without falling backwards Figure 1. Two attempts are allowed.

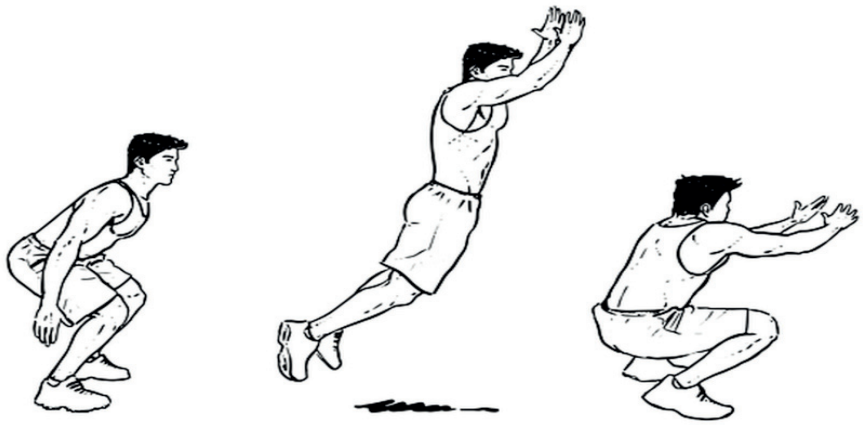

Figure 1. Standing Broad Jump

– Scoring: The measurement is taken from takeoff the line to the nearest point of contact on the landing (back of the heels). Record the longest distance jumped, the best of two attempts.

Procedures followed during the program implementation period:

1. Ensure the safety of the participants from the Corona virus.
2. Physical distancing between athletes 1.5 m at least to avoid risks of transmission to the virus.
3. No gym, no equipment just body weight movement and sprint and all sessions held outdoor.
4. Ensure that the participants give all what they have (speed and power).
   Ensure that the heart rate is 100% during the interval workout. Participants independently track their pulse rates. (220–age= maximum heart rate, it's 100%). as described in Figure 2 heart rate measurement technique.

Figure 2. Method to measure heart rate

5. No masks face to avoid the toxicity by CO_2 during breathing and up taking the clean air. The use of masks during a short exercise with an intensity around 6–8 METS decreases O_2 by 3.7% and increases the CO_2 concentration by 20%. (Pifarré & al, 2020)
6. Avoid public showers and changing rooms as much as possible.

Statistics

All analyses were performed using IBM Statistical Package for Social Sciences (SPSS) v24.0 and excel. The normality of the data was assessed using the Shapiro-Wilk, Kolmogorov-Smirnov statistic and a visual inspection of their histograms and normal Q-Q plots and box plots showed that the data were approximately normally distributed. Also, using paired sample t-test, mean, standard deviation to compare between pre-test and post-test. Statistical significance was set at $p < 0.05$. Effect sizes (ES) was calculated using Cohen's d ($d = M_1 - M_2 / s_{pooled}$), it seems appropriate to revise the rules of thumb for effect sizes to now define d (0.01) = very small, d (.2) = small, d (0.5) = medium, d (0.8) = large, d (1.2) = very large, and d (2.0) = huge(Sawilowsky, 2009). Ratio % were calculated to know the percentage of progress and development of the participants after applying the program.

RESULTS

Training characteristics

There was full training adherence for the participants who completed the study (all 11 participants completed all 21 sessions, 03 preparation sessions, 12 HIIT and 06 sprint sessions). Total time of exercise during the whole protocol from the first day till the final day was 549 min with average (78.42 min in a week and 26.46 min per session) with full compliance to training session requirements within each session as we describe in the previous Table 2.

Pre-test characteristics

The researchers conducted a series of procedures to ensure the study's effectiveness and the adoption of the recommended program. As a result of our testing, we were able to establish the participants' level. and to allow us to compare the findings between the pree test and the post test at the end. as describe in Table 3. As well as to determine the efficacy of our suggested protocol.

Table 3. Comparison between weight, distance of running, VMA, VO_2max and power before and after applying the training workout program.

tests	Pre-test		Post-test		Δ%	t-test	Effect size	Sig (p-value)
	mean	SD	mean	SD				
weight	84.24	11.25	81.94	9.61	–2.73	2.87	0.87	0.01
Distance of running	1309.72	132.05	1536.27	72.35	17.30	5.81	1.75	0.00
VMA	13.09	1.32	15.36	0.72	17.34	5.81	1.75	0.00
VO_2max	45.84	4.6	53.76	2.53	17.28	5.81	1.75	0.00
Power	198	18.86	204.27	18.51	3.17	1.93	0.58	0.08

Note: significant differences ($P \leq 0.05$). Δ% = magnitude of change (post-training – baseline) as a percentage of the baseline.

Results analysis

Weight

In pre-test weight was (84.24± 3,211 kg) and in the post-test was (81.94±9.61 kg) it decreased by 2.73%. while t-test was –2.87. p= 0.01 so there is a significant difference between pre and post-test in favor of the post-test. In addition, the program applied has a large effect size in decreasing weight d= 0.87.

Distance of running

In pre-test distance of running on 06 minutes was (1309.72 ±132.05 m) and in the post-test was (1536.27± 72.35 m) it increased by 226,54m with 17.30%. While t-test was 5.81. p= 0.00 so there is a significant difference between pre and post-test in favor of the post-test. Moreover, the program applied has a very large effect size in increasing the endurance of athletes and develop their ability to run quicker d= 1,75.

VMA

VMA (km/h) maximum aerobic speed in pre-test was (13.09±1.32 km/h) however, in post-test it increased at (15.36±0.72 km/h) it enhanced by 2.26 km/h with 17.34%. while t-test was 5.81. p= 0.00 so there is a significant difference between pre and post-test in favor of the post-test. Moreover, the program applied has a very large effect size in increasing the maximum aerobic speed of the participant d= 1.75

VO_2max

VO_2max (mL/kg/min) maximum oxygen consumption it's developed by 17.28% (7.92 mL/kg/min). In post-test (53.76±2.53 mL/kg/min). But, in pre-test it was (45.84 ±4.6 mL/kg/min). While t-test was 5.81 and d= 1.75 we can say this training, program has a very large effect size in increasing the maximum oxygen consumption of the members of this study. Further, p= 0.00 so there is a significant difference between pre and post-test in favor of the post-test.

Power

The power of legs according Standing Broad Jump it boosted by 3.17% (6.27 cm) in the post-test (198±18.86 cm) compared to pre-test (204.27±18.51 cm). While t-test was 1.93 and d= 0.58 this showed that the training work program has as small effect size on developing the power of legs in participants. Furthermore, p= 0.08 so there is no significant difference between pre and post-test in favor of the pre-test.

DISCUSSION

This study was intended to measure the effectiveness of six weeks of high-intensity training with using body weight movement and sprint on VO_2max, VMA, endurance, body fat. And try to enhance immunity of the cardiac and respiratory system especially during the pandemic of Coronavirus. HIIT may be a potential beneficiary of cardiac rehabilitation therapy for patients with COVID-19 infection after discharge from the hospital (Li & al, 2020). Ron Gilat and his colleagues says in their article: We understand now more than ever that sports keep our body and mind healthy." The results of this study demonstrated a positive improvement in all variables.

Many previous studies agreed that aerobic exercise is the best type of exercise for total body fat loss (Juliana & Wahed, 2019). While this study highlights a positive improvement on losing weight even though the time of exercise is short. Researchers promotes HIIT is great strategy to combat obesity and it has a positive effect on metabolism. (Miguet et al., 2018) clarified this in their study that an acute session of HIIT favors reduced subsequent energy intake and food reward despite unchanged appetite feelings in adolescents with obesity. Zeng and his colleagues found HIIT are an efficient weight-reducing procedure, and HIIT can be selected for people who can endure high-intensity exercise and are in urgent need of fat loss (Zeng, Peng, Zhao, & Chen, 2020). Moreover, HIIT had greater influence on most of the components of the metabolic syndrome compared to the equivalent energy expenditure of moderate intensity (Karlsen & al, 2017).

HIIT can enhance capacity for oxidative metabolism in skeletal muscle owing to an increase in mitochondria. And of course, this will help the body to get more energy, build muscles and losing fat (Moris, & al, 2020). Hammad and associates reported that HIIT increased fat utilization during exercise, decreased percentage of body fat and improved cardiovascular parameters (Hammad & al, 2019).

Taken together, these results suggest that HIIT can boost the VO_2max, VMA and endurance in high level and this kind of session would be an ideal training. Paquette and all recommended coaches and athletes who wish to improve VO_2max through central adaptations should include short intervals to their program (Paquette & al, 2019). Researchers determined that HIIT improved aerobic performance and increased aerobic capacity (Alonso-Fernández, et al, 2017; J. Edge*, n.d. (Paper & Tetik, 2020). Rosenblat and his colleagues (2020) indicate that long-HIIT may be the optimal form of interval training to augment performance. They are determined a moderate effect (ES = 0.70) in favor of HIIT over SIT in maximal aerobic power (MAP) or maximal aerobic velocity (VMA). Similar idea was published by(Sabri & Gheorghe, 2014). The more abruptly speed increases and the shorter event duration, the more the VMA value is overestimated. This can be explained by the fact that anaerobiosis (lactic acid production and tolerance to its accumulation) can also be improved the VO_2max methodical procedure the ratio between effort/res. In fact, HIIT improves performance in part by enhancing the capacity for aerobic energy provision and increased whole-body maximal oxygen uptake (Gibala, 2020. Delgado-Floody et al., 2019; Roloff et al., 2020Delgado-Floody et al., 2019). Delgado and others affirm HIIT boost (VO_2max), performance in the intermittent Yo-Yo test and maximal aerobic speed.

Corte and his colleagues conclude HIIT methodology could influence in negative ways on strength performance, they found a significant reduction on total repetitions on Leg Press (–22.97) and Leg Curl (Δ%= –17.56) exercises (Corte, 2017). However, results of this study although there are no statistically significant differences between pre-test and post-test on Standing Broad Jump, but it obvious that HIIT has a positive effect on strength, it enhances the power of legs by 3.17%, this difference it maybe refers to the kind of HIIT protocol used. This study consistent with (Ulvestad, Durheim, Kongerud, Lund, & Edvardsen, 2020) there was a clear benefit of HIIT on cardiorespiratory fitness among participants who adhered to the exercise intervention after lung transplantation. In addition, HIIT led to significant improvements in muscular strength, demonstrated by a significant increase of 11% in 1RM leg press. And they suggest that HIIT may help speed recovery (Burley, Drain, Sampson, Nindl, & Groeller, 2020). Burley et all advocated that HIIT Promote power of leg they found (ES 0.65) on squat jump and (ES 1.05) on squat.

Participants felt positive, fun, challenge and confident because they understood that contributing to group engagement activities was not a waste of time and that they had a hand in the decision-making process to deter the spread of the Covid-19 virus, and this research helped them realize that sports and fitness are good tools for creating a healthier community.

CONCLUSION

Despite concerns about the coronavirus, the program was adopted. When all precautions of training and medical precautions are taken, exercising outside the gym tends to be less dangerous than indoor training. It is recommended to arrange the equipment and participants in rows that are perpendicular to the wind direction as far as possible so that they are not downwind and directly exposed to exhaled droplets and aerosols of other participants (Blocken et al., 2020). Findings of this study showing the great positive effect of HIIT and benefit of 06 weeks of HIIT

based on body weight movement and sprint on developing (VO_2max, power, VMA, endurance, and losing weight) during the pandemic of covid-19.

The authors strongly advise using this program at home or in fresh and pure areas but remember to follow the implementation procedures to stay fit and safe at the same time. However, the program must be based on the personal intrinsic motivation of the participants and their motivation should be encouraged.

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STUDIA SPORTIVA 2022/1

Bilateral Differences in Handgrip Strength in Czech Female Tennis Players Aged 11–12 Years and Injury Prevention

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Abstract

The term laterality refers to the preference or dominance of the lateral asymmetry of the human body. The prevalence of left-handedness is reported to be 10–13%, but in some sports (e.g. boxing, ice hockey, tennis), the proportion of left-handers is higher. The left-handedness is considered an advantage in tennis; however, the one-sided load can cause muscular dysbalances leading to injuries. The research aim was to assess bilateral differences in handgrip strength in top Czech female tennis players U12 as to injury prevention. The participants were tennis players (n = 165) aged 11.0–12.9 years taking part in the regular testing by the Czech Tennis Association using the TENDIAG1 test battery between 2000 and 2018. 87.3% of all players were right-handed (RH) and only 12.7% left-handed (LH). Bilateral differences between the right- and left-hand strength of all players were medium significant in favor of the right hand. The assessment of differences between RH and LH players showed only small differences in favor of LH players. There was a medium significant difference between RH and LH players in favor of the dominant hand (DH) over the non-dominant one (NDH). As to injury prevention, it is surprising that a difference between DH and NDH strength >15% was found in 40.91% of RH players and even in 40.06% of LH players. This predicts an increased risk of injury, so it is desirable to pay attention to both sides of the training load and to include compensatory or strengthening exercises.

Keywords: *bilateral asymmetry, dynamometer, handedness, isometric strength, laterality*

INTRODUCTION

The prevalence of left-handedness in the general population is in the range of 10–13% (Faurie & Raymond, 2004), a higher proportion of left-handers was found mainly in some interactive sports (boxing, ice hockey, tennis). In tennis, the proportion of left-handers is higher among the world's elite tennis players (Holtzen, 2000). In an analysis of the World Ranking of tennis players (1968–1999), it was found that the percentage of left-handers among elite players was significantly higher (Grand Slam finalists: male = 22.27%, female = 18.75%; winners: male = 22.66%, female = 21.88%). However, the results of the study among players participating in four Grand Slam tournaments between 1968 and 2011 (Loffing, Hagemann, & Strauss, 2012) document a lower representation of left-handers among elite male finalists and winners (Grand Slam finalists: male = 8.70%, female = 17.17%; winners: male = 9.76%, female = 21.15%). The one-sided preference or functional advantage of limbs or organs, also known as laterality, reveals the individual's tendency to use coordinated, more accurate and stronger body parts mainly regarding to upper and lower limbs and the brain hemisphere during life. If we use them more often, the movement or work-related tasks will become more economic, confident, and precise (Domino, Świątkowski, & Matłosz, 2015; Hagemann, 2009; Loffing, Hagemann, Strauss, & MacMahon, 2016; Ziagkas, Mavvidis, Grouios, & Laios, 2017). Favoring one hand in everyday life creates a difference within the hands and then, a dominant hand develops. Laterality could be related to other parts of the body as well, but for our research intention, we focused on the handedness issue

which referred to the left- (sinistrality) and right-hand (dextrality) dominance. In some sport fields, a higher percentage of left-handers occurred (e.g. tennis, box, baseball, handball, football). In tennis, a limited number of numerously performed activities could be seen during training or game matches and might be a cause of injury due to flexibility and strength imbalances. Upper limb injuries mostly happened by the repeated excessive load of the speed-strength movement character. Fu, Ellenbecker, Renstrom, Windler, and Dines (2018) found out musculoskeletal affliction due to joint loading and overusing amongst junior tennis players. Ellenbecker, Roetert, Bailie, Davies, and Brown (2002) claimed that strength differences could be visible as early as at the age of 11–12 and this could lead to an injury in the future during their carrier. According to Fu et al. (2018), acute injuries tended to be more likely in the lower body, but upper body suffered more by chronic overuse injuries (referred to 47% of junior tennis players problems in the study of Pluim, Loeffen, Clarsen, Bahr, and Verhagen (2016) and in Colberg, Aune, Choi, and Fleisig (2015) even 67%). Kovacs, Ellenbecker, Kibler, Roetert, and Lubbers (2014) examined 861 elite junior tennis players in their study, and they came with the result that injury rates were 11% in the 12 and underage group, 28% in the 14 and underage group, and 36% in the 16 and underage group. McCurdie, Smith, Bell, and Batt (2017) found a higher injury rate among female players compared to men. Pienimäki, Tarvainen, Siira, Malmivaara, and Vanharanta (2002) claimed that grip strength reduction up to 25% could be caused by previous injury (mainly tennis elbow) and because strength of the forearm (grip strength respectively) played the crucial role as well as muscular endurance due to the length characteristics of the match; it seemed to be important to maintain the ideal level of grip strength and to avoid overloading (Roetert & Kovacs, 2018). This approach could be helpful for prevention and performance optimization during the training process. Hutchinson, Laprade, Burnett, Moss, and Terpstra (1995) found the most common musculoskeletal injuries amongst the junior tennis players which included strains, sprains, and cramps. Tennis players at pubertal age could tolerate progressive training if it is interspersed by appropriate recovery time. But insufficient recovery will rise the risk factors such as fatigue, overtraining, and burnout. This could lead to increasing the injury risk, reducing the training effectiveness and performance dropping during the competitions. With years of training, changes are also visible in flexibility and strength on body parts that are subject to a repetitive movement and therefore tensile overload. Those maladaptation processes then alter proper function of joints and muscles and could be taken as injury risk factors or a cause that affects the performance. Compared to boys, girls have higher percentage of the injury mainly on the shoulders, wrists, and knees. This is due to a lower strength level in the upper body and inferior conditioning status comparing to their male rivals. With regards to handedness, a few percentages of players (3.6% among male and female) who play with the opposite hand to that used for tasks like writing could be, mainly due to sport-specific tasks (or sport-specific dominance), benefit from this advantage on the court (cross-dominance). So, while in some cases being left-handed could be disadvantageous in the competition (regulations, equipment, etc.), in some fast and quick sports such as tennis, left-handers are considered having more chance to success because of their weaker brain lateralization for specific tasks (Lawler & Lawler, 2011; Loffing et al., 2016; Vodička et al., 2018). This is also because laterality has been regarded as one of the significant factors for developing the talent (Sterkowicz, Lech, & Blecharz, 2010), considered inherited and developed through infancy (Kubota & Demura, 2011). It is believed that bilateral differences, or let's say sidedness, could cause a reduction in performance or predisposition to injury. The assessment of this (a) symmetries should be taken into consideration during the training process not only at the beginning but also as feedback to training effect (Loffing et al., 2016).

The purpose of the study was to evaluate the handgrip strength and its bilateral differences in the context of potential injury risk. The main purpose of the study was further divided into

sub-goals which were identification of (1) the levels of somatic and strength characteristics, (2) the ratio of right-handed and left-handed players, (3) bilateral differences in handgrip strength between the dominant and non-dominant hand.

METHODS

The sample consisted of Czech female junior tennis players. Ages ranged between 11 and 12.9 years (n = 165, age: M ± SD = 12.00 ± 0.54, height: M ± SD = 155.08 ± 7.31 cm, weight: M ± SD = 43.86 ± 7.30 kg). Female players took part in the project testing called Complex diagnostics in tennis (1999) in the years 2000–2018. The testing battery TENDIAG1 (Zháněl et al., 2015) was used, especially research-related parts such as: base anthropometrics (height, weight) and maximal hand grip strength (HGS) using the handgrip dynamometer Takei T.K.K. 5401 GRIP-D (Takei Scientific Instruments Co. Ltd, Tokyo, Japan). The manufacturer states the results of HGS in kilograms (kg). The players' handedness for racket use in tennis was determined by asking which hand they use when playing forehand. This hand was labeled as the playing or dominant hand and the female players as right-handers (RH) or left-handers (LH). The formula BSA = Stronger limb – Weaker limb / Stronger limb x 100 (Bishop, Read, Lake, Chavda, & Turner, 2018) was used to calculate bilateral strength asymmetry (BSA). As the authors state, the values of BSA calculated in this way are about 45% higher than those calculated using the BAI-1 formula. The authors Bishop et al. (2018), Davies, Ellenbecker, and Wilk (2009) and Hepping, Ploegmakers, Geertzen, Bulstra, and Stevens (2015) consider bilateral differences >15.0% a high risk and bilateral differences >20% a very high risk in terms of potential injury.

Players always completed two attempts on each hand and the highest obtained score was considered as a result. The execution of the measurement was strictly controlled, every player had to keep her hand parallel to the body during standing without touching it with the elbow extended and the wrist in the neutral position. To assess the effect size (ES) for bilateral differences, we used the effect size index d (Cohen, 1988), which can be interpreted as a small (d = .2), medium (d = .5) or large effect (d = .8). The data was processed using the licensed software IBM SPSS Statistics (version 28.0, SPSS Inc., Chicago, IL USA).

RESULTS

Statistical analysis (Shapiro-Wilk test) showed that the data came from a normal distribution. Base statistical and anthropometric characteristics and maximal handgrip strength are presented in Table 1. Of the 87.3% (n = 144) of the cases, the sample consisted of right-handed (RH) players and the remaining 12.7% (n = 21) were left-handed (LH) players. It was obvious from Table 1 that in comparison to the mean value of the handgrip strength of the right hand (SRH = 23.11 kg) and the left hand (SLH = 20.75 kg), the result was in favor of the RH players. For verifying the significance of the differences in mean values for the strength of both hands (2.36 kg), we used Cohen's d and it showed the medium effect size (d = 0.51, medium).

Table 1. Basic statistical characteristics of the sample

Sample	Female players (n = 165)			
Variables	M	SD	min	max
Age (y)	12.00	0.54	11.0	12.9
Height (cm)	155.08	7.31	135.5	181.0
Weight (kg)	43.86	7.30	28.2	66.8
SRH (kg)	23.11	4.36	12.4	35.7
SLH (kg)	20.75	4.80	10.0	43.3

Note: SRH = strength of right hand, SLH = strength of left hand, M = mean, SD = standard deviation, y = years, cm = centimeter, kg = kilogram.

Table 2 shows the results of the assessment of bilateral differences between the stronger limb and the weaker limb obtained by calculating bilateral strength asymmetry (BSA). Out of 165 observed players, 71 of them (43.03%) had bilateral differences >15%. The strength difference >20% was found in 44 players (26.67%).

Table 2. The assessment of bilateral differences between the stronger and the weaker limb

Bilateral differences	n	%
RH vs LH	144 vs 21	87.27 vs 12.73
BSA >15%	71	43.03
BSA >20%	44	26.67

Note: BSA = bilateral strength asymmetry between stronger limb and weaker limb, RH = right-handers, LH = left-handers, >15% = bilateral strength differences >15%, >20% = bilateral strength differences >20%.

The results of the comparison of handgrip strength dominant (DH) and non-dominant hand (NDH) levels in right-handers (Table 3) and left-handers (Table 4) are supplemented by the percentage of players for whom bilateral differences between DH and NDH >15% were found. The right-handed players (Table 3) showed relatively high percentage of the strength differences (40.91%) between the dominant and non-dominant hand that exceeded the 15% strength level asymmetry.

Table 3. Bilateral differences between the dominant and non-dominant hand (RH players)

Handgrip strength	M ± SD	min	max	$D_{(R/L)}$ >15%
DRH (kg)	23.28 ± 4.28	12.40	35.70	40.91%
NDLH (kg)	20.04 ± 4.05	10.00	30.90	

Note: DRH = dominant right hand, NDLH = non-dominant left hand, M = mean, SD = standard deviation, D(R/L) = strength difference between DRH and NDLH higher than 15% percent, kg = kilogram.

The left-handed players (Table 4) showed similar tendencies and even higher percentage of the strength differences (43.06%), which was almost the half of the cases.

Table 4. Bilateral differences between the dominant and non-dominant hand (LH players)

Handgrip strength	M ± SD	min	max	$D_{(R/L)}$ >15%
DLH (kg)	25.60 ± 6.45	16.70	43.30	43.06%
NDRH (kg)	21.99 ± 4.71	15.00	32.40	

Note: DLH = dominant left hand, NDRH = non-dominant right hand, M = mean, SD = standard deviation, $D_{(R/L)}$ = strength difference between DLH and NDRH higher than 15% percent, kg = kilogram.

We also focused on comparison between dominant and non-dominant hand of the right-handers (RH, Table 3) and left-handers (LH, Table 4) which showed small differences between both dominant hands (M_{DRH} = 23.28 ± 4.28 kg, M_{DLH} = 25.60 ± 6.45 kg, d = 0.42, ES small) in favor of the LH players. The assessment of the dominant (DRH) and non-dominant (NDLH) bilateral differences was medium (M_{DRH} = 23.28 ± 4.28 kg, M_{NDLH} = 20.04 ± 4.05 kg, d = 0.78, ES medium) for RH players and also medium for LH players (M_{DLH} = 25.60 ± 6.45 kg, M_{NDRH} = 21.99 ± 4.71 kg, d = 0.64, ES medium).

DISCUSSION

The representation of left-handers in our study (12.73%) corresponds to the proportion of left-handed people (10–13%) in the population; data on higher representation in tennis were not shown. Also, a comparison of the proportion of left-handers among U12 female players and the results of studies by Holtzen (2000) and Loffing et al. (2012) among elite male and female players (Grand Slam finalists and winners) strongly favors elite players. The results of our study showed moderately significant bilateral differences between the right- and left-hand strength of all players (in favor of the right hand). The assessment of differences between RH and LH players showed only small differences in favor of LH players. Both RH and LH players showed moderately significant bilateral differences in favor of the dominant hand. There are only few comparable studies in the sport literature (Table 5), more authors have analyzed handgrip strength and bilateral differences in 11–12-year-old children (Butterfield & Lehnhard, 2009; Fredriksen, Mamen, Hjelle, & Lindberg, 2018; Gómez-Campos et al., 2018; Hepping et al., 2015; Kocher et al., 2017; Omar, Alghadir, Zafar, & Al Baker, 2018; Ploegmakers, Hepping, Geertzen, Bulstra, & Stevens, 2013).

Table 5. Hand grip strength and bilateral differences of different female participants (U12*)

Authors (Ch)	***n***	**SRH** (M ± SD)	**SLH** (M ± SD)	**BSA** (%)
1. Butterfield and Lenhard (2009)	69	23.1 ± 4.8	21.5 ± 4.5	3.59
2. Fredriksen et al. (2018)	284	17.4	16.1	3.88
3. Gómez-Campos et al. (2018)	313	18.8	17.5	3.58
4. Hepping et al. (2015), RH	195	22.6 ± 4.4	20.5 ± 4.1	4.87
5. Hepping et al. (2015), LH	24	21.6 ± 3.6	21.4 ± 3.8	0.47
6. Kocher et al. (2017)	398	25.9 ± 5.5	24.1 ± 5.3	3.60
Authors	***n***	**DH** (M)	**NDH** (M)	**BSA** (%)
7. ZeDI (unpub.), Tennis	166	22.8	20.3	5.80
8. Omar et al. (2018), Ch	92	17.5	16.8	2.04
9. Ploegmakers et al. (2013), Ch	219	22.3	20.6	4.21
10. Toong et al. (2018), Ice Hockey	107	21.1	20.3	1.93

Note: n = sample size, SRH = strength of right hand, SLH = strength of left hand, DH = dominant hand, NDH = non-dominant hand, Ch = Children, ZeDI = Zentrum für Diagnostik und Intervention im Sport (Ruhr-Universitaet Bochum), unpub. = unpublished, M = mean, SD = standard deviation, * = for studies reporting HGS values separately for ages 11 and 12, the values for U12 were calculated using a weighted arithmetic mean.

While 43.03% of research participants were found to have bilateral differences >15%, 26.67% were found to have differences as high as >20%. Comparison with the results of 10 studies showed significantly lower interlimb asymmetries in sets of children of the same age. The statistical characteristics of the BSA values from all 10 studies (BSA: M ± SD = 3.40 ± 1.55, range of variation:

0.47–5.80) are well below our results, with the highest value found in German tennis players (ZeDI, unpub.), while the majority of children have low values. Both these results and the results of our study support the assumption of a higher prevalence of interlimb asymmetries in some interactive sports. Values of bilateral strength asymmetry, especially differences >15% or >20%, must be considered – in agreement with Bishop et al. (2018), Davies et al. (2009) and Hepping et al. (2015) – as a risk factor for possible injuries not only in tennis.

CONCLUSION

The aim of the study was to assess bilateral differences in grip strength in Czech U12 female tennis players in the context of injury prevention. Significant bilateral differences were found between dominant (DH) and non-dominant hand (NDH) in both right-handed (RH) and left-handed (LH) players. Detected values of bilateral strength asymmetry >15% or >20% should be considered as a predictor of possible injuries (not only) in tennis.

Lateral asymmetry could be a cause of an injury or muscle imbalances. Players and coaches should take this into consideration and a proper exercise (or compensation) should be an important part of training. An exercise for eccentric external rotators strength may help with the balancing the antagonist group strength. This crucial exercise should be incorporated into the training process in tennis mainly due to repetitively performed explosive concentric and eccentric contractions. Tennis strokes are most of the time characterized by the so-called stretch-shortening cycle so training sessions should consist of exercises of concentric and eccentric character.

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Disclosure statement
No potential conflict of interest was reported by the authors.

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Relationship between speed and explosive power of lower limbs in semi-elite football players

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ABSTRACT

PURPOSE: *This study focuses on the relationship between speed (acceleration, maximum speed, and change of direction speed) and explosive power of lower limbs represented by countermovement jump (CMJ) in semi-elite football players.*

METHODS: *Twenty semi-elite football players (n = 20; 25.1 ± 6.2 years) participated in the study. All participants were assessed using the following 5 tests: countermovement jump (CMJ), 5-0-5 Agility test with dominant lower limb turn and non-dominant lower limb turn, 10-meter linear sprint, 30-meter linear sprint.*

RESULTS: *Pearson's correlations ($p \leq 0.05$) calculated the relationship between CMJ and speed tests. Subjects displayed a very large correlation between 10 and 30-meter sprints and CMJ ($r = -0.75$ and -0.76). There was a moderate correlation between 505 COD tests (non-dominant and dominant) and CMJ ($r = -0.54$ and -0.61, respectively).*

CONCLUSIONS: *There are large to very large relationships between speed and power attributes in semi-elite soccer players, especially between linear speed and CMJ. Improving the explosiveness and power of lower limbs can lead to increasing velocity and enhancing sport-specific speed.*

Keywords: *acceleration, maximal speed, change of direction speed, countermovement jump, correlation*

INTRODUCTION

Speed abilities are one of the critical factors in team sports that contribute to the success of individuals and thus the victory of the entire team. UEFA technical reports, which examine Europe's most prestigious competition – Champions League, show that the most successful teams have the fastest players in their squads. At the same time, the analyses demonstrate the direction in which football and players' individual performances are evolving. For example, in the season 2018/19, the number of sprints above 30 km/h doubled compared to the previous year. (UCL 2019/19 Technical report, 2019). In 2019/20, Kylian Mbappe (Paris Saint-Germain FC) reached the highest speed of 33.98 km/h (UCL 2019/20 Technical report, 2020). In the following season, 7 players exceeded this limit (UCL 2020/21 Technical report, 2021).

Football performance is not only a matter of maximum speed. From the point of frequency of individual actions in a match, it seems that immediate stopping, change of direction, and short acceleration are the key aspects of modern football. Players change their direction more than 700 times during a ninety-minute match (Bloomfield et al., 2007). Research has also proved that most sprints last less than 5 seconds (Andrzejewski et al., 2013).

According to the data stated above, focusing on the speed abilities seems crucial and may give a player a significant advantage over the others during the match. The question for coaches is how these abilities can be developed and improved.

Keiner et al. (2019) examined the long-term influence of strength training on change of direction speed. They concluded that specifically aimed strength training has a considerable effect on the evolution of direction speed. Subjects of this research were divided into two groups, in which case a strength-training group achieved a 5–10% improvement in a 10-meter sprint compared to a control group. It was also proved that strength training influences the force-velocity profile. Increasing the maximum strength level can positively affect explosive power and velocity (Østerås et al., 2002).

Among research conducted to examine the correlation between maximum power, explosive power, and speed belongs a study by Wisloff et al. (2004). It compares speed in a 10 and 30-meter sprint with the performance in a vertical jump. Researchers discovered a very large correlation ($r = -0.72$) between acceleration speed (the 10-meter sprint) and jumping height (CMJ). They also proved ($r = -0.60$) dependence between maximum speed (30-meter) and jumping height (CMJ).

The researchers also pursued the speed and force-explosive parameters and compared them with half-squat performance. They found large to almost perfect correlations between the level of 1RM and the 10 m sprint time ($r = 0.94$), 30 m sprint time ($r = 0.71$), 10 m shuttle run ($r = 0.68$) and jumping height ($r = 0.78$).

The same results ascertained Cronin and Hansen (2005), who tested 5-meter sprint, 10-meter sprint, and 30-meter sprint and compared these results with the jumping height. Authors found a large correlation ($r = -0.60$) between starting speed (the 5-meter sprint) and jumping height (CMJ), as well as between acceleration speed (the 10-meter sprint) and jumping height (CMJ), where the correlation was largest ($r = -0.62$). Moderate correlation ($r = -0.52$) was found between maximum speed (the 30-meter sprint) and jumping height (CMJ).

On the other hand, studies (Popowczak et al., 2019; Salaj and Markovic, 2011) showed no or very little correlation between explosive power and speed ($r = -0.01$ and $r = -0.04$ to -0.33, respectively).

A brief review of the role of maximal strength and explosive power training in a change of direction speed claims that this type of training improves strength production in the vertical plane and thus contributes to improved performance in a change of direction speed. Specific factors influencing such performance types are unilateral strength, eccentric strength, reactive strength, and SSC (stretch-shortening cycle). From the point of maximum strength, the level of relative strength seems to be more important than the absolute one (Watts, 2015).

This research aims to examine the relationships between speed, which means the linear speed at 10 and 30-meter, change of direction speed, and explosive power of lower limbs represented by countermovement jump (CMJ).

MATERIALS AND METHODS

Participants

Twenty semi-elite football players ($n = 20$) participated in the study. All the participants were members of one team, competing in the 4th Czech football division. The average age of the players was 25.1 ± 6.2 years, the average height was 179,5 ± 10,1 cm, and the average weight was 81,3 ± 9,2 kg. All the participants were asked about their lower limb dominance; 16 out of 20 described themselves as right-footed and 4 as left-footed.

The study was conducted in accordance with the Declaration of Helsinki and followed the ethical standards of Masaryk University. Before the study, all participants were informed about the nature and aim of the research and were familiar with the potential risks of the study. All players agreed voluntarily with the participation in this study.

Design

The first test performed regarded the countermovement jump. The MyJump 2 software measured the jumping height and other parameters. It is considered valid and thus could be used as a cheaper substitute for the force plates (Stantona et al., 2017). CMJ can be regarded as the most valid and reliable test designed to assess the explosive power of the lower limbs (Markovic et al., 2004).

Another test the participants performed was a 10-meters linear sprint and a 30-meters linear sprint. Times were recorded by photocells (Brower Timing System, Brower Timing Systems, Draper, USA) at the start line, at the 10-meter mark, and the finish line (30-meter mark). The research by Wisloff et al. (2004) used the 10-meter linear sprint and 30-meter linear sprint tests to assess elite football players' acceleration and maximum speed levels.

The last test was the 505 COD test, which tested the change of direction speed and is very similar to the typical game situation in football. The player has to decelerate quickly from the maximum speed (a 15-meter sprint), turn in 180 degrees, and then accelerate back to the level of the photocells. Therefore, this test is used in research to examine the change of direction speed in team sports, especially football (Beato et al., 2019). 505 COD test is a highly reliable assessment with a coefficient of variation of 2.8% (Stewart et al. 2004).

All tests were conducted on the same day and under the same circumstances.

Statistical analysis

Test results are presented as mean ± standard deviation. Statistica software (Statsoft Inc, Tulsa, Oklahoma, USA; version 12) was used for data processing. Pearson's correlation coefficient was used to evaluate the degree of linear correlation between variables. The magnitude of the association between variables was interpreted as trivial (0–0.1), small (0.11–0.3), moderate (0.31–0.5), large (0.51–0.7), very large (0.71–0.9), and almost perfect (0.91–1.0) (Hopkins, 2000). The proportion of the variance was defined by the coefficient of determination (r^2). The level of significance (α) was set at $p < 0.05$.

RESULTS

The study's results are processed in Table 1, where in the first column is the mean of the values and in the second is the standard deviation.

Table 1. Descriptive statistics of performed tests

	10m [s]	30m [s]	505 D [s]	505 ND [s]	CMJ [cm]
Mean	1.93	4.51	2.62	2.64	35.06
SD	0.12	0.18	0.12	0.15	3.67

Note: SD – standard deviation; 10m – 10-meters linear sprint, 30m – 30-meters linear sprint; D – dominant leg; ND – non-dominant leg; CMJ – countermovement jump

Table 2 shows the correlation matrix, while the individual columns show the dependencies between the individual variables, i.e., the performance in a 10-meter sprint, 30-meter sprint, 505 COD test non-dominant lower limb, 505 COD test dominant lower limb, and finally CMJ.

Table 2. Associations between the individual variables

	10m	30m	505 D	505 ND	CMJ
10m	1	0.98	0.59	0.6	–0.75
30m	0.98	1	0.58	0.58	–0.76
505 D	0.59	0.58	1	0.94	–0.61
505 ND	0.6	0.58	0.94	1	–0.54
CMJ	–0.75	–0.76	–0.61	–0.54	1

Note: 10m – 10-meters linear sprint, 30m – 30-meters linear sprint; D – dominant leg; ND – non-dominant leg; CMJ – countermovement jump

When comparing explosive power and speed, it can be stated that the largest correlation is between the performance in 30-meter sprint and jumping height ($r = –0.76$; $r^2 = 0.58$; $p < 0.05$).

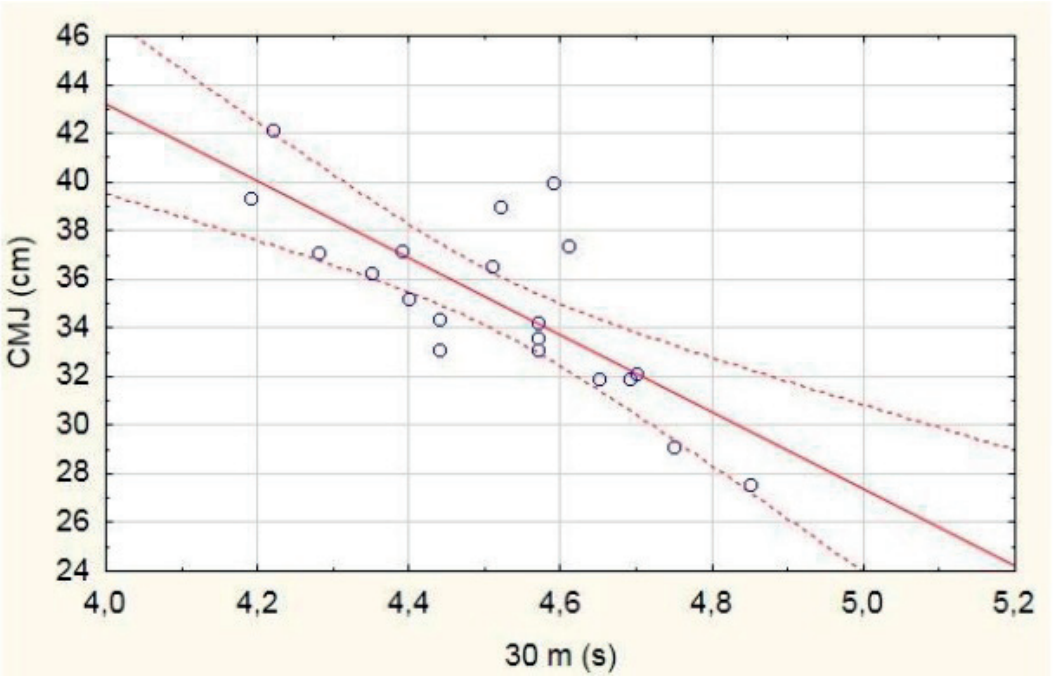

Figure 1. Correlation between 30-meter sprint and CMJ

Very large correlation was also revealed between the 10-meter sprint and jumping height ($r = –0.75$; $r^2 = 0.56$; $p < 0.05$).

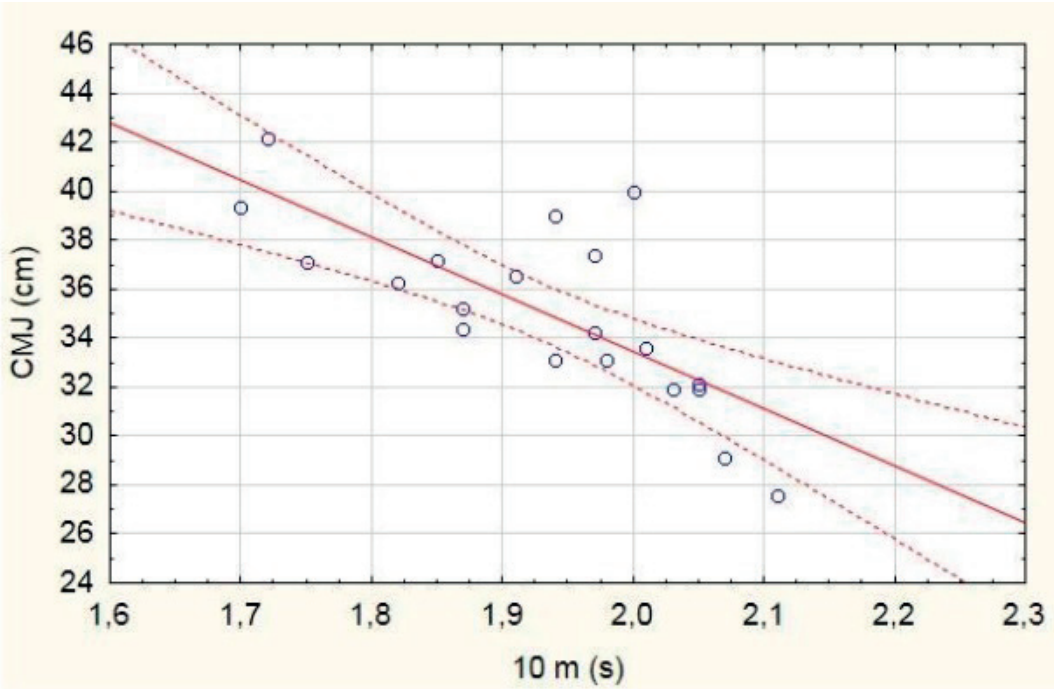

Figure 2. Correlation between 10-meter sprint and CMJ

Large correlation was also demonstrated in 505 COD tests (non-dominant and dominant) and jumping height test, respectively ($r = -0.54$ and -0.61; $r^2 = 0.29$ and $r^2 = 0.37$; $p < 0.05$).

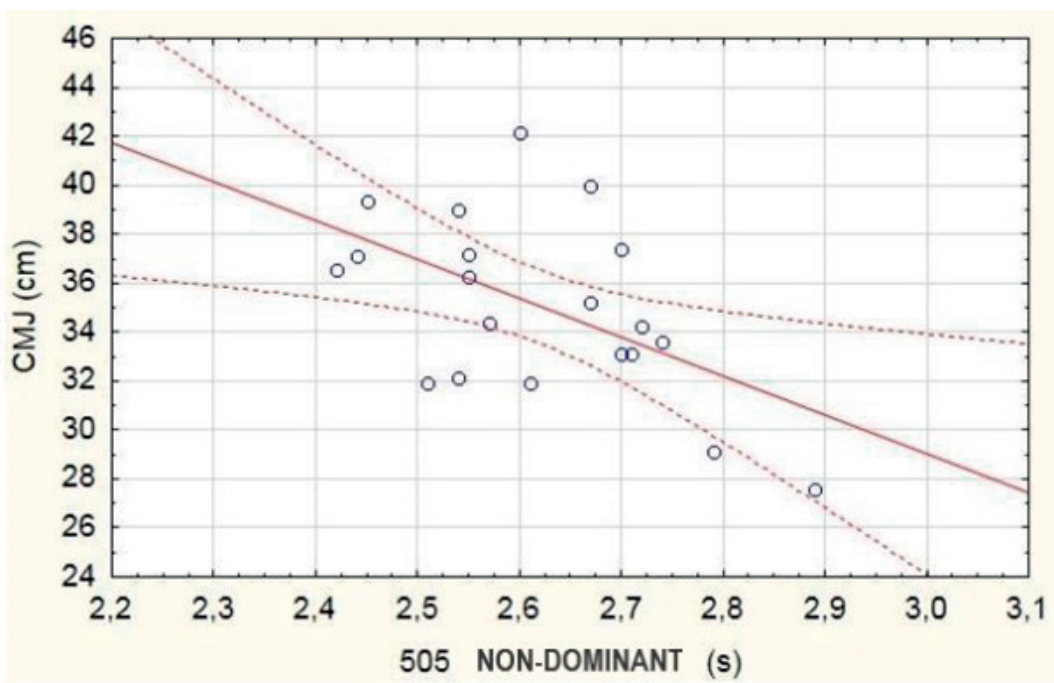

Figure 3. Correlation between 505 COD non-dominant and CMJ

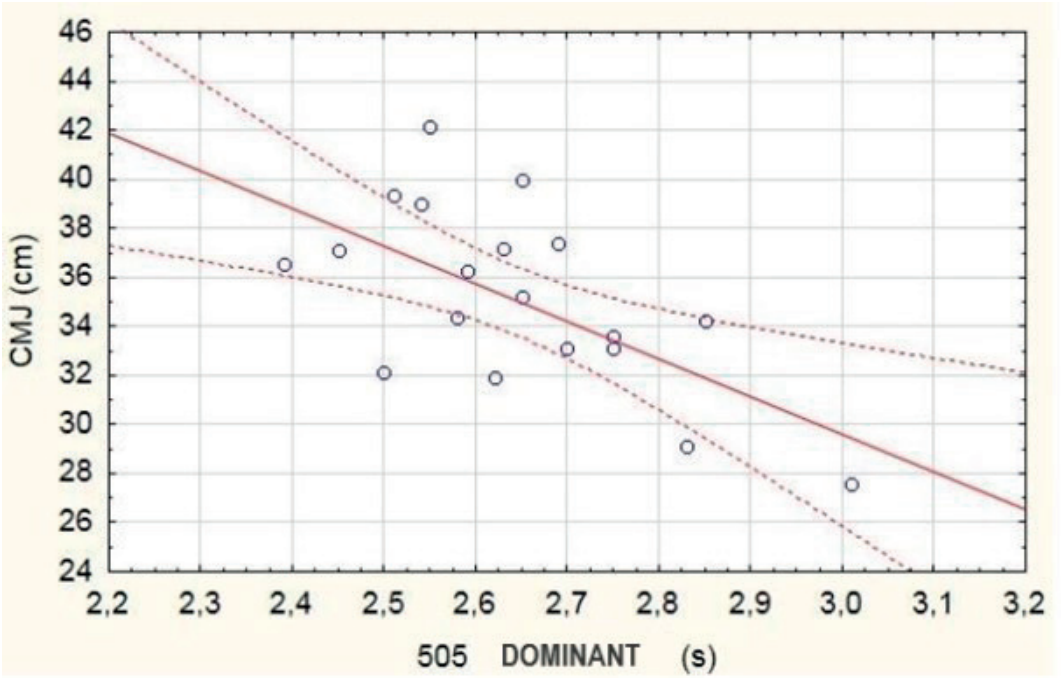

Figure 4. Correlation between 505 COD dominant and CMJ

DISCUSSION

Results of the study imply that the speed abilities for performance in acceleration speed (a 10-meter sprint), maximum speed (a 30-meter sprint), and change of direction speed (505 COD test) improve significantly as the jump height increases.

These conclusions were also confirmed by Wisloff et al. (2004) and Cronin and Hansen (2005), who proved a strong relationship between explosive power and linear speed. As a matter of interest, the researchers discovered that increasing a sprint distance positively affects the influence of jumping height on resultant sprint time. On the contrary, further studies like Ates and Cetin (2016), McFarland et al. (2016), and our research show that jumping height has a larger impact on starting and acceleration speed.

Scientists have united opinions regarding the relationship between linear speed and vertical jumping height, representing lower limbs' explosive power.

However, research that assesses the degree of correlation between change of direction speed and explosive power is often contradictory. The main factors include greater coordination and technical complexity of movement. It is not just about acceleration and transition to maximum speed in the straight plane. Still, it is necessary to have a good level of eccentric strength for deceleration and adequate isometric strength to utilize motion and transition to the concentric phase responsible for the subsequent acceleration. The correct mechanics of movement must condition the individual steps. From the point of view of the biomechanics of movement and the use of the ATP-CP system, the whole process seems to be even more demanding (Švantner et al., 2021).

Other factors affecting the research outcomes indisputably include the variability in tests used to measure the change of direction speed and participants' selection concerning their sport and physical abilities.

The outcomes of our research confirm the conclusions of Suarez-Arrones et al. (2020) and Keiner et al. (2019). On the opposite, Salaj and Markovic (2011) and Petersona et al. (2006) revealed only a slight correlation between explosive power and change of direction speed.

CONCLUSION

According to currently available literature and research, both strength and explosive-strength training can influence the level of speed abilities.

Positive effect on the SSC (stretch-shortening cycle), influencing the force-velocity curve, and improving force production in horizontal and vertical planes are the most probable mechanism that may cause such adaptations.

Strength and conditioning training in sports, where sprints and jumps occur, should work on the entire force-velocity curve. Athletes should train in both – the maximum strength and plyometric. However, it is crucial to prepare athletes between extreme points, which are strength-speed, peak power, and speed-strength. The optimally set training program thus works with different loads and different speeds of movement to achieve specific adaptations that will improve sports performance. Good coaches should always consider the game-specific demands when creating training plans.

However, this issue needs further examination, particularly the relationship between explosive power parameters and change of direction speed, which is a more complex movement than linear speed.

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