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KINESIOLOGY

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Success of elite adolescent female runners in adulthood

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Abstract

Every talented sportsperson should be developed by an optimal training load applied in order to achieve her limit performance capacity by training adequate to the given age, with no early specialization. This opinion has been confirmed by our study. Through an analysis of the performance capacity of the best female runners of the Czech Republic in youth categories and in adulthood, we examined the link between the performance capacity of female runners in adolescence and that in adulthood. Elite adolescent female runners achieved a considerably lower limit performance capacity in comparison with elite adult female runners. This is probably caused by accelerated performance development. Moreover, the former achieve the top performance level earlier than usual. While the age of the top performance capacity in the best adult female runners is 26.0 ± 3.8 years for 800m, 25.0 ± 3.1 years for 1,500m and 26.0 ± 3.1 years for 3,000m, elite of U20 female runners reach their top performance capacity at the age of 21.1 ± 3.1 for 800m, 21.0 ± 3,4 for 1,500m and 22,0 ± 3,5 for 3,000m, of U18 females at the age of 19.1 ± 2.7 for 800m, 19.3 ± 3.5 for 1,500m and 20.7 ± 4.1 for 3,000m, and in case of U16 at 16.6 ± 2.8 years for 800m, 18.0 ± 4.2 years for 1,500m and 17.4 ± 3.5 years for 3,000m. Only a small percentage of elite adolescent female runners is able to improve their performance in adulthood. The top performance capacity in the adolescent age does not vouch for the top performance capacity in adulthood nor is it a guarantee for an individual limit performance capacity.

Key words: *Run, adolescents – girls, talent, development of performance capacity, early specialization.*

INTRODUCTION

Although female running disciplines (medium and long tracks) may not be those of the most successful group of disciplines in the Czech athletics, our history is abundant with female runners whom we have every right to be proud of. An indelible mark on our sports history was made by Jarmila Kratochvílová, Ludmila Formanová, Jaroslava Jehličková, Ivana Kleinová (Walterová-Kubešová), Milena Matějkovičová, or Zuzana Moravčíková. With the view of the size of the base of runners, it is necessary to try and develop each talent we discover to ensure that their dispositions develop. This presupposition is even more important in the light of the fact that male and female runners from our region do not have ideal prerequisites for medium and long tracks in comparison with other ethnic groups (Grasgruber & Cacek, 2008). For a talented runner to fully realize his/her dispositions, a many-year cultivation and the fulfilment of certain conditions for sports development are required. The ultimate top sports performance is a result made of talent and training (Bunc, 2004). In cultivating a sports talent, it is imperative to respect general biological regularities, which will enable the given individual to reach the maximum performance at an optimal age (Hofmann & Schneider, 1985; Malina, 1993; Malina, Bouchard & Bar-Or, 2004; Písařík & Liška, 1985). The level of sports performance capacity is influenced, in addition to the chronological age, by the biological age and its implications (Schnabel, Harre & Krug, 2008). The effect of the biological age, mainly in the pubescence period, is critical for motoric performance, functional indicators of the organism and the body build (Dovalil et al., 2005; Malina & Bouchard, 1991; Zmajic, 1996). The biological age does not always correspond to the chronological age.

Women, when maturing, undergo physiological and morphological changes, which may cause a drop in the endurance, strength and speed levels. In addition, women have a relative larger quantity of fat than men; this difference is even more prominent in pubescence. Growing and other pubescent changes are completed for girls between ages from 16 to 17. This is a period when a certain stagnation in performance capacity may emerge (Máček & Radvanský, 2011).

A large number of male and female runners finish their sports careers around the age of 17; in other words, at the age when they are far from reaching their top performance capacity (Bahenský & Semerád, 2016; Enoksen, 2011). Reasons for an early termination of sports career across various types of sports vary: sometimes, performance indicators are to blame, or the reason is training conditions, obligations related to work or study, motivation, social situation, switchover between various types of sports, etc. The age most often mentioned in connection with the top performance capacity is the interval between 24 and 26 years (Dovalil et al., 2005) or 24 and 30 years (Moss, 2004; Vobr, 2009). These data correspond to the curve of development of values VO_2max according to the given age. In running disciplines, the age of top performance capacity tallies with the period of maximum oxygen consumption (Neumann, Pfützner & Berbalk, 2000). This is one of the reasons why to accelerate sports development for (not only) female runners is unsuitable (Dovalil et al., 2005; Kampmiller et al., 2012).

Optimum development of performance capacity may be disrupted by endogenous and exogenous effects; *inter alia*, by the fact that certain youth sports coaches are unable to rise above their craving for immediate success. Importantly, objectives of individual preparation stages must be accomplished (Birrer, Griesemer, & Cataletto, 2002; Dovalil et al., 2005). Sports preparation of the youth is not the same as that of adults. In adolescence, the essential objectives of sports training consist in creating the base for training later in life (Arens, 1983; Bompa, 2000; Perič, 2004). Unless the principles of training for the age concerned are observed, early specialization sets in, and, as a consequence, the growth of performance capacity is accelerated and the final performance potential in adulthood decreases, the performance capacity stagnates around the age of 18, injuries tend to occur more often and there occurs a loss of motivation (Dovalil et al., 2005; Drabik, 1996; Feige, 1973; Helgerud et al., 2007; Moss & Dick, 2004).

OBJECTIVE

The objective of the paper is to determine and evaluate the success of a selected set of the best Czech youth female runners in medium and long track runs in adulthood. Our results may reveal effects of early specialization.

METHODOLOGY

In terms of time, the subject of our research is centred on the period from 1960 to 2018. The examined sets include only those female runners for whom, at the moment of performance of the study, at least four years elapsed from the moment when they had achieved the best performance in the given discipline, or, as the case may be, female runners who reached at least an average age of the top performance capacity determined in each discipline. We evaluated performance capacity separately in the following individual categories: U16 (up to 15 years of age, including), U18 (up to 17 years of age, including) and U20 (up to 19 years of age, including) and in the category of women. The observed disciplines were: medium (800m and 1,500m) and long tracks (3,000m) – master disciplines of youth categories, track without hurdles. Performance data for both outdoor and indoor were used. The criterion for including a subject into the observed set

was the placement in no worse than the 20th position in historical tables of the given discipline and category in the Czech Republic.

Performance data were derived from the website of the Czech Athletic Federation (ČAS) in the section Statistics and from respective annuals of the Czech Athletic Federation, or the Athletic Federation of the Czech Central Committee, Czech Association of Physical Education (ČÚV ČSTV).

The observed set was examined for the age of reaching the top performance capacity – personal best (PB) time. The 3,000m run served as a master category of women until the year 1994, and was replaced in 1995 with the 5,000m run, which, as a result, consolidated the range of disciplines with the male category. The 5,000m track is not a master discipline for youth categories and, as such, it was not included in our study.

Cohen's d was used for determining the substantive significance of the difference between the performance capacity level of the best female runners in the adult category and the youth categories in the individual disciplines in the Czech Republic. This parameter was applied to ascertain the substantive significance of difference in the ages of the top performance capacity of elite women in the adult category and the age when elite female runners reach their limit performance capacity (personal best time) in the individual youth categories in the respective disciplines. The data were processed using Microsoft Excel 2016 and Statistica 12. The average value of processed data and the standard deviation are given.

RESULTS

Figures 1 to 3 present performance data of the twenty best female runners in the Czech Republic in the categories of U16, U18 and U20 and in the category of adults in disciplines 800m, 1,500m and 3,000m. These figures show how the performance level of elite female runners have changed with their age in the individual categories. The greatest increase in performance capacity, save for the 3,000m run, appears between the category of U20 and the category of adults (by 4.17% for 800m, by 4.84% for 1,500m and by 5.39% for 3,000m), and the lowest increase was found to happen between the category of U18 and U20 (by 2.14% for 800m, by 1.95% for 1,500m and by 1.93% for 3,000m. Between categories of U16 and U18 show in increase by 3.45% for 800m, by 4.66% for 1,500m and by 5.79% for 3,000m.

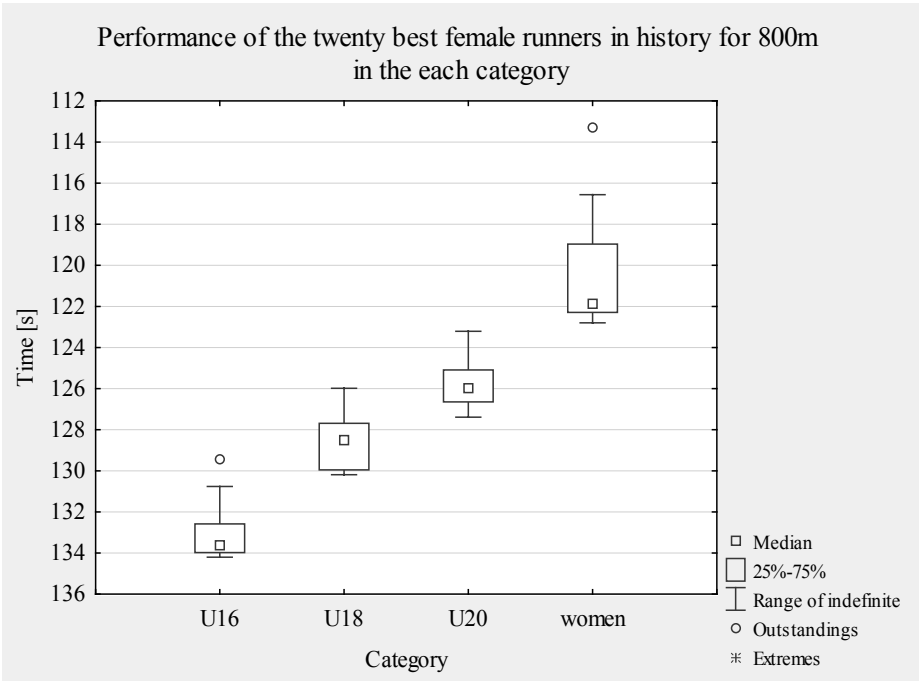

Fig. 1: Performance of the twenty best female runners in history for 800m in the each category

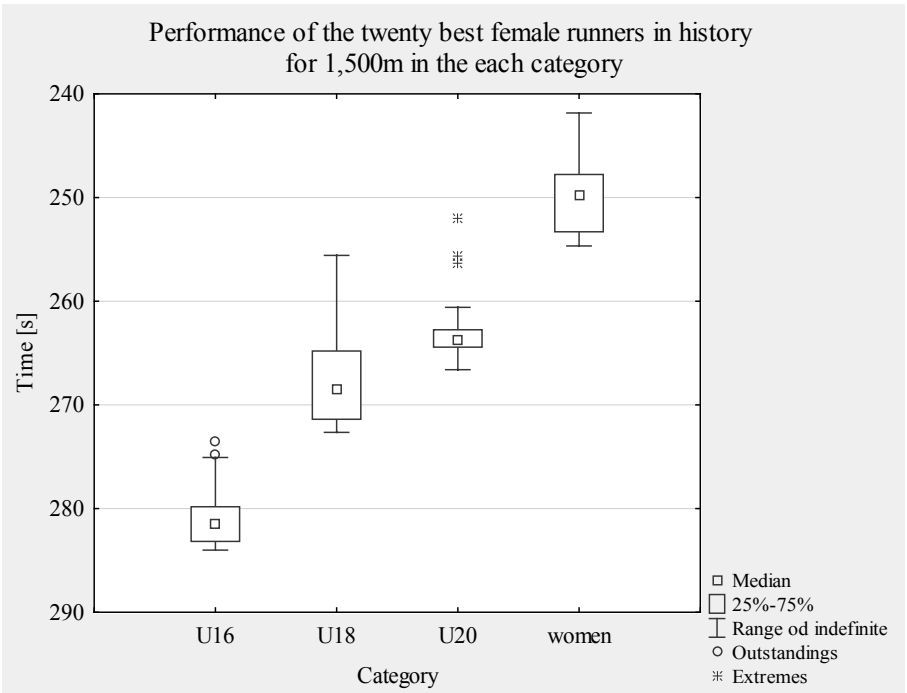

Fig. 2: Performance of the twenty best female runners in history for 1,500m in the each category

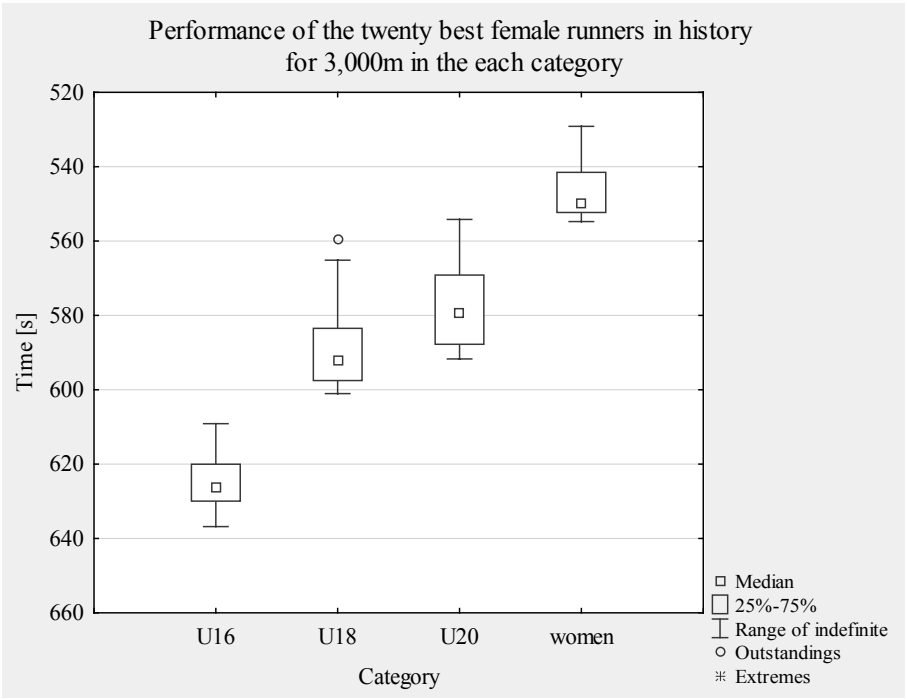

Fig. 3: Performance of the twenty best female runners in history for 3,000m in the each category

Tables 1–3 present the significance of differences in personal best times achieved by elite female runners in the individual categories. The coefficient shows the difference in the limit performance reached by female runners who ranked among the top young sportspeople up to 15, 17 and 19 years of age in comparison with women who are at the absolute top level in the category of adult women. The younger category of elite female runners, the larger difference in the achieved personal record in comparison with performance in the category of adults.

Tab. 1: Substantive significance (Cohen's d) of differences in achieved PB times of the twenty best female runners in the individual categories and the adult top female runners in Czech Republic in 800m run

800m	U16	U18	U20	women
U16		1,39	2,20	3,17
U18	1,39		0,92	2,06
U20	2,20	0,92		1,18
women	3,17	2,06	1,18	

Tab. 2: Substantive significance (Cohen's d) of differences in achieved PB times of the twenty best female runners in the individual categories and the adult top female runners in Czech Republic in 1,500m run

1500m	U16	U18	U20	women
U16		0,88	1,59	2,80
U18	0,88		0,64	1,69
U20	1,59	0,64		1,08
women	2,80	1,69	1,08	

Tab. 3: Substantive significance (Cohen's d) of differences in achieved PB times of the twenty best female runners in the individual categories and the adult top female runners in Czech Republic in 3,000m run

3000m	U16	U18	U20	women
U16		1,20	1,68	2,82
U18	1,20		0,51	1,88
U20	1,68	0,51		1,52
women	2,82	1,88	1,52	

Table 4 presents the average age when the top performance (personal best time) is reached by female runners of the individual sets in the observed disciplines. The younger set, the lower age of the top performance capacity. The largest differences in the ages of the top performance capacity between the youth sets and the adult set were found in the 800m run, and lowest differences were identified in the 1,500m run. Similarly, in the category of U20, the age of the top performance capacity is considerably lower than that the top performance capacity of the best female runners in the category of adults, and, as in the category of U16 and U18, this difference is significant with a large effect, see Tables 5–7.

Tab. 4: Age (in years) when the top performance (PB time) is reached by female runners in the individual categories and disciplines in Czech Republic

	top U16	top U18	top U20	top women
800 m	16,6 ± 2,8	19,1 ± 2,7	21,1 ± 3,1	26,0 ± 3,8
1500 m	18,0 ± 4,2	19,3 ± 3,5	21,0 ± 3,4	25,0 ± 3,1
3000 m	17,4 ± 3,5	20,7 ± 4,1	22,0 ± 3,5	26,0 ± 3,1

Distribution of the age of top performance capacity in the individual sets is illustrated in figures 4–7.

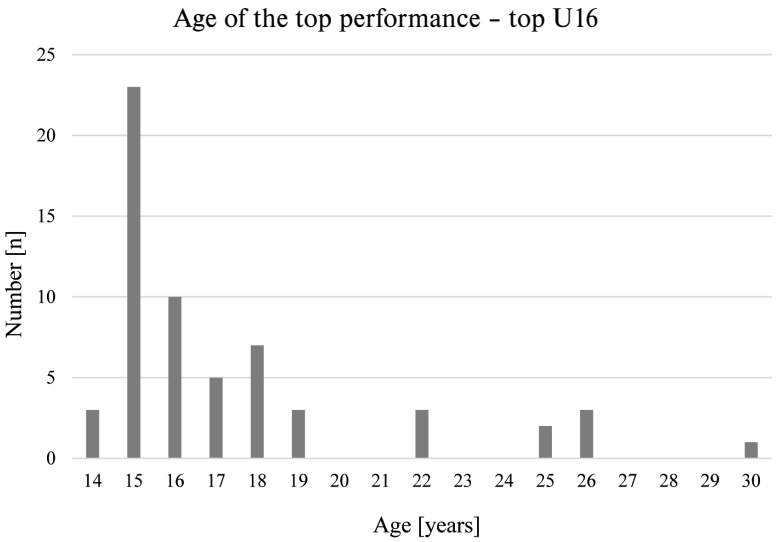

Fig. 4: Age of reaching the personal best time by the twenty best female runners in the category of U16 in 800m, 1,500m and 3,000m runs in Czech Republic

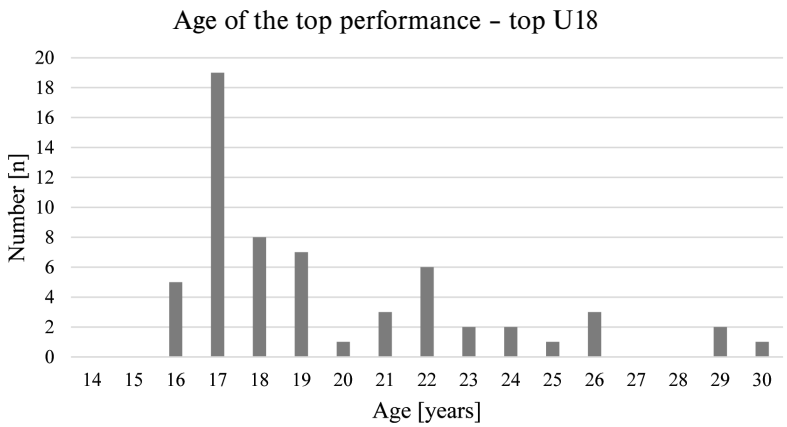

Fig. 5: Age of reaching the personal best time by the twenty best female runners in the category of U18 in 800m, 1,500m and 3,000m runs in Czech Republic

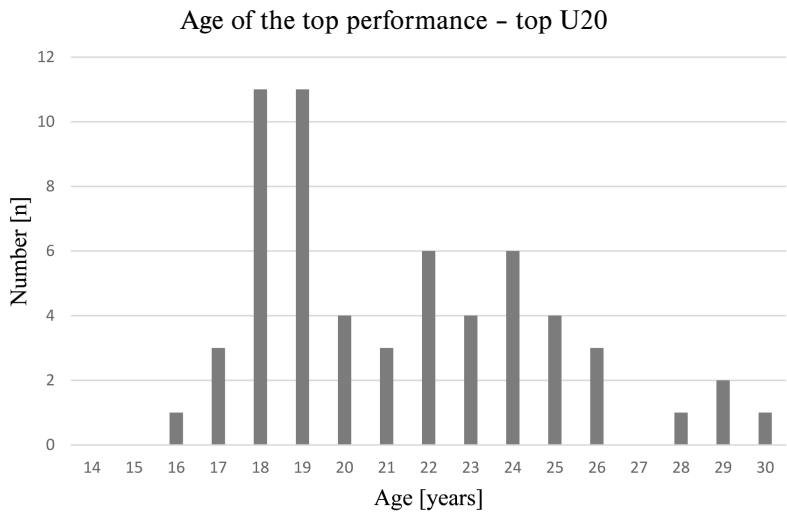

Fig. 6: Age of reaching the personal best time by the twenty best female runners in the category of U20 in 800m, 1,500m and 3,000m runs in Czech Republic

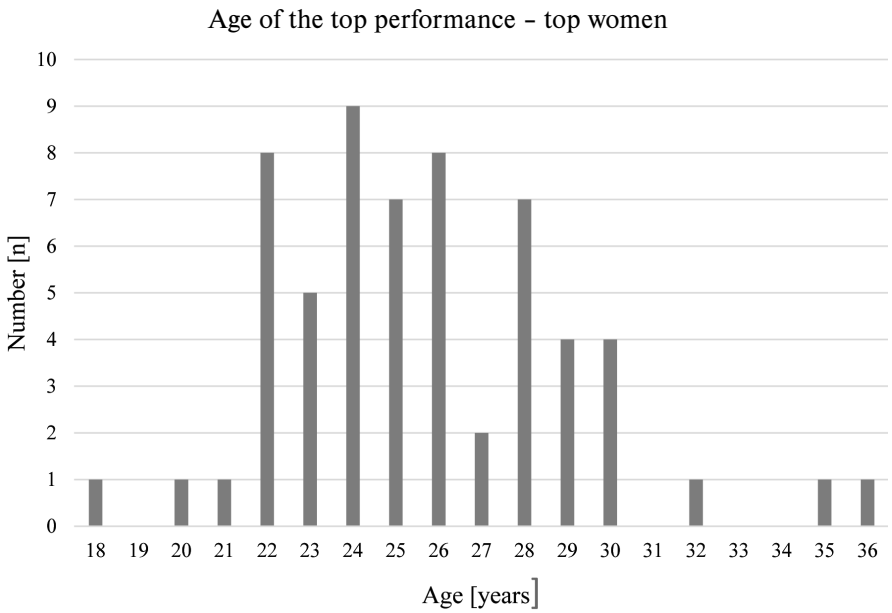

Fig. 7: Age of reaching the personal best time by the twenty best female runners in the category of women in 800m, 1,500m and 3,000m runs in Czech Republic

Figures 4–7 clearly show that of the twenty best female runners in each observed discipline in the category of U16, the personal best time is reached by as many as 85% at the age of 15–19. Only 5% of female runners reached their personal best time at the age of 20–23 and the remaining 10% is made up of those female runners who reached their best performance at the age of 24 or later. Of the historical top twenty female runners in the category of U18, the best performance was achieved by 65% of female runners at the age of 15–19. At the ages from 20 to 23, the best performance was reached by 20% of female runners, and at the age over 24, 15% of female runners noted their best performance. In the of U20 set, 43.33% of female runners achieved their best performance capacity before the age of 19, other 28.33% of female runners reached their best performance at the ages from 20 to 23 years, and for 28.33% of female runners, the best performance came at the age of 24 years and later. In the category of adult women, 1.67% of female runners achieved their best performance capacity before the age of 19, for other 26.67% of female runners, the best performance was accomplished at the ages from 20 to 23, and for 71.67% of female racers, the best performance came at the age of 24 years and later.

Tables 5–7 show the significance of the difference in the current age in reaching the limit performance capacity (personal best time) among the individual sets of female runners. The coefficient shows the difference in the limit performance reached by girls who ranked among the top young sportswomen up to 15, 17 and 19 years of age in comparison with women who are at the absolute top level in the category of adult women.

Tab. 5: Substantive significance (Cohen's d) of differences in age of achievement PB times of the best female runners in the individual categories and the adult top female runners in Czech Republic in 800m

800m	U16	U18	U20	women
U16		2,73	2,96	3,30
U18	2,73		2,93	3,27
U20	2,96	2,93		3,46
women	3,30	3,27	3,46	

Tab. 6: Substantive significance (Cohen's d) of differences in age of achievement PB times of the best female runners in the individual categories and the adult top female runners in Czech Republic 1,500m run

1500m	U16	U18	U20	women
U16		3,87	3,80	3,67
U18	3,87		3,47	3,34
U20	3,80	3,47		3,26
women	3,67	3,34	3,26	

Tab. 7: Substantive significance (Cohen's d) of differences in age of achievement PB times of the best female runners in the individual categories and the adult top female runners in Czech Republic in 3,000m run

3000m	U16	U18	U20	women
U16		3,77	3,48	3,28
U18	3,77		3,79	3,60
U20	3,48	3,79		3,31
women	3,28	3,60	3,31	

Of 60 elite adult female runners, only 22 (8 female runners for 800m, 9 female runners for 1,500m and 5 female runners for 3,000m) appeared among the twenty best racers in the youth categories, see Table 8. However, in the category of U16, only 6.7% of female runners demonstrated the elite performance capacity, in the category of U18, the elite performance capacity was reached by 25% of female runners, and by 36.7% female runners in the category of U20.

Tab. 8: Number of runners whose placement was no worse than the 20th position in historical tables for 800m, 1,500m a 3,000m runs in the adult category and who, at the same time, figure no worse than in the 20th position in youth categories

	U16	U18	U20
800 m	1	4	8
1500 m	1	6	9
3000 m	2	4	5

DISCUSSION

The 1970s and 1980s saw a large portion of the best performance on the track accomplished by the category of women; however, the dominance of this period is not as prevailing as that in male categories (Bahenský, 2017; Bahenský & Semerád, 2014; Bahenský & Semerád, 2016). As regards women, unlike male categories, data in tables change considerably even today, i.e. after the year 2010. The age of the top performance of our set is compliant with values reported in literature for all disciplines (Dovalil et al., 2005; Moss, 2004; Vobr, 2009). In comparison with the age of the top performance capacity of elite adult female runners, the age of the top performance capacity in the set of elite female runners in the individual youth categories is significantly lower; it will be significantly lower the younger the age of the set of female runners. The difference between the age of the top performance capacity in sets of elite adolescent female runners and that of the set of adult elite female runners in long tracks is not noticeably lower when compared with medium tracks in female categories. This is the aspect which distinguishes categories of women from categories of men (Bahenský & Semerád, 2016). When compared with boys of U16 and boys of U18, a significantly larger percentage girls of U16 and U18 reach the maximum performance capacity before the age of 17, and then they improve no longer. This study is not concerned with the determination of causes of the small percentage of elite U16 who improve their performance capacity until they reach adulthood. Needless to say, this condition is also affected by changes caused by puberty. Physiological changes that take place in girls during puberty do not in fact support the maximum performance in medium and long tracks (Máček & Radvanský, 2011). Another cause may be seen in early specialization of female runners, the biological age, social situation and other factors. The data of our study confirm that one of the conditions of the top elite performance capacity is a many-year systematic work, and the physical and emotional maturity of individuals (Bompa, 2000; Dovalil et al., 2005; Perič, 2004). These criteria are not met by adolescent female runners, especially at the category of U16, which is the reason why their performance does not approach the performance capacity of elite adult runners. As a matter of fact, the elite set of U16 is not a ticket to elite female runners in adulthood. In the category of U18, one fourth of elite female runners maintained their position in the Czech top sports base until adulthood. In the category of U20, this was accomplished by less than one half of female runners, excepting the 3,000 run, where the road to the top performance capacity takes more time (Vobr, 2009). Our results considered, it may be stated that the most suitable variant of reaching the top national level in adulthood is to accomplish this level only in adulthood or at the category of U20.

CONCLUSION

Our study suggests that to belong to the top at the adolescent age does not necessarily mean that one will belong to that same group in adulthood, whatever the reasons for performance stagnation or for termination of running career before the end of the biological development may be. There may be female runners who have managed to assert themselves from the category of U16 to adulthood, but these are outright exceptions. Obviously, at the adolescent age is a direct proportion between the age of reaching the elite performance level in the scope of the Czech Republic and the performance level (PB time value) in adulthood (the higher age, the higher level). Results of our study confirm that the top performance capacity of female runners in medium and long tracks at the adolescent age does not guarantee the accomplishment of an individual limit performance capacity. We do not recommend accelerating the performance of female runners by early specialization. Emphasis on performance in adolescent age also does not benefit to performance

level in adult age. However, there is no universal recipe for achieving top performance in adult age, which is applicable to everyone.

Reference list:

Arens, D. (1983). Young runners avoid specialization. *Modern Athlete & Coach Jan, 21* (1), 22–24.

Bahenský, P. (2017). Analýza vývoje výkonnosti v běhu mužů na 800 m v ČR 1945–2016. *Studia Sportiva*, 11(2), 55–67.

Bahenský, P., & Semerád, M. (2014). Analýza vývoje výkonnosti v běhu mužů na 1500 m v ČR 1945–2013. *Studia Kinanthropologica*, 15(3), 131–140.

Bahenský, P., & Semerád, M. (2016). Úroveň výkonnosti elitních adolescentních běžců v dospělém věku. *Studia Kinanthropologica*, 17(3), 185–193.

Birrer, R. B., Griesemer, B. A., & Cataletto, M. B. (2002). *Pediatric sports medicine for primary care.* Philadelphia: Lippincott Williams & Wilkins.

Bompa, T. O. (2000). *Total Training for Young Champions. Proven conditioning programs for athletes ages 6 to 18.* Champaing: Humans Kinetics.

Bunc, V. (2004). Současné pohledy na identifikaci sportovního talentu (na příkladu biatlonu a fotbalu). In: *Sborník mezinárodní konference „Identifikace pohybových talentů"*, Praha: UK FTVS, 19–24.

Dovalil, J., Choutka, M., Svoboda, B., Hošek, V., Perič, T., Potměšil, J., Vránová, J., & Bunc, V. (2005). *Výkon a trénink ve sportu.* Praha: Olympia.

Drabik, J. (1996). *Children and sports training: how your future champions should exercise to be healthy, fit and happy.* Island Pond, Vt.: Stadion Publishing Company, Inc.

Enoksen, E. (2011). Drop-out rate and drop-out reasons among promising Norwegian track and field athletes: A 25 year study. *Scandinavian Sport Studies Forum*. 2, 19–43.

Feige, K. (1973). *Vergleichende Studien zur Leistungsentwicklung von Spitzensportlern. Schorndorf*: Karl Hofmann.

Grasgruber, P., & Cacek, J. (2008). *Sportovní geny.* Brno: Computer Press.

Helgerud, J., Hoydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., … & Hoff, J. (2007). Aerobic High-Intensity Intervals Improve VO_2max More Than Moderate Training. *Medicine and science in sports and exercise*, *39*(4), 665.

Hofmann, S., & Schneider, G. (1985). *Eignungsbeurteilung und Auswahl im Nachwuchsleistungssport*. Theorie Praxis Körperkultur, 34, 44–52.

Kampmiller, T., Vanderka, M., Laczo, E., & Peráček, P. (2012). *Teória športu a didaktika športového tréningu.* Bratislava: ICM Agency.

Máček, M., & Radvanský, J. (2011). *Fyziologie a klinické aspekty pohybové aktivity.* Praha: Galén.

Malina, R. M. (1993). Youth Sports: readiness, selection and trainability. In: Duquet, W, Day, J. A. P. (eds.): *Kinanthropometry IV,* E & FN Spon, London, 285–310.

Malina, R., Bouchard, C., & Bar-Or, O. (2004). *Growth maturation and physical activity.* 2nd ed. Champaign IL: Human Kinetics.

Moss, D. (2004). *Tricks of the Trade for Middle Distance, Distance & Cross-country Running.* Physical Education Digest-Book Division.

Moss, D., & Dick, R. W. (2004). Avoid Early Specialization for Runners. *Tricks of the Trade for Middle Distance, Distance & Cross-Country Running. 6* (1), 4–9.

Neumann, G., Pfützner, A., & Hottenrott, K. (2005). *Trénink pod kontrolou: Metody, kontrola a vyhodnocení vytrvalostního tréninku*. Grada Publishing as.

Perič, T. (2004). *Sportovní příprava dětí.* Praha: Grada.

Písařík, M., & Liška, J. (1985). *Běhy na střední a dlouhé tratě – Základní programový materiál pro vrcholový sport, I. část.* Praha: ÚV ČSTV – vědeckometodické oddělení.

Schnabel, G., Harre, H. D., & Krug, J. (2008). *Trainingslehre – Trainingswissenschaft*. Aachen: Meyer & Meyer.

Vobr, R. (2009). *Vývoj věku vrcholné výkonnosti v atletice, plavání, běžeckém lyžování, ledním hokeji a fotbalu v letech 1970–2007.* České Budějovice: JU v Českých Budějovicích.

Zmajic, H. (1996). Are the top tennis players born in January? *Coaching and Sport Science Review,* 4 (9), 3–4.

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Complex approach to monitoring athletes in the scope of overtraining prevention

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Abstract

The article introduces the issue of monitoring intensively training athletes who wish to avoid overtraining and want their training to be as effective as possible. The current definitions of overreaching and overtraining are addressed, together with the summary of causes, development and prevention of such conditions. The focus of the article is on the overview of relevant diagnostic methods including the latest non-invasive biochemical methods. The complex approach to the selection of psychological and physiological methods to establish the degree of the internal load of athletes is emphasised. A three--degree concept of athlete monitoring according to the demandingness and periodicity of diagnostic methods usage is presented.

Key words: *Athletes, Monitoring, Fatigue, Overreaching, Overtraining, Overtraining syndrome, Heart Rate Variability, Profile of Mood States*

INTRODUCTION

Overreaching is a permanent risk for athletes who train and compete. The negative impacts of the overreaching lie both in performance decline or stagnation and in health problems connected with more frequent injuries and overtraining syndrome. Meta-analytic study by Meeusen et al. (2013) collected important data on overtraining prevalence at 7–37% of athletes, mostly at endurance sports and disciplines.

Athletes and trainers should know and use instruments for overreaching detection in order to individually optimise the training process. The problem lies in the difficulty of establishing the current extent of the athlete training load which should not be exceeded.

DEFINITION OF THE OVERREACHING AND OVERTRAINING

The definitions of these conditions are not unified. According to the experts (Meeusen et al., 2013; Myrick, 2015; Soligard et al., 2016; Gazzano & Gabbett, 2017) the relevant conditions are defined as follows:

Load is a combination of both sport and out of sport stimuli.

External load is an objectively measurable load (performance, work, distance, time) which is performed by the athlete in and outside the sport; it is and indicator of the working capacity of the athlete.

Internal load is an individual reaction of an athlete to the external load and other biological factors. It can be measured and expressed (e.g. with a heart rate, lactate concentration, subjective perception of the load); it stimulates training adaptation.

Overloading (OL) means a higher load, of a higher intensity, necessary for a sufficient physiological stimulation leading to a positive adaptation to the load

Acute fatigue is an imminent form of fatigue which develops already during the load and with enough rest lasts up to a few days.

Overreaching (OR) – temporary (e.g. 2 weeks) signs of a complex fatigue from overreaching at a certain stage of the training (e.g. fatigue, decreased performance, bad mood). It is the initial stage of overtraining; the accumulation of this temporary fatigue leads to overtraining.

Functional overreaching, short-term (OR, FOR) is an accumulated training and out of training load leading to a short-term decline of the working capacity without any signs of physical or mental disorders. It requires a recovery lasting a few days or weeks.

Non-functional overreaching, extreme (OR, NFOR) is an accumulated training and out of training load with an accentuated decline in working capacity and with signs of physical (hormonal) and mental (feeling tired) disorders. It requires a recovery lasting a few days or weeks.
The NFOR seems to create the border between the optimal load and negative overtraining.

Overtraining (OT) – a long term process with repeated overreaching of the athlete, leading to the overtraining syndrome.

Overtraining syndrome (OTS) is a collection of pathophysiological and clinical problems which occur because of a lack of rest after extreme overreaching. These problems persist for several months. Burnout and staleness are used as synonyms.

The literature also uses the term *Unexplained underperformance syndrome (UPS)*, which was introduced by British scientists dealing with fatigue diagnostics at the end of the last century. (Budgett, Newsholme & Lehmann, 2000). Even though this term encompasses a wider definition and seems to be more suitable for the sport environment, it has not become widespread worldwide.

We tend to use the differentiation between and terminology for the individual stages of training loads and the development of overtraining as listed in Table 1. There are no clear boundaries between the stages.

Tab. 1: An overview of the extent of load and fatigue types (amended and completed according to (Meeusen et al., 2012; Myrick, 2015; Soligard et al., 2016; Gazzano & Gabbett 2017)

Training	under-training	training	optimal training	overtraining	
Internal loading	under-loading	Overloading	Functional overreaching	Non-functional overreaching	Overtraining syndrome
Work capacity	decreasing	increasing	short-time decreasing	decreasing	decreasing
Fatigue	no fatigue	acute (short-time)	sub-chronic	chronic (long-time)	
Period of recovery	–	days	days – weeks	weeks – months	more months
Health state	–	good		malfunction maladaptation	serious disease

CAUSES, PREVENTION AND DEVELOPMENT OF OVERTRAINING

The cause of overtraining is repeated non-functional overreaching without a sufficient recovery. It is a state of a long-term inadequate internal load of the athlete and his or her insufficient adaptation to the load. This situation leads to the decline in performance (2–3 months) without an apparent reason which might explain it. The inadequate performance is accompanied by several symptoms. These symptoms are diverse and highly individual which means that different athletes may show different symptoms.

Both the inadequate training and other stressful factors such as work / school, home environment, family, team mates, pressure of competition, new sponsors, etc. are the causes of overtraining. It is thus the sum of all the stresses (including training) that an athlete must cope with (Halson &Jeukendrup, 2004).

Causes and prevention of overtraining are illustrated in Fig. 1

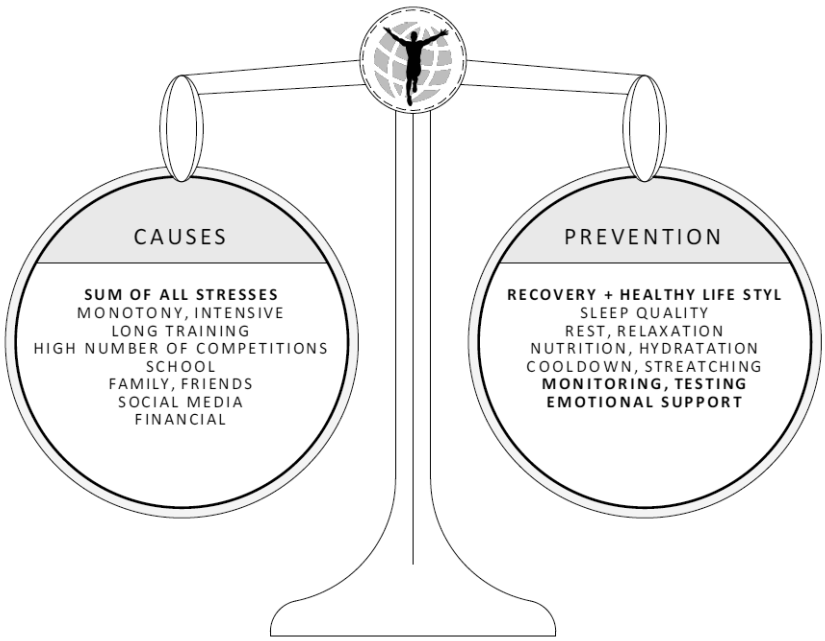

Fig. 1: Causes and prevention of overtraining (amended according to Jeukendrup, 2015).

The prevention of overtraining lies in the elimination of the causes, i.e. reducing the occurrence of non-functional overtraining. The training process needs to have an adequate loading and a sufficient recovery of the athlete, taking into consideration his or her current fatigue and load resistivity.

The prevention of overtraining requires the knowledge and ability to correctly use the tools for monitoring the current state of athletes (fatigue and load resistivity) – more information to follow. The basic tools for athletes and their trainers are training plans, training diaries and regular testing of athletes.

Development of overtraining is simplified in the following diagram (Fig. 2).

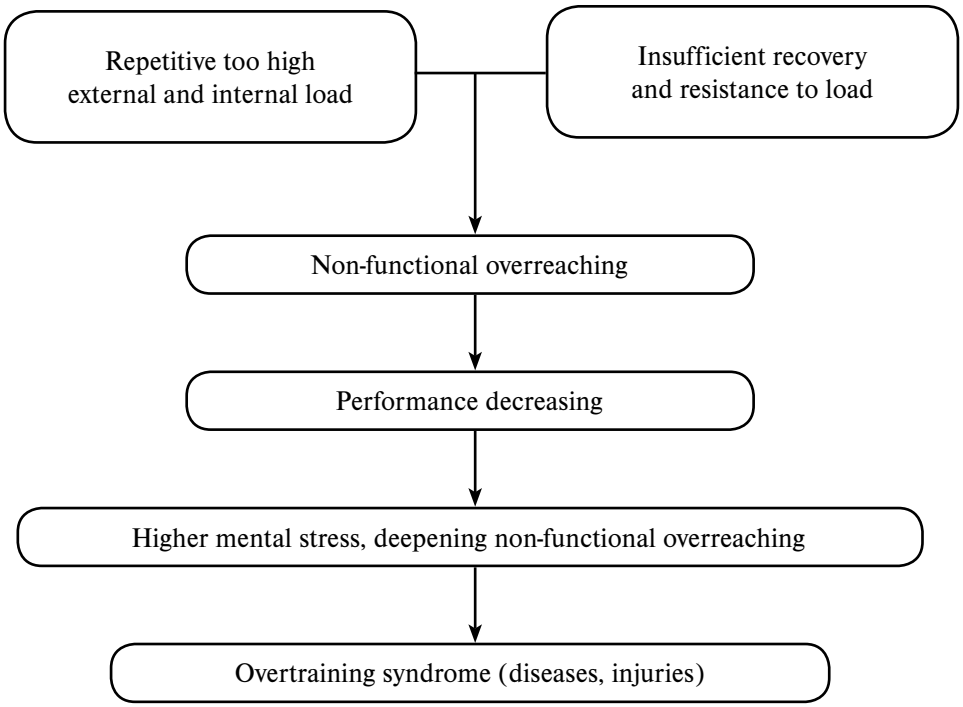

Fig. 2: Development of overtraining (based on Meuessen et al., 2012 and Gazzano & Gabbett, 2017)

The most common symptoms of overtraining syndrome you can see in Tab 2. Parasympathetic Alternations is more common in aerobic sports and Sympathetic Alternations is more common in anaerobic sports. (Kreher & Schwartz, 2012).

Tab. 2: Symptoms of overtraining syndrome (Kreher & Schwartz, 2012).

Parasympathetic Alterations	**Sympathetic Alternations**	**Other**
Fatigue	Insomnia	Anorexia
Depression	Irritability	Weight loss
Bradycardia	Agitation	Lack of mental concentration
Loss of motivation	Tachycardia	Heavy, sore, stiff muscles
	Hypertension	Anxiety
	Restlessness	Awakening unrefreshed

OVERREACHING AND OVERTRAINING DIAGNOSTICS

Diagnostic methods for monitoring fatigue and internal load of an athlete can be divided for example into these three groups: dynamometric and ergometric, psychological and physiological (Tab. 3).

Tab. 3: Overview of diagnostic methods to detect athlete overreaching (Holzer, 2012; Meeusen et al., 2013; Thorpe, Atkinson, Drust & Gregson, 2017, modified and amended)

Groups of diagnostic methods		Specific diagnostic methods and tools
Dynamometric and ergometric		Dynamometry, ergometry – field and laboratory measuring and analysis of athlete performance
Psychological		Reviews and questionnaires for detection and evaluation of perceived load and exertion, and of mental state and fatigue
Physiological	Neuro-circulatory	Evaluation of neural autonomic regulation by heart rate measuring and analysis
	Cardiological	Evaluation of cardiac functions by electrocardiograph and blood pressure analysis
	Anthropologic	Evaluation of body composition (e.g. by electro-impedance analysis, DEXA, plethysmography)
	Spiroergometric	Evaluation of respiratory response to load during spiroergometry
	Biochemical	Evaluation of energetic and mineral metabolism as well as markers of tissue damage by analysis of body fluids (urine, blood, saline etc.)
	Immunological	Evaluation of immune functions by blood analysis
	Haematological	Evaluation of blood cells state and blood functions by microscopic and biochemical analyses

Dynamometry and ergometry

These methods provide information about the current working capacity of an athlete. A significant decrease in the capacity is a symptom of fatigue. The methods can be simple and affordable, e.g. manual dynamometry, jump and bicycle ergometry. Strength, performance, work, height of jump, etc. are among measured and evaluated indicators. These tests are not able to distinguish between acute and chronic fatigue. Chronic fatigue might be considered at decreased working capacity even after a long-term recovery. Then there might a problem of distinguishing it from the symptoms of detraining, though. Therefore, it is essential to employ psychological and physiological indicators of chronic fatigue.

Psychological methods

The simplest and fastest is a dialogue with the closest family members and the trainer. There is a risk, though, that an unprofessional approach might cause a lot of harm, e.g. huge stress and frustration due to too ambitious parents. That is the reason why standardised methods, mostly questionnaires, developed by experts – psychologists should be used.

Psychological questionnaires for detection of subjective experience and feelings of athletes – cramps, pain, activity, fatigue, stress, discomfort, moods, anxiety, fear, confusion, sleep quality, concentration, nervousness, social conflicts, etc. Questionnaires detecting the psychological state of athletes are not always able to satisfactorily distinguish whether the causes lie in sport or outside

it (Meussen et al., 2013). When formulating questions, it is essential to use clear and easy to understand terms. To express the extent of the perception five- or six-degree scales are used.

- *Rating of perceived exertion* – (RPE) has been used as an indicator of internal load for a long time. A ten-degree scale is used for athletes (Foster, 1998). According to Gazzano and Gabbett (2017) the total amount of internal load is expressed as a product of RPE and time. Then a daily or weekly amount of this load, index of short-term load (amount of load in a week) and chronic load (a four-week average) and an index of the load monotonicity (the standard error of measurement of weekly load) can be calculated.
- *Training Distress Scale* (TDS; Grove et al., 2014) is a questionnaire with 19 items to detect exertion in the last 24 hours.
- *Profile of Mood States* (POMS; McNair et al., 1971; Terry, Lane, Lane & Keohane 1999) is a standardised and internationally acknowledged questionnaire. It is used to profile emotion and mood states. It is popular in sport psychology as it is economical, fast and easy to administer. It is considered to be one of the most reliable tools for overtraining detection (Meeusen et al. 2013). Over-trained athletes score significant higher in negative moods compared to positive moods.
- *Recovery Stress Questionnaire for Athletes* (RESTQ-Sport; Kellmann & Kallus, 2001) a wide-spectrum questionnaire for athletes to detect and evaluate the state of the athlete – general stress, emotional stress, social stress, conflicts/pressure, lack of energy, physical complaints with a six-degree scale.
- *Performance Failure Appraisal Inventory* (PFAI; Conroy, Willow & Metzler, 2002) is a questionnaire to detect athlete's fear of failure which belongs to causes of overtraining. High values relate to a state of burnout (Gustafsson, Sagar, Stenlink, 2017).
- *Daily Analyses of Life-Demands* (DALDA; Rushall, 1990) assesses the response of an athlete to training. The questionnaire consists of two parts and contains 34 items and athletes choose from three degrees for each item. The questionnaire should be completed daily and is thus not very practical.
- *Pitsburg sleeping quality index* (PSQI; Buysse, Reynolds, Monhk, Berman & Kupfer, 1989) – this questionnaire evaluates the sleep quality, it is a simple screening method consisting of 9 self assessment items.
- *Athlete Sleeping Screening Questionnaire* (ASSQ; Samuels, James, Lawson & Meeuwisse, 2016) is a newer tool for sleep quality evaluation for athletes.

Good applicability of TDS and POMS questionnaires in our conditions has been, for instance, evaluated by Burešová, Demlová & Bartošová, (2016).

Physiological methods

Neuro-circulatory methods lie in the evaluation of neural autonomic system (ANS) by heart rate measuring and analysis at rest and during a stress test. Neural autonomic system regulation disorder appears during sub-chronic and chronic pathological fatigue. During initial phases of a long-term fatigue from overreaching it is first the sympathetic and then the parasympathetic system having the biggest influence.

- *Heart rate evaluation* (amended according to Máček et al, 2011). Right before, during and after a physical exercise the activity of the sympathetic neural system increases, together with HR. After the exercise HR decreases. The steepness of the HR decline depends on the intensity and amount of the preceding exercise. With greater fatigue and after substantial physical exercise HR decreases at a slower rate. If the fatigue persists until the following morning, the morning resting HR may be slightly higher. With persisting fatigue, a decline in the physical fitness indexes can be observed at step tests. Unusually higher HR at a certain load might also signal

presence of an infectious or another inflammatory disease. On the contrary, unusually lower HR at rest or at a load may by a case of an ANS disorder with a prevalence of parasympathicotonia or a heart disease. Gradually (over a few months) developing bradycardia should be a consequence of an expected adaptation to the endurance load.
Some studies dispute the HR_{rest} monitoring as a suitable marker for overreaching diagnostics (Bosquet, Merari, Arvisais & Aubert, 2008), but despite this there are still reports on morning rest heart rate (HR_{rest}) being a usable indicator of a current state of ANS with athletes (de Araújo et al., 2017). It seems HR_{rest} should not be condemned, even though it is mostly the HRV analysis being often used for these purposes (Bisschoff, Coetzee & Esco, 2016).

- *Heart rate variability analysis (HRV)*: Already introduced "classical" indicators of HRV, such as spectral performance and its density in the established frequency ranges, are a part of athlete monitoring in the scope of overreaching prevention (Makivić, Djordjević, Wilis, 2013; Novotný, 2013; Botek, Krejčí & McKune, 2018). Athletes who are well-rested and well-adapted to the physical load, such as marathon runners, reach a high spectral performance in the HF range, which is an indicator of a higher parasympathetic activity at rest and after a load. Stejskal et al. (2002) has created a new method of evaluating HRV with associated indicators of spectral analysis from three 5-minute intervals at ortho-clinostatic test (lying – standing – lying) – Overall Score (OS), Vagus Activity Index (VA), Sympathicus – Vagus Balance Index (SVB), Functional Age (FA). Botek et al. (2018) has added that based on his studies the first interval of lying could be shortened to 1 minute as it does not negatively influence the quality of results. Same author (Botek et al., 2018) also recommends time-domain parameters: Normal to Normal intervals (NN), Standard Deviation of all intervals (SDNN), Standard Deviation of the Average of NN intervals (SDANN), square Root of the Mean of the Squares of the Successive Differences between adjacent NN intervals (rMSSD).

Biochemical, immunological and haematological methods

In blood samples which are analysed, it is possible to detect substances which are markers of pathophysiological changes due to the load to athletes' bodies. (Halson, Lancaster & Jeukendrup, 2003; Wyatt, Donaldson & Brown, 2013; Lee et al., 2017), e.g.:

- Suppression or insufficiency of energetic catabolism (↓ maximal lactacidemia)
- Endocrinal suppression or insufficiency of adrenals at rest or after a load (↓ stress hormones – Adrenalin and Noradrenalin, Testosterone, Cortisol)
- Immunosuppression (↓ Leukocytes, ↓ immunoglobulins IgG, IgA, IgM, Interferons, C-reactive protein, Interleukin 6)
- Erythrocyte damage (↓ Ery, Hb, Htc, ↓ Fe)
- Proteogenesis disorders (↓ essential amino acid Glutamine and its ratio to Glutamate)
- Muscle impairment, rhabdomyolysis (Myoglobin, Creatine kinase, Lactate-dehydrogenase)

Non-invasive biochemical methods: Methods which do not require unpleasant punctum to the athlete's body in order to get a blood sample are gradually developing (Lindsay & Costello, 2017). These are analyses of other body fluids – saliva, urine, expiratory condensate or sweat. Correlations between plasma and saliva concentrations of Testosterone and Cortisol (Tanner, Nielsen, Allgrove, 2014) and between concentrations of lactate in blood and in expiratory condensate (Marek, Volke, Hawener, Mückenhoff & Marek, 2010) have been discovered. The dynamics of the lactate concentrations in saliva probably corresponds the changes of the lactate in blood. It is possible to establish the lactate threshold by saliva analysis (Bocanegra, Diaz, Teixeira, Soares & Espindola, 2012).

Complex approach to overtraining diagnostics

The attributes of a *complex approach* are as follows:

- A rational selection and combination of diagnostic methods (tab. 3) for evaluation of external and internal load of an athlete.
- When evaluating the external load all stress factors should possibly be detected – from the domain of sports (realised training, competition performance, trainer's activity) and from the out-of-sport domain (school or work load, parents, other social challenges) .
- When evaluating the internal load, sufficiently sensitive and if possible non-invasive psychological and physiological methods for monitoring should be used.
- Periodicity of monitoring.

Three-degree monitoring and overtraining diagnostics concept

Diagnostic methods can be categorised into three degrees according to their demands on athletes, demands on results processing and the speed of their applicability and according to instrument and financial resources availability:

- Degree I – simple unexacting methods which do not inconvenience athletes and provide applicable results for training regulation instantly: RPE (after training), morning rest HR. Periodicity: once a day.
- Degree II – more complex methods which inconvenience athletes only to a small extent and provide results quickly: short psychological questionnaires (e.g. POMS, TDS), HRV analysis during a tilt test. Periodicity: once to three times a week according to the method and demand.
- Degree III – more exacting methods which put an adequate strain on athletes and provide results usually within three days: Longer psychological questionnaires (TESTQ-Sport, biochemical and immunological methods of saliva analysis). Periodicity: one a month or according to the demand.

If the degree I result provides a suspicion that there might be overreaching or overloading, a degree II test should be conducted. If positive results are obtained, a degree III method should be used and demanding training should be avoided. When the suspicion is confirmed, the athlete should be referred to a sport medicine physician and all training should be suspended until then.

We will verify the validity and reliability of the proposed diagnostic model in upcoming projects.

CONCLUSION

A satisfactory performance of an athlete is a result of an optimal training with regulated load without a counterproductive impact of non-functional overreaching and overtraining. The internal load of an athlete depends on the external load and other stress factors. Its rate should be adequate to the degree of the athlete adaptation to the load.

This requires a systematic monitoring of fatigue indicators, or physiological disorders in the body of athletes respectively.

For this purpose, we recommend a complex monitoring with a combination of psychological and physiological methods, which are, for practical reasons, categorised into three degrees, according to their demandingness and periodicity. The development of this concept at the Faculty of Sports Studies of the Masaryk University is a part of the project MUNI/51/05/2018.

References

de Araújo, J. A., Queiroz, M. G., Novelli, F. I., de Jesus Lima de Sousa, L. C., Tricot, G. K., Lourenço Dias, A. R., …Lucieli Teresa Cambri, L. T. (2017). Aerobic fitness influences rest and heart rate recovery on young men regardless of body mass index. *Sport Sciences for Health, 13*(1), 217–223.

Bisschoff, Ch. A., Coetzee, B. & Esco, M. R. (2016). Relationship between Autonomic Markers of Heart Rate and Subjective Indicators of Recovery Status in Male, Elite Badminton Players. *Journal of Sports Science and Medicine, 15*(4), 658–669.

Bocanegra, O. L., Diaz, M. M., Teixeira, R. R., Soares, S. S. & Espindola, F. S. (2012). Determination of the lactate threshold by means of salivary biomakers: chromogranin A as novel marker of exercise intensity. *Eur J Appl Physiol*, 112, 3195–3203.

Bosquet, L., Merkari, S., Arvisais, D. & Aubert, A. E. (2008). Is heart rate a convenient tool to monitor over-reaching? A systematic review of the literature. *British Journal of Sports Medicine,* 42, 709–714.

Botek, M., Krejčí, J. & McKune, A. J. (2018). *Variabilita srdeční frekvence v tréninkovém procesu: historie, současnost a perspektiva*. Olomouc: Univerzita Palackého v Olomouci.

Budgett R., Newsholme E., Lehmann M., et al. (2000). Redefining the overtraining syndrome as the unexplained underperformance syndrome. *British Journal of Sports Medicine,* 34: 67–68.

Burešová, I., Demlová, T. & Bartošová, K. (2016). Coping strategies prefered byx adolescents when managing stress in sport – pilot study. The European Proceedings of Social and Behavioural Sciences. Future Academy: 240–254. (http://dx.doi.org/10.15405/epsbs.2016.11.25).

Buysse, D. J., Reynolds, C. F., Monhk, T. H., Berman, S. R. & Kupfer, D. J. (1989). The Pittsburgh Sleeping Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res., 28*(2), 19–213.

Conroy, D. E., Willow, J. P. & Metzler, J. N. (2002). Multidimensional fear of failure measurement the performance failure appraisal inventory. *J Appl Psychol*, 14, 76–90.

Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. *Med Sci Sports Exerc, 30*(7), 1164–1168.

Gazzano, F. & Gabbett T. (2017). A practical guide to workload management and injury prevention in college and high school sports. *NSCA Coach, 4* (4), 30–35.

Grove, J. R., Main, L. C., Partridge, K., Bishop, D., Russel, S., Shepherdson, A., & Ferguson, L. (2014). Training distress and performance readiness: Laboratory and field validation of a brief self-report measure. *Scandinavian Journal of Medicine and Sicience in Sports*, 24, 483–490.

Gustafsson, H., Sagar, S. S. & Stenlink, A. (2017). Fear of failure, psychological stress, and burnout among adolescent athletes competing in high level sport. *Scand J Med Sports,* 27, 2091–2102.

Halson, S. L. & Jeukendrup, A. E. (2004). Does overtraining exist? An analysis of overreaching and overtraining research. *SportsMed*, 34(4), 967–981.

Halson, S. L., Lancaster, G. I., Jeukendrup, A. E. & Gleeson, M. (2003). Immunological responses to overreaching in cyclists. *Medicine and Science in Sports and Exercise*, 35(5), 854–861.

Holzer, K. (2012). The tired athlete. In: Brukner P. & Khan K. (eds.). *Clinical Sports Medicine*. Sydney: The Mc Graw-Hill Co: 1118–1131.

Jeukendrup, A. (2015). *Causes and prevention of overtraining.* Retrieved from http://www.mysportscience.com/single-post/2015/03/08/Causes-and-prevention-of-overtraining.

Kellman, M. & Kallus, K. W. (2001). The Recovery – Stress Questionnaire for Athletes: User manual. Champaign, IL: Human Kinetics.

Kreher, J. B. & Schwartz, J. B. (2012). Overtraining Syndrome: A Practical Guide. *Sports Health, 4* (2), 128–138.

Lee, E. C., Fragala, M. S., Kavouras, S. A., Queen, R. M., Pryor, J. L. & Casa, D. J. (2017). Biomarkers in sports and exercise: Tracking heatlh, performance, and recovery in athletes. *Journal of Strength and Conditioning Research, 31*(10), 2920–2937.

Lindsay, A. & Costello, J. T. (2017). Realising the potencial of urine and saliva as diagnostic tools in sport and exercise medicine. *Sports Med*, 47, 11–31.

Máček, M., Radvanský, J., Brůnová, B., Daďová, K., Fajstavr, J., Kolář, P., … Zeman, V. (2011). *Fyziologie a klinické aspekty pohybové aktivity*. Praha: Galén.

Main, L. & Grove, J. R. (2009). A multi-component assessment model for monitoring training distress among athletes. *Eur J Sport Sci* 2009; 9:195–202.

Makivić, B., Djordjević, M. & Willis, M. S. (2013). Heart rate variability (HRV) as a tool for diagnostic and monitoring performance in sport and physical activities. *J Exerc Physiology, 16*(3), 103–131.

Marek, E. M., Volke, J., Hawener, I., Mückenhoff, K. & Marek, W. (2010). Measurements of lactate in exhalted breath condensate at rest and after maximal exercise in young and healthy subjects. *J Breath Res*, 4, 017105 (8 pp).

Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., … Urhausen, A. (2013). Prevention, diagnosis and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science (ECSS) and the American College of Sports Medicine (ACSM). *European Journal of Sport Science, 13*(1), 1–24.

Morgan, W., Brown, D., Raglin, J., O'Connor, P. & Ellickson, K. (1987). Psychological monitoring of overtraining and staleness. *Br J Sports Med*, 21, 107–114.

Myrick, K. M. (2015). Overtraining and Overreaching. Syndrome in Athletes. *The Journal for Nurse Practitioners, 11* (10), 1018–1022.

Novotný, J. (2013). Biologické ukazatele odezvy a adaptace na zátěž, únavy a regenerace sil. In: Kolektiv autorů. *Regenerace a výživa ve sportu*. Brno: Fakulta sportovních studií MU.

Rushall, B. S. (1990). A tool for measuring stress tolerance in elite athletes. *Applied Sport Psychology, 2,* 51–66.

Samuels, C. H., James, L., Lawson, D. & Meeuwisse, W. (2015). The Athlete Sleeping Screening Questionnaire: a new toll for assessing and managing sleep in elite athletes. *Br J Sports Med*, 50, 418–422.

Soligard, T., Schwellnus, M., Alonso, J. M., Bahr, R., Clarsen, B., Dijkstra, H. P., … Engebretsen, L. (2016). How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *British Journal of Sports and Medicine, 50*(17), 1030–1041.

Stejskal, P., Šlachta, R., Elfmark, M., Salinger, J. & Gaul-Aláčová, P. (2002). Spectral analysis of heart rate variability: New evaluation method. *Acta Universitatis Palackianae Olomucencis Gymnica, 32* (2), 13–18.

Tanner, A. V., Nielsen, B. V. & Allgrove J. (2014). Salivary and plasma cortisol and testosterone responses to interval and tempo runs and a bodyweight-only circuit session in endurance-trained men. *Journal of Sports Sciences, 32*(7), 680–689.

Terry, P. C., Lane, A. M., Lane, H. J., & Keohane, L. (1999). Development and validation of a mood measure for adolescents. *Journal of Sports Sciences*, 17, 861–872.

Thorpe, R. T., Atkinson, G., Drust, B. & Gregson W. (2017). Monitoring fatigue status in elite team-sport athletes: Implications for practise. *International Journal of Sports Physiology and Performance, 12*(2), 27–35.

Wyatt F. B., Donaldson A. & Brown E. (2013). The Overtraining Syndrome: A Meta-Analytic Review. *Journal of Exercise Physiologyonline, 16*(2), 12–23.

Thermal response of hands to computer work: comparison of three assessment procedures

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Abstract

Introduction: Unlike other imaging modalities thermography is absolutely non-invasive and suitable to assess functional changes. However, in some fields, a methodology for its use has not even been set yet. This work compares three different methods to study the dynamics of skin temperature changes in hands during computer work. Methods: A total of 306 measurements of 20 office employees and 6 non-office employees was performed with a thermographic camera during a work shift. The thermograms were subsequently evaluated and three methodologies - regions of interest, two of them newly proposed H2 and H5 – were compared mathematically. In addition, two other methods were compared without mathematical confirmation. Results: The results shown the same tendencies of thermal changes comparing our methodologies with the methodology used earlier in more than 80% (88 % in case of the first method, named H2 method and 85 % in case of the second one, named H5). However, in comparison to an older procedure, our procedures have shown higher sensitivity to temperature changes in more than 60% of cases (61 % in case of H2 and 68 % in case of H5). We measured a variation range difference of 1.6 °C, and, with the H5 method, the whole 2.1 °C compared to the method used earlier. Conclusion: This work has determined a new procedure for measuring of dynamics of hands temperature changes, which is not only easier and faster to perform and evaluate, but it is also more capable of detecting temperature changes on hands.

Keywords: *hands, thermography methods, computer work*

INTRODUCTION

In various economic sectors, employees have been using a personal computer as a primary work tool (usually equipped with a keyboard and computer mouse) for approximately thirty years. Many of them experienced some musculoskeletal problems such as forearms tendinitis, carpal tunnel syndrome etc. These problems cause an increase in the number of days spent away from work and the related economic loss. In 2016, they made up for the whole 19.8 % of all causes of sick leaves among employees in the Czech Republic. Therefore, they were the second most frequent cause of sick leaves right after airway respiratory tract diseases. On average, the period of this leave stretched to 65.7 days (Ústav zdravotnických informací a statistiky ČR, 2017). The actual prevalence of pain localized in upper limbs, but not causing incapacity for work, was set by Andersen et al. (Andersen, Haahr, & Frost, 2007) to approximately 11–28 % of all employees and services. The relationship between personal computer use and musculoskeletal problems in upper limbs has already been proved many times (Gerr, Monteilh, & Marcus, 2006). The same applies to the relationship between musculoskeletal problems and temperature of hands (Gold, Cherniack, Hanlon, Dennerlein, & Dropkin, 2009; Novotný, 2009).

Despite the fact that thermographic cameras have been used in medicine since the 1960s, (Ring & Ammer, 2000; Ammer, 2008) and since 1990s many scientific papers have been published about "progress of thermal imaging technology" (Ring, 1990), still, in some fields of thermography, no significant research has been conducted. This unsatisfactory state was evaluated directly

by Ring and Ammer in 2006 (F. Ring & Ammer, 2006), when they wrote that infra-red imaging "is often misunderstood or not been used due to lack of knowledge of thermal physiology". Seixas et al. commented on the problems almost identically in 2014 (Seixas, Vardasca, Gabriel, & Vilas-Boas, 2014) more than twenty years after the topic was published for the first time (Sharma, Smith, Hazleman, & Jenner, 1997).

The first study dealing with the relationship between the temperature of hands and computer work was written by Sharma et al. in 1997 (Sharma et al., 1997). They used their own methodology on how to measure and evaluate temperatures. From now on only two or three methods have been introduced so far. However, no work dealing with the methodology alone was published since.

According to our findings, confirmed by Seixas and Rodrigues in their review (Seixas & Rodrigues, 2016), only five works focusing on computer work-related thermal changes in hands have been published so far (Gold, Cherniack, & Buchholz, 2004; Gold et al., 2009; Gold, Cherniack, Hanlon, & Soller, 2010; Reste et al., 2015; Sharma et al., 1997).

These five works, however, written by only three authors (Sharma et al., Reste et al. and Gold et al.), present us only three used methods. All of them focus on the dorsal side of the hands. All authors explain why their method is the very best one. But none of them provides a comparison with other authors. They also do not explain why they haven't chosen any other – not so good – method. All the methods are charted in Fig. 1.

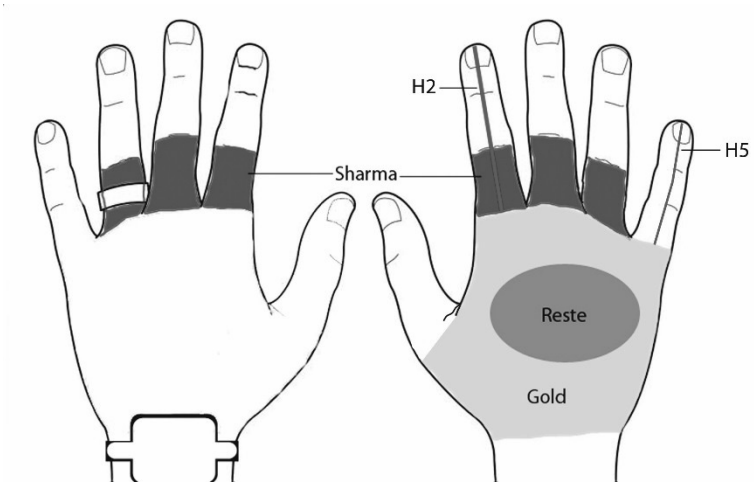

Fig 1: Regions of interest in accordance with Sharma, Reste, Gold and Author (H2 and H5).

Sharma used "over 200–350 pixels on the 2nd, 3rd, and 4th proximal phalanges of both hands"(Sharma et al., 1997).

With the utmost probability, *Gold* performed all measurements in all her researches using the same method. She measured the average temperature of the metacarpal region of the dorsal right hand. This region was demarcated by heads of ulna and radius and with metacarpal joints (Gold et al., 2004, 2009, 2010). She explained that this area is the most reliable location for detecting vascular response and abnormality in the hand (Stansberry et al., 1999; Gold et al., 2004).

Reste used her own research method. As we can see at her figures, she measured the mean temperature in an ellipsoid area placed it in the middle of the metacarpal region without more accurate localization (Reste et al., 2015).

The method used by Sharma et al. has several limitations such as the problematic feasibility and significant amount of time required without the utilization of specialized localization software. We have also considered the imaging of proximal phalanx of the 4th finger to be very problema-

tic because in many cultures over the world, it is reserved for a wedding ring as well as the 3rd finger, on which rings are often worn for different, less frequent reasons. If the researcher wanted to compare both hands for any reason, gathering data would either be very difficult/inaccurate, or it would not meet the conditions of the natural environment. The same applies if the people wearing rings would be asked to remove them. Also, we believe that there may be some changes in blood circulation in a finger, on which a ring is worn in the long term, but they are not yet scientifically confirmed.

The region of interest chosen by Reste was found by us to be very similar to Gold's methodology. Unlike Gold's it wasn't sufficiently defined and so it has also been excluded from the comparison.

Hypothesis made by Gold regarding the suitability of hand dorsum was built on the findings of Stansberry et al. (Stansberry et al., 1999), who has described the back of the hand showing significant differences in vessel vasodilation during different kinds of induction. All of this was done without any comparison to any other, similarly hairy regions of the hand. The method introduced by Gold, even though it would correspond to our requirements regarding sensitivity and specificity to changes of perfusion of the hand with blood, did not correspond to our requirements of simplicity and time required to data analysis. Manual delimitation of the monitored region in thermographic software was very laborious, especially in case of larger files. Also, in the pilot study (Horáček & Novotný, 2017), we have discovered that during field measurements, in which we strive for the highest possible authenticity, large wristwatch of several measured people interfered with the measured region, which distorted results and made delimitation of the monitored region even more difficult.

None of the presented methods met our expectations regarding speed and ease of use (Sharma and Gold), and, at the same time, the accuracy of localization (Reste). This led to the creation of our own methods and to a subsequent comparison.

As we can see from the arguments, from all the methods used hitherto, only the method by Gold was left as a reference for comparison with our regions of interest. One of the reasons for this was also often proven the ability of Gold's method to detect specific pathologies in upper limbs (Gold et al., 2004, 2009).

The aim of this work was to find the most suitable method – region of interest (ROI) – for scanning of temperature changes on the hands of subjects working on the computer. Specifically, to find a method, which would be not only sufficient but also simple and fast to evaluate. Among other requirements belonged its usability outside of laboratory conditions, and, last but not least, possible larger sensitivity to thermal changes and probably related pathological changes, described by Gold et al. (Gold et al., 2009).

METHODS

The Thermographic Imaging in Sports and Exercise Medicine checklist (TISEM) (Moreira et al., 2017) recommendations were followed during data collection, data analysis and data reporting. Before taking thermograms, all participants signed written informed consent after explained the goals and procedures of the study. Whole research was approved by the ethical committee for research of our university following the Declaration of Helsinki.

Participants

For our study volunteered 26 participants. 20 of them working primarily on a personal computer and 6 using computer merely superficially but also using their hands as a working tool. All of them were white, ethnic Czechs. The distribution of sex was 21 women and 5 men. The aver-

age age at the time of measuring was 34,3 years with a standard deviation of 11,1 years. There were 22 right-handed people and 4 left-handed people among the participants. But only one of them used a left-handed computer mouse at work. Three of them were smokers. One man and two women. Three participants reported upper limb symptoms (such as pain, burning, tingling etc.) at the time of assessment, 9 reported recent symptoms but not in a day of assessment and 14 participants did not report any symptoms.

As we can see from the description of the measured persons, the group was significantly heterogeneous in age, sex, occupation and all other factors. As we did not investigate the similarity of subjects or their thermal response to stress, but the similarity of thermal dynamics in ROIs it did not cause any problem. These ROIs were the same with all the participants as well as the procedure of measurements and data analysis.

Regions of interest

During selection of a more suitable location for temperature monitoring, we followed findings of Stansberry et al. (Stansberry et al., 1999) about better suitability of the hairy part of the hand, and also from findings of Mercer and Weerd (Mercer & Weerd L, 2005). In accordance with them, blood serves as the primary carrier of heat in the body (therefore in hands as well), its perfusion is controlled by vascular tonus and hand temperature is therefore mostly determined by blood flow and rather insignificantly by muscular metabolism.

At the same time, we attempted to satisfy our requirement regarding simplicity of ROI determination. The mean temperature of a line leading through the centre of a finger was chosen. The line was led from the most distal part of a finger (including the nail part) to the base of proximal phalanx on the dorsal side of a finger. If necessary (especially in case of index fingers), the line was adjusted to always pass through the centre of a finger. With regard to the findings of Gold (Gold, 2002) concerning finger temperature being less constant than hand dorsum temperature, more significant temperature fluctuations were expected. For our interest in work with the computer, we assumed that on a keyboard both hands are loaded approximately the same. The difference is on a dominant – usually right – hand using a computer mouse, where usually index finger is loaded specifically by "clicking" and therefore there is the possibility of the larger response to stress. For this reason, the right-hand index finger (and the left-hand index finger, for control and on behalf of the left-handed people) was selected. This region was designated H2. Even thou that working on the personal computer doesn't mean just "clicking". Still right (or left) index finger is in some way specifically involved in this work. Differently than the fifth finger for sure. For this reason, we have selected the same region on the fifth finger of both right and left hand. Our assumption was that the little finger will not be stressed using a computer mouse in contrast to the index finger. This region was designated H5. Analogically, the area of hand dorsum in accordance with Gold was shortly named G in charts and graphs. Another reason for choosing second and fifth fingers was that usually on these fingers there are no rings or other jewellery which could interfere with reading.

Methodological procedures

Standard conditions for thermal imaging have been defined earlier (E. F. Ring, 1990; Ammer, 2008; Ammer & Ring, 2013; Moreira et al., 2017). Except for the conditions which could, or even had to be adhered to, such as the perpendicular and consistent distance of the imaging device and the measured subject, some conditions could not be adhered to because of logical reasons in this field measuring. To satisfy the requirement of measuring under real conditions, the actual measuring was performed from the beginning of a work shift to its end. During this shift, we simply could not prohibit our subjects to use restrooms and probably also to smoke and drink coffee at work. Because of this, we had to exclude some recommendations of paragraph 2) of

TISEM. Specifically avoiding caffeine, large meals, smoking and showering for four hours before the assessment. In the end, most problems were caused by using of toilet, specifically by washing hands after its use between measuring sessions. This was the cause of the largest number of missing thermograms, because the surface of hands cooled significantly after washing and it took a couple of minutes (approximately 5–10) before restoration of the original temperature occurred (question remains, to what extent was the restoration even possible and what was the impact of washing in comparison to the impact of change of activity performed with hands). As we wanted to measure under real conditions, we also didn't order measured subjects to take off any rings, wristwatches or other jewellery. All other recommendations were followed.

Nevertheless, the goal of our work was not to measure specific temperatures or their dynamics but the difference between three ROIs, so any possible temperature differences made by caffeine, nicotine or food did not interfere with our measurements as far as we measured all three ROIs under the same conditions. All extrinsic factors affecting skin temperature (e.g. massage, heat or cold exposure etc.) were avoided.

The exact measuring time differed significantly, because most employees got to work at different times and left at different times. However, the period of measuring always corresponded with the morning shift. Therefore, approximately from 7–8 o'clock to lunch, or several hours after lunch. Prior to every measuring, thermal acclimatization of the measured subjects to the work environment took place. During the acclimatization, they have read, they have been explained and they have signed the informed consent with the research, and they have also filled in the worklist, into which they have entered their initials and other required information. This always took approximately 15 minutes. As far as all person spend their work shift in the same place, no other acclimatization was needed for any other measurements that day. The introductory measuring followed. All other measurements took place every other half-an-hour. Always on the hour and on the half hour, within five minutes interval – depending on the ability to interrupt the given activity. Regarding the varying time of arrival to the place of employment, lunch break and/or going home, we have performed a total of 306 measuring sessions of 26 subjects.

With office employees, the measuring took place in their offices. In the case of physical therapists, it took place in the emergency rehabilitation gym. Since the measuring sessions took place during four different days, the measuring conditions were slightly different but rather consistent during the whole period of measuring. These were performed in the period from June to August. The mean temperature was 25.7 °C with a standard deviation of 1.7 °C and the average relative humidity was 46.1 % with a standard deviation of 4.7 %. All four days were rainless and higher than average in terms of temperature. All places where measuring took a place were without air conditioning.

All thermograms were taken using FLIR P660 camera (NETD < 45 mK and sensor array size of 640 × 480 pixels) with emissivity setting of 0.98. Before every measurement camera was turned on and it was waited few seconds until "calibrating" disappeared from the display. During a measurement, camera was held perpendicularly to the hand in approximately 80 cm above a table so both hands lying next to each other with spread fingers took about 80 % of thermogram. The measured person was sitting behind a table with hands flexed in elbows to right angle. Hand was held slightly above a table.

After measurement thermograms were processed in ThermaCAM™ Researcher Pro 2.10, FLIR. At figure 2, thermogram with marked ROIs in accordance with Gold is to be seen. It is interfered with by a wristwatch and with four H lines on the 2nd and 5th finger. The measured person does have a ring on the third finger of their left hand, but it does not interfere with any of the measured areas. On the thermogram, we can also see a slight adjustment of the H2 line because of the unevenness of the measured finger. All the acquired data were subsequently processed in Excel ® (Microsoft ® Office Professional Plus 2016, version nr. 1809). STATISTICA (Dell, version 12) software was used for statistical analysis.

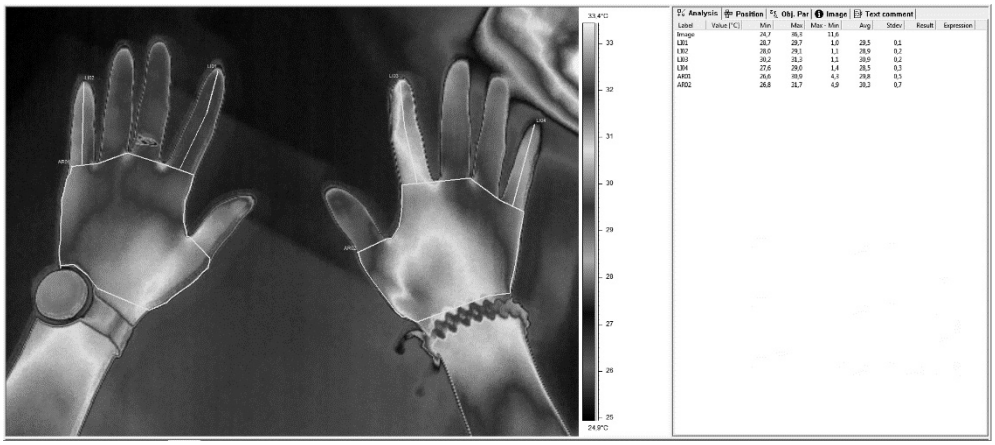

Fig. 2: One thermogram, processed in ThermaCAM™ Researcher Pro 2.10, FLIR. More detailed description in the text.

Data analysis

For statistical processing, all the data were entered into charts with a strict time range of 30 minutes. In 29 cases the data were missing due to a technical problem or an absence of the employee at his or her workplace. In case of these missing data, the temperatures were calculated as an arithmetic average of the neighbouring temperatures

For the graphic representation, we have used a rainbow palette with an attached heat scale as recommended for use in medicine by Ring and Ammer. (Ring & Ammer, 2012)

Considering that Gold et al. method is an accepted methodology when analyzing hand temperature changes, it was used as a reference standard to compare the results of the two newly proposed methods.

Several operations were performed to mathematically confirm some aspects of similarity of our method with the method of Gold. At first, all the temperatures were entered into a chart calculator and thermal curves for measured persons during the entire day were created. One of these curves is to be seen at Figure 3. In the right side of the graph, there is an hour-long lunch break to be seen.

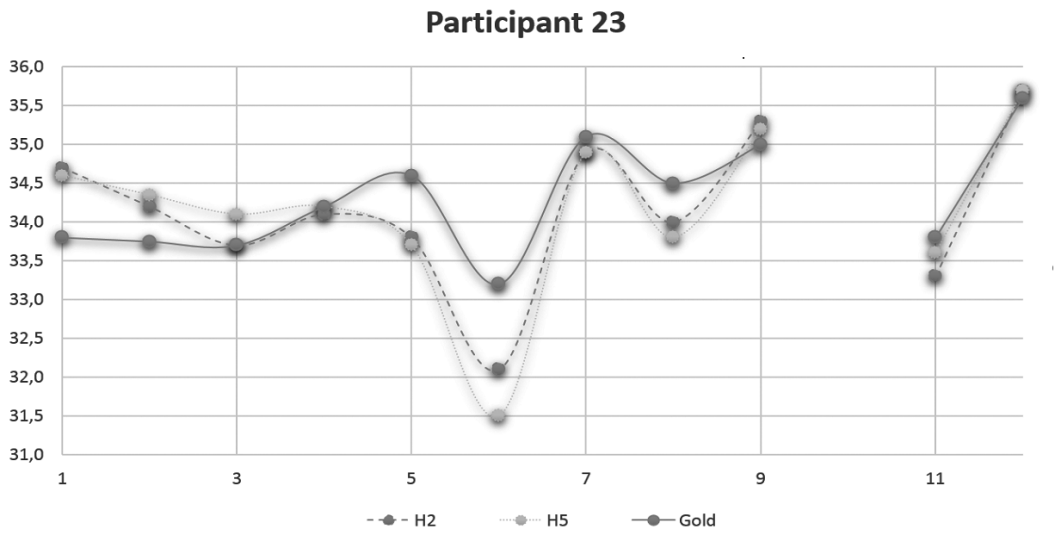

Fig. 3: Graphics processing of a thermogram of participant 23. On the X-axis, the elapsed time from the initial measuring in minutes can be seen, on the Y-axis, the temperature in °C can be seen. The curves represent thermal changes in the right hand of the participant 23 and their mutual relationships.

Mean temperatures of H2, H5 and dorsal area of Gold were calculated as the first mathematical operation. Then we performed a matrix matching of all the measured temperatures with evaluation of the warmest region during all measurements.

The next mathematical operation was performed to confirm the same temperature tendencies (to confirm if the curves are similar or not). Only two options were allowed. It is, or it is not the same. The temperature is increasing or decreasing. Therefore, we were trying to find out, whether the cooling or warming occurs in all measured regions identically. During this calculation, the value of the earlier temperature T_1 was subtracted from the following temperature, T_2, as can be seen at Figure 4. This applies not only to both our methods but also to the method of Gold. These two (three) results were multiplied by each other. This formula was used:

$$X = (T_{2H} - T_{1H}) * (T_{2G} - T_{1G}).$$

If the sign of the final number was positive, it meant that the temperature tendencies were the same. If it was negative, the tendencies were different. The final of 0 pointed to zero change of one of the temperatures and the accord or discord of temperature curves had to be completed (corrected) manually after an optical evaluation of the graph regarding a larger period of time.

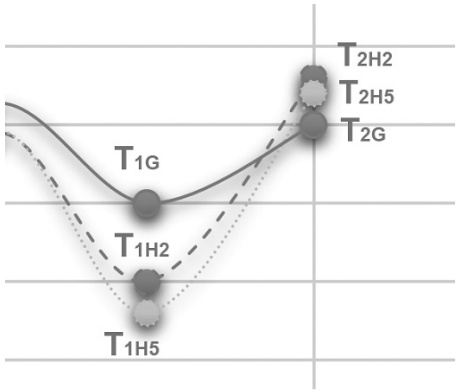

Fig. 4: Graphic representation of temperature reading on a cut-out of one of the thermograms. On every curve, we can see temperature T1 on the left and temperature T2 on the right. During the comparison of the following temperature section, T2 is marked T1 and the T_2 marking is transferred to the next value.

After mathematical calculation of temperature tendencies, and therefore specificity with a reference to Gold, we have performed mathematical description of sizes of curves amplitudes and therefore, the sensitivity of the method to any pathologies or ongoing phenomena. This was achieved in two ways. First by variation range of measured temperatures of every subject for all methods.

The second approach to the comparison of temperature amplitudes was the comparison of areas under the curve by subtraction of the integrals of temperature changes between all measuring sessions. For this, we used formula:

$$Y = |T_{2H} - T_{1H}| - |T_{2G} - T_{1G}|$$

Once again, if the final number was positive, the H method had a larger temperature difference (either to higher or lower temperatures). If the number was negative, it was the method of Gold, which was the more sensitive one. Resulting 0 pointed on the same deviation, which was a good result for the methods we have selected because their processing was significantly easier and faster while achieving the same, previously confirmed results. Therefore, the confirmation of the result being identical to the result of Gold is also positive, even though we did not consider it in that manner in terms of statistical importance.

Subsequently, differences between H2 and H5 methods were evaluated in accordance with the aforementioned procedures.

At the end, the conformity (tendencies/directions of thermal curves) of office workers and non-office workers for all three ROIs were compared to check if our methodology works not only for office workers but also for people doing other than computer work. The same mathematical method as was used for comparing thermal curves before was applied.

RESULTS

Both of our methods for evaluation of temperatures on hands during work on the computer were found to be significantly simpler and faster to perform without the use of a special software than the method used by Gold.

After the temperatures have been entered into the graphs it was seen that the resulting curves of Gold and both H methods are very similar (Fig. 3).

The different amplitudes and different temperature levels, through which the curves run, are a visually significant phenomenon. The following results were acquired by mathematical processing:

Mean temperature

During the whole period of measuring, mean temperatures of the monitored regions were, in descending order, 33.9 °C in the region of Gold, 33.8 °C in the dorsum of the second finger (H2) and 33.5 °C in the dorsum of fifth finger (H5). However, during a comparison of the frequency of the warmest and the coldest region, the results were different. Most often, the warmest part of the hand was the dorsum of the right index finger (H2) in 287 cases (42 %), subsequently hand dorsum of Gold in 275 cases (40 %) and lastly the dorsum of the little finger in 121 cases (18 %).

Dynamics

During comparison to curves of Gold, prior to manual correction, an 80 % match was identified in H2 curves (444 cases from 554), 10 % were in opposite direction and in 10 % of cases, the direction of one of them was horizontal and the match, therefore, could not be determined mathematically. After the manual correction, the match was identified in 88 % of cases (486 out of 554 cases) and only 12 % had the opposite tendency. In the case of the H5 curves, the situation was very similar in comparison to the temperature curves of Gold. Prior to correction, there was 79% of matching tendencies (437 out of 554 cases), 13 % with the opposite directions and 8 % with no way to determine tendency. After correction, there was 85 % of matching tendencies (470 out of 554 cases) in contrast to 15 % in the opposite direction. The results of the comparison of temperature trends are clearly summarized in tab. 1.

Tab. 1: The counts of matching and opposite time temperature trends in the H2 and H5 methods in comparison to the method of Gold and to each other (after correction)

Compared methods	Ratio of trend conformity (%)	Ratio of trend difference (%)
H2 vs. Gold	486 (88%)	68 (12%)
H5 vs. Gold	470 (85%)	84 (15%)
H2 vs. H5	530 (96%)	24 (4%)

Amplitude

The mean variation range was determined by a comparison of variation ranges – in the descending order, it constituted 5.8 °C in the H5 method, 5.3 °C in the H2 method and 3.7 °C in hand dorsum by Gold. The results of comparison absolute values of mean temperatures are clearly summarized in tab. 2.

Tab. 2: Absolute values of mean temperatures in the H2 and H5 in comparison to the method of Gold

Methodology	Mean temperature (°C)	Standard deviation (°C)	Variation range (°C)	Difference to Gold (°C)
Gold	33.9	1.3	3.7	
H2	33.8	2.0	5.3	1.6
H5	33.5	2.0	5.8	2.1

By comparing the amount of temperature change in every period against the method of Gold, in case of H2 method, we have discovered a larger deviation in 61 % of cases (340 out of 554 cases), in 9 % of cases, the change was of similar size and in 30 % of cases, the region in accordance with Gold had larger thermal response to stress. In case of H5 method, the change in tem-

perature was higher in 68 % of cases (379 cases out of 554), similar to Gold in 9 %, and in 22 % of cases, the change was larger in Gold. The results of the comparison of temperature changes are accurately summarized in table 3.

Tab. 3: Amounts of larger, same and lower temperature differences in the H2 and H5 methods in comparison to the method of Gold and to each other

Temperature changes			
	H* > Gold	**H* = Gold**	**H* < Gold**
H2 vs. Gold	340 (61%)	50 (9%)	164 (30%)
H5 vs. Gold	379 (68%)	51 (9%)	124 (22%)
H2 vs. H5	158 (29%)	83 (15%)	313 (56%)

Dynamics for office and non-office workers

It was found that while for a whole group of 26 subjects the conformity of H2 curves to curves of Gold was 80 % before correction (444 cases out of 554) the conformity for office workers was 81 % (319 out of 394) and for the non-office worker 78 % (125 out of 160 cases). For H5 method the results were very similar. Conformity for the whole group was 79 % (437 out of 554 cases) while for office workers only was 78 % (309 out of 394 cases) and for non-office workers 80 % (128 out of 160). As can be seen, the difference is only 2% for both groups of office and non-office workers. The results are summarized in table 4.

Tab. 4: Ratio of trend conformity before manual correction

Ratio of trend conformity (%)		
	H2 vs. Gold	**H5 vs. Gold**
For whole group	**80**	**78**
For office workers	81	78
For non-office workers	78	80

DISCUSSION

The fact that both methods proposed by us (even as a whole, i.e. both used together) are significantly easier, faster and so cheaper to perform in comparison to the method recommended by Gold is not to be found in the result and it is also very hard to be measured. Our results point out that both our methods are capable of recording of thermal changes on the surface of hands with higher amplitude during work than methods of Gold (as seen in table 2).

One can agree with Gold et al. that the increase in temperature of hands while using a personal computer cannot be done by the production of heat by these muscles (Gold et al., 2004). However, it is necessary to question if the participating muscles can influence the resulting temperature in a different manner. For example, as a heat accumulator, which would either slow down the temperature change or even decrease it. The reason, why during the comparison of current temperatures of Gold, H2 and H5 regions did the H2 regions come out as the warmest, followed by the region selected by Gold and lastly the H5 region, remains a question. There can be plenty of mechanisms causing this phenomenon.

When comparing with thermal curves of the Gold's method, the tendencies of H2 method came out as 1% (before correction), respectively 3 % (after correction) more similar than the H5 method (as seen in table 1). Regarding the amplitude of thermal change, the H5 method came

out as having higher amplitudes in the whole 7 % than the H2 method in comparison to Gold's method (as seen in table 3). In absolute numbers, this difference between H2 and H5 was 0.5 °C (seen in table 2). It is a question whether this difference of half a degree can relevantly affect the sensitivity of the method, regardless of what should be diagnosed using this method. If we consider the method of Gold to be capable of diagnosing musculoskeletal problems (Gold et al., 2004) in upper limbs with range of 3.7 °C (as seen in table 2), we say that the H5 method with a range of 5.8 °C is more sensitive and thus could be a better method for the price of losing only 12, respectively 15 % of curve shape. All of this regarding the fact that the difference of 15 % from the shape of curves of Gold points out just their difference but not lower specificity in the representation of pathological processes. Since this work only compares the consistency of two methods, it is well possible that this 15 % difference stands for 15 % increased accuracy. This would have to be proven by another more statistical study. The fact that the temperature range of hand surface of some subjects consisted of 2–3 °C during the whole shift also reflects the importance of this temperature difference. Theoretically, in case of some measured people, emphasizing the measured results by 2.1 °C could create a difference of up to 100 %.

For further research, it might be interesting to consider the temperature differences of the index finger (H2) and the little finger (H5) in employees using primarily a computer mouse. This comparison could be performed both regarding employees using primarily a keyboard or a different control element of the computer and regarding employees working in a different field (drivers, tradesmen etc.).

These differences, though they look promising and suggest bigger suitability of H5 method before the Gold's one, require further research. This research would prove whether the discovered difference stands for higher or lower specificity of these methods to the detection of musculoskeletal problems already proven by Gold and her team.

CONCLUSION

Computer work-related musculoskeletal disorders are widespread nowadays and the use of thermal imaging devices to detect them has many advantages. However, only small progress on this field was made in recent years. This paper shows a possibly better way how to measure thermal dynamics on hands. All of this by comparing newly proposed regions of interest to already published ones. These regions of interest were measured in real conditions out of the laboratory.

The newly proposed H2 and H5 regions of interest for monitoring of hand surface temperature were compared to the known and verified one of Gold.

In comparison with this method, both newly proposed methods were found to be capable of measure the same dynamics in more than 85 %. In contrast to the method of Gold, the results suggested the ability to measure higher fluctuation of temperature in more than 61 %, the actual difference being up to whole 2.1 °C.

In addition, both new methods were found to be significantly simpler and easier to perform. However, that was not measured and thus cannot be supported statistically.

Although this paper is presenting in our opinion a better way to measure temperature changes on hands still there are many other ways how it could be done which needs to be scientifically proven to be better or worse. From this point of view, this work just shows the work which still must be done to fully appreciate the value of thermography in clinical practise.

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References

Ammer, K. (2008). *The Glamorgan Protocol for recording and evaluation of thermal images of the human body* (Vol. 18).

Ammer, K., & Ring, E. F. (2013). Standard Procedures for Infrared Imaging in Medicine. In *Medical infrared imaging: principles and practices*. Boca Raton, FL: CRC Press/Taylor & Francis.

Andersen, J. H., Haahr, J. P., & Frost, P. (2007). Risk factors for more severe regional musculoskeletal symptoms: a two-year prospective study of a general working population. *Arthritis and Rheumatism*, *56*(4), 1355–1364.

Gerr, F., Monteilh, C. P., & Marcus, M. (2006). Keyboard use and musculoskeletal outcomes among computer users. *Journal of Occupational Rehabilitation*, *16*(3), 265–277.

Gold, J. E. (2002). *Indicators of upper extremity musculoskeletal disorders: Digital vibration threshold testing and infrared thermography.* University of Massachusetts Lowell.

Gold, J. E., Cherniack, M., & Buchholz, B. (2004). Infrared thermography for examination of skin temperature in the dorsal hand of office workers. *European Journal of Applied Physiology*, *93*(1–2), 245–251.

Gold, J. E., Cherniack, M., Hanlon, A., Dennerlein, J. T., & Dropkin, J. (2009). Skin temperature in the dorsal hand of office workers and severity of upper extremity musculoskeletal disorders. *International Archives of Occupational and Environmental Health*, *82*(10), 1281–1292.

Gold, J. E., Cherniack, M., Hanlon, A., & Soller, B. (2010). Skin temperature and muscle blood volume changes in the hand after typing. *International Journal of Industrial Ergonomics*, *40*(2), 161–164.

Horáček, J., & Novotný, J. (2017). *How hard is work with personal computer and how to measure it – Thermographic methods. Not new, but still just promising*. Presented at the 11th International Conference on Kinanthropology 'Sport and Quality of Life', Brno.

Mercer, J., & Weerd L., de. (2005). *The effect of water-filtered infrared-A (wIRA) irradiation on skin temperature and skin blood flow as evaluated by infrared thermography and scanning laser Doppler imaging* (Vol. 15).

Moreira, D. G., Costello, J. T., Brito, C. J., Adamczyk, J. G., Ammer, K., Bach, A. J. E., … Sillero-Quintana, M. (2017). Thermographic imaging in sports and exercise medicine: A Delphi study and consensus statement on the measurement of human skin temperature. *Journal of Thermal Biology*, *69*, 155–162. https://doi.org/10.1016/j.jtherbio.2017.07.006.

Novotný, J. (2009). Využití termografie pro sportovce. *Studia sportiva*, *3*(1).

Reste, J., Zvagule, T., Kurjane, N., Martinsone, Z., Martinsone, I., Seile, A., & Vanadzins, I. (2015). Wrist Hypothermia Related to Continuous Work with a Computer Mouse: A Digital Infrared Imaging Pilot Study. *International Journal of Environmental Research and Public Health*, *12*(8), 9265–9281.

Ring, E. F. (1990). Quantitative thermal imaging. *Clinical Physics and Physiological Measurement: An Official Journal of the Hospital Physicists' Association*, *11 Suppl A*, 87–95.

Ring, E. F. J., & Ammer, K. (2000). *The Technique of Infra red Imaging in Medicine* (Vol. 10).

Ring, E. F. J., & Ammer, K. (2012). Infrared thermal imaging in medicine. *Physiological Measurement*, *33*(3), R33–46.

Ring, F., & Ammer, K. (2006). Thermal Imaging in Diseases of the Skeletal and Neuromuscular Systems. In *Electrical Engineering Handbook*. *Medical Devices and Systems* (Vols 1–3, pp. 31–1–31–15). CRC Press.

Seixas, A., & Rodrigues, S. (2016). Dynamics of skin surface temperature in the hand after computer work: A review. In *Occupational Safety and Hygiene IV* (Vols 1–0, pp. 287–291). CRC Press.

Seixas, A., Vardasca, R., Gabriel, J., & Vilas-Boas, J. (2014). Recent application of infrared thermography in work-related musculoskeletal disorders. In P. Arezes, J. Baptista, M. Barroso, P. Carneiro, P. Cordeiro, N. Costa, … G. Perestrelo (Eds.), *Occupational Safety and Hygiene II* (pp. 737–741). CRC Press.

Sharma, S. D., Smith, E. M., Hazleman, B. L., & Jenner, J. R. (1997). Thermographic changes in keyboard operators with chronic forearm pain. *BMJ : British Medical Journal*, *314*(7074), 118.

Stansberry, K. B., Peppard, H. R., Babyak, L. M., Popp, G., McNitt, P., & Vinik, A. (1999). Primary nociceptive afferents mediate the blood flow dysfunction in non-glabrous (hairy) skin of type 2 diabetes: A new model for the pathogenesis of microvascular dysfunction. *Diabetes Care; Alexandria*, *22*(9), 1549–1554.

Ústav zdravotnických informací a statistiky ČR. (2017). *Ukončené případy pracovní neschopnosti pro nemoc a úraz 2016*.

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Analysis of the game characteristics of the female U14 juniors final matches at World Junior Tennis Finals in 2017

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Abstract

Analysis of the course of a match serves in many sports as a tool to obtain feedback for players and coaches. The most common method of analysis in tennis is the analysis of game characteristics which is used in the training process both in pre-match preparation and post-match analysis. The results of this analysis, centre on different ages and performance cohorts, are published in a number of studies. At present, special computer software is often used to analyze game characteristics in tennis – IBM Slam Tracker is used on all four grandslam tournaments. Game characteristics processed with this software have been taken into account when choosing 13 game characteristics used in our research. The aim of the research was to analyze the game characteristics of the best female junior players (n = 4), participants of the World Junior Tennis Finals (WJTF) final in 2017 in Prostejov. Based on the analysis of the research data, the differences in the level of the game characteristics of the winning and defeated finalists were determined, then comparison of the game characteristics of finalists WJTF 2017 and finalists of the women tournament at Roland Garros (RG) 2017 was carried out. In the final matches between Ukraine (UA) and the United States (US), the selected game characteristics were evaluated using the Dartfish 9.0 software. The results of the analysis of the game characteristics showed that the winning players gained more points after the first and second serve in both matches. The winning players also obtained more breaks and winners, committing a significantly lower number of double faults and unforced errors. When comparing the level of game characteristics of the winning players at WJTF, it was found that they had a higher success rate of the first serve than the RG winner and had a higher success rate in the number of gained breaks. It was found that the RG winner had a significantly higher ratio of winners over a defeated player than it was by winners at WJTF. The ratio of total points won by the winning players versus the losers was higher for the WJTF than for the RG winner, which suggests a more balanced match at the RG final.

***Key words*:** *female junior players, comparison, software Dartfish, tennis, feedback*

Introduction

Analysis of game characteristics – in addition to the most commonly used game characteristics, the terms of match characteristics, match-play features, tennis metrics, match statistics, performance indicators (Albamonte, 2011; Bedford, Barnett, Pollard & Pollard, 2010; Brody, 2004; Cross & Pollard, 2009; Filipcic, Filipcic & Berendijas, 2008; Choe, O'Donoghue & Hughes, 2009; Tudor, Zecic & Matkovic, 2014) – is a significant feedback to both coaches and players in a range of collective and individual ball sports (Hohmann, Lames & Letzelter, 2007). These analysis are common in basketball, football, hockey, tennis, rugby, golf, etc. In tennis, analysis of the game characteristics has become a common part of the training process, especially during pre-match preparation when choosing the optimal strategy and tactics of the game with respect to the opponent. Post-match analysis is used mainly to assess the reasons for a victory or loss in a match and to use this knowledge in training. The analysis of game characteristics allows to formulate the goals of the training, to evaluate strategy and tactics, psychological readiness and to analyze

the game of the opponent (Crespo & Miley, 2003; Filipcic, Caks & Filipcic, 2011; Filipcic et al., 2008; Schönborn, 2012). Sanz and Terroba (2012) emphasize that the most important element in the analysis process is not the information we have at our disposal but its correct interpretation and subsequent transfer to coaching practice. Instead of the previously used hand methods (Schönborn, 2012), Internet or software products such as SIMI Scout, Dartfish, Silicon Coach, Tennis Analytics, TennisStats (Hui, Lijuan & Jinju, 2010; Terroba, Kosters, Varona & Manresa-Yee, 2013) are used for tennis game analysis, which allow to track the analysis of game characteristics from the most important tournaments during and after the game on TV screens or on the Internet. For the analysis of game characteristics, all four grandslam tournaments use the IBM SlamTracker software to evaluate 12 game characteristics. Game statistics are available to players and coaches after the match, and they can be searched for on dedicated web sites (e.g. www.matchstat.com, www.atpworldtour.com or www.oncourt.info). Dartfish software can also be used to analyze game characteristics using predefined gaming indicators, the evaluation is based on the principle of marking selected game activities during the game from the video. A number of tennis experts have dealt with analysis of game characteristics in tennis matches in the long term. Brody (2004) analyzed men's servis and found out that for winning games after own serve is a decisive number of points won after own serve, not the high percentage of serves in. Choi et al. (2009) concluded that the winning players are mostly better only in some game characteristics, with the resulting characteristics not necessarily in line with the course of the match. Kachel et al. (2015) found that the pressure in tennis balls had an impact on the level of game characteristics in both male and female games and found that this factor mainly affected the exchange rate and the correct timing of bumper hit. In a comprehensive analysis of 72 grandslam tournaments in 1991–2009, Cross et al. (2009) found out that about one-third of all the played men's rallies are ended by the winners, one-third ends with unforced errors and one-third ends with forced errors. The importance of different game characteristics in men's matches on different surfaces was presented by Katic, Milat, Zagorac & Durovic (2011). They found that during the Wimbledon (W) tournament (grass courts), the key game characteristics concerned the serve while the Roland Garros (RG) tournament results mainly on the characteristics of the forehand and the backhand from the baseline. An interesting demonstration of the use of the results of the game characteristics analysis when assessing the game strategy was presented by Tudor et al. (2014), who surveyed the differences in game characteristics of men's matches between 2010 and 2011 in three grandslam tournaments RG, W and US Open (USO). The authors found that statistically significant differences in game characteristics between the two years were the least manifested in the RG, but there was a significant increase in the number of unnecessary errors – as opposed to the W and USO tournaments, when there was a decrease. In all three tournaments, there was a significant slowdown in first and second serve in 2011, and W and USO tournaments saw a decrease in the number of winners. These facts are attributed to a change in the style of the game where the prevailing tendency to a safer, less risky game prevails on fast surfaces (W and USO), while on slow courts (RG) there is a clear tendency for an aggressive game. Some authors (Terroba et al., 2013) dealt with the analysis of tennis players – men and women – on the court and using special algorithms in video analysis they found that the place where tennis players predominantly play balls is closely related to their gaming tactics.

On the basis of the synthesis of knowledge and previous studies, the research objective was formulated by finding the differences in the level of the game characteristics of the top female juniors – World Junior Tennis Finals (WJTF) finalists in 2017 in Prostejov (Czech Republic). Subsequent comparison of the game characteristics of finalists WJTF 2017 and finalists of the women tournament at Roland Garros (RG) 2017 was supposed to find out differences between two categories – juniors and adults. The text is conceptually based on previously published works

by Janak, Paces & Zhanel (2017) and Polach, Zhanel, Paces & Cernosek (2016) dealing with the analysis of the game characteristics of junior players in 2013 and 2014.

METHODS

The basis for the game characteristics' analysis of the final matches (August 12, 2017) of the female junior teams (n = 4) of Ukraine (UA) and United States of America (US) at the WJTF 2017 (clay) were videorecordings of both final single matches. The research data were obtained from the videorecordings of each final single match by the observation method using the Dartfish 9.0 software. Individual game characteristics were selected based on the analysis of foreign studies, publications and statistical software, especially considering game characteristics which are used in IBM SlamTracker. Based on consultations with tennis trainers and experts, the 13 most significant game characteristics were chosen:
number of aces
number of double faults
success rate of the first serve in (%)
number of points won after the first serve
number of points won after the second serve
number of return points won
number of forehand winners
number of backhand winners
number of forehand unforced errors
number of backhand unforced errors
number of net points won
success rate of breakpoints won (%)
number of total points won

The research data obtained from the final single matches were compiled into tables which enabled to compare the individual game characteristics of both the winner and the defeated player. The analysed game characteristics of the juniors (WJTF 2017) were then compared with the women's singles final's data at RG 2017 tournament. There were 3 sets played in RG final and higher absolute values on the number of serves, returns, winners, unforced errors and breakpoints of RG final players were reached. Simple comparison would not provide such a valid data. Given this fact, relative numbers, resp. ratios between single game characteristics were used and then these ratios between two monitored categories (juniors and adults) were compared.

We have formulated two research questions:
1. What are the differences in the level of game characteristics of winning and defeated players in WJTF 2017 final matches?
2. What are the differences in the level of game characteristics of the world's top female juniors and female adult players?

RESULTS

Analysis of the first match
Second players of both teams – LK from Ukraine a GP from United States of America – participated in the first final match and the player of Ukraine won (6 : 3, 6 : 3). The analysis of the game characteristics of each set and for the match are listed in Table 1.

Tab. 1: Analysis of game characteristics (first match)

Set / match	First set (6 : 3)		Second set (6 : 3)		Match (6 : 3, 6 : 3)	
Game characteristics/Players	**LK (UA)**	GP (US)	**LK (UA)**	GP (US)	**LK (UA)**	GP (US)
Aces	0	1	0	0	0	1
Double faults	1	2	0	2	1	4
First serve in (%)	26/35 74 %	19/26 73 %	21/28 75 %	16/22 73 %	47/63 75 %	35/48 73 %
Points won after first srv.	16	10	10	5	26	15
Points won after second srv.	5	3	3	2	8	5
Return points won	14	15	17	13	31	28
Winners – forehand	7	6	2	4	9	10
Winners – backhand	4	5	8	1	12	6
UE – forehand	0	5	3	3	3	8
UE – backhand	3	8	1	5	4	12
Net points won	3	1	4	1	7	2
Breakpoints won (%)	2/3 66 %	1/4 25 %	4/4 100 %	2/5 40 %	6/7 86 %	3/9 33 %
Total points won	34	28	31	20	65	48

Notes: bold text ... winning player; UE ... unforced errors

The match result and individual game characteristics indicate the unequivocal course of the match. Apart from the negligible difference in the number of aces (LK 0 vs GP 1), the winning player LK was better in almost all observed game characteristics. Only first serve in characteristic was comparable for as the defeated player (LK 75 % vs GP 73 %), nevertheless the winning player LK won more points after her serve (LK 34 vs GP 20) and also return points won (LK 31 vs GP 28). The winning player also obtained more winners (LK 21 vs GB 16) and made less unforced errors (LK 7 vs GP 20). Bigger activity of the winning player LK is evidenced by the higher number of net points won (LK 7 vs GP 2). The player LK won 6 breakpoints out of 7 breakpoint opportunities. The number of total points won indicates that first set was tighter (LK 34 vs GP 28) than the second one (LK 31 vs GP 20) although the score was equal (6 : 3, 6 : 3). The winning player LK won 65 points in total against 48 total points won of the defeated player GP. The higher number of points won after the first serve, lower number of unforced errors and a higher number of breakpoints won are considered to be the most important game characteristics for the winning player LK.

Analysis of the second match

In the second match, player DL from Ukraine and player CG from the USA competed. The American player was more successful (6:4, 6:0). The analysis of the results is presented in Table 2.

Tab. 2: Analysis of observed game characteristics (second match)

Set / match	First set (4:6)		Second set (0:6)		Match (4:6, 0:6)	
Game characteristics/Players	DL (UA)	**CG (US)**	DL (UA)	**CG (US)**	DL (UA)	**CG (US)**
Aces	0	1	0	0	0	1
Double faults	4	2	5	2	9	4
First serve in (%)	15/23 65 %	18/27 67 %	10/16 63 %	16/17 94 %	25/39 64 %	34/44 77 %
Points won after first srv.	10	9	5	12	15	21
Points won after second srv.	3	7	2	1	5	8
Return points won	13	13	5	14	18	27
Winners – forehand	2	9	2	2	4	11
Winners – backhand	2	3	2	1	4	4
UE – forehand	6	7	4	1	10	8
UE – backhand	1	6	4	0	5	6
Net points won	0	0	1	3	1	3
Breakpoints won (%)	2/3 67 %	3/5 60 %	0/1 0 %	3/6 50 %	2/4 50 %	6/11 55 %
Total points won	27	30	12	28	39	58

Notes: bold text ... winning player; UE ... unforced errors

Also, in this match, the result and individual game characteristics indicate the unequivocal course of the match. Different level of each game characteristic corresponds with unambiguous match result in favor of the tennis player CG, especially in the second set 6:0. The winning player CG reached first serve in of 94 % which is unusually high value. In this set the winning player won 14 return points and made only 1 unforced error. The winning player was better in all game characteristics during the whole match. She scored 1 ace and made four double faults and the defeated player didn't score any aces and made 9 double faults (almost quarter of her serve). First serve in percentage (DL 64 % vs CG 77 %) was increased by the winner in the second set. There is a big difference in total points won after own serve (DL 20 vs CG 29), return points won (DL 18 vs CG 27) and a number of winners. The American player scored triple the number of forehand winners in comparison to her opponent (DL 4 vs CG 11). The number of unforced errors (DL 15 vs CG 14) and net points won (DL 1 vs CG 3) are tighter. The winning player CG won 6 breakpoints and obtained 21 total points more than her opponent DL. The higher number of return points, winners and total points are considered to be the most important game characteristics for the winning player CG.

Comparison of the final matches of WJTF 2017

Both final matches were comparable in both duration (76 min, resp. 59 min) and a number of games played (18, resp. 16). The players of the first match (LK from Ukraine and GP from the USA) played more actively which is apparent from 21 winners scored by the winning player LK (9 forehands, 12 backhands) and 16 winners scored by the defeated player GP, total of 37 winners. In the second match, both players scored almost 1/3 less winners (23 in total). In the first match, the players gained more net points (total of 9 points) whilst the players of second match obtained 4 net points altogether. The first serve in success rate was relatively high in both matches (73 %, 75% and 77 %) apart from player DL (64%). In the first match the players were more confident about the second serve, they made 5 double faults only whilst in the second match the players

played a total of 13 double faults. It has been demonstrated by the game characteristics' comparison that winning players of both final matches scored more points after first serve (47:30 in total) as well as after second serve (16:10 in total). Also, the number of breakpoints won (total of 12:5) and winners (36:24 in total) was higher for the winning players. The winning players made less double faults (5:13) and unforced errors (total of 21:35).

Comparison of the game characteristics of first and second match with the RG women's single final 2017
Participants of the RG 2017 women's final were SH from Romania (RO) and JO from Estonia (ES). JO won by 6:4, 4:6, 6:3. The analysis of this match's game characteristics is part of Table 3.

Tab. 3: Comparison of the game characteristics of junior finals of WJTF 2017 and women's single final RG 2017

Matches	WJTF First match (6:3, 6:3)		WJTF Second match (4:6, 0:6)		RG 2017 final (6:4, 4:6, 3:6)	
Game characteristics/Players	**LK (UA)**	GP (US)	DL (UA)	**CG (US)**	SH (RO)	**JO (ES)**
Aces	0	1	0	1	0	3
Double faults	1	4	9	4	0	5
First serve in (%)	47/63 75 %	35/48 73 %	25/39 64 %	34/44 77 %	73/100 73 %	55/96 57 %
Points won after first srv.	26	15	15	21	40	38
Points won after second srv.	8	5	5	8	8	12
Return points won	31	28	18	27	46	52
Winners (in total)	21	16	8	15	8	54
UE (in total)	7	20	15	14	10	54
Breakpoints won (%)	6/7 86 %	3/9 33 %	2/4 50 %	6/11 55 %	6/16 38 %	8/19 42 %
Total points won	65	48	39	58	94	102

Notes: bold text ... winning player; UE ... unforced errors

Table 3 contains less game characteristics, since the statistics of the RG 2017 final match do not distinguish between forehand and backhand winners and forehand and backhand unforced errors neither net points won. Also, when comparing the WJTF matches with RG match, it is necessary to consider that there were 3 sets played at RG, therefore the number of total points won (196) is significantly higher than with WJTF matches (113 in the first match and 97 in the second match).

The WJTF winning player achieved a higher first serve success rate (75 %, resp. 77 %) in comparison to the winning player of RG (57 %). The similar level was found in the ratio of a number of points won after first and second serve by winning, resp. defeated players at WJTF (LK 3.3; CG 2.6; resp. GP 3.0; DL 3.0) whereas at RG this ratio was surprisingly lower for winning player JO (3.2) than for defeated player SH (5.0). In comparison to defeated players, the WJTF winning players scored more winners (LK 1.3; CG 1.9) however this ratio was significantly lower with the RG winner (JO 6.75). Fact that JO played more risky is also indicated by higher ratio value of the number of unforced errors compared to defeated player (JO 5.4), LK's and CG's ratios was lower again (2.9 and 0.9). In terms of the success rate of breakpoints won, the winning player of RG achieved 42 % only whilst winning player of WJTF obtained significantly more, 86 % (first match), resp. 55 % of breakpoints (second match). The ratio of total points won was higher for the winning players of WJTF (1.35 first match; 1.49 second match) than the RG winning player (1.09) which suggest a tighter match at the RG finals.

DISCUSSION

Most of the published studies of various authors are devoted mainly to the analysis of game characteristics in male tennis, respectively comparison of male and female tennis analysis. Analysis of game characteristics in female tennis was dealt with by Filipcic et al. (2011). Based on match analysis of 93 tennis players (n = 57) from the age of 12 to 23, the authors searched in which game characteristics there are significant differences between the winning and the defeated players. They found that the winning players gained a significantly higher number of points both after their own serve and total points won (mean 30, resp. 64) against the defeated players (mean 16, resp. 31). In a previously unpublished study of the game characteristics level of the female junior final matches at WJTF 2013 between the CL from USA and SZ from Russia was found that in the first more equable match (CL vs. SZ – 2 : 6, 6 : 4, 6 : 3), the winner CL scored both more winners (CL – 37, SZ – 20) and more total points won (CL – 84, SZ – 80) than the defeated SZ. However, in the game characteristics of the success rate of the first serve (CL – 55%, SZ – 61%) and unforced errors (CL – 26, SZ – 19) the defeated Russian junior was better. In the second match (CB vs. EL – 6 : 1, 6 : 2) the american winning player CB was highly more successful than the defeated player EL from Russia in these analysed characteristics – number of winners (CB – 16, EL – 11), number of unforced errors (CB – 4, EL – 11), number of total points won(CB – 60, EL – 32). Nevertheless, this fact is obviously influenced by the clear result of the match. The above game characteristics were compared to the characteristics of the women's final match of the RG 2013 between SW from United States of America (US) and MS from Russia (RU) – SW vs. MS – 6 : 4, 6 : 4. Comparison of results showed that the winner of RG SW (US) played more aggressive tennis than winning players at WJTF 2013, she played a total of 10 aces of 35 first serves and 29 winners out of 71 total points won. The winner of the WJTF first final match CL (US) did not play any ace in her 20 first serves and played 37 winners out of 95 total points won. The second winner at WJTF EL (RU) played 2 aces of the 85 first serves and 16 winners out of 60 total points won. The defeated finalist at the RG MS (RU) was more successful only in the number of points won after the second serve and in the number of unforced errors. It can be stated that the game characteristics level of the defeated finalist at RG was comparable to the level of characteristics of the defeated juniors in the WJTF 2013 final matches.

In male tennis, the analysis of game characteristics at RG 2005 was pursued eg. by Filipcic et al. (2008), who found that the winning players played more aggressively – scored more aces (mean 1.43, resp. 1.33) and recorded more net approaches (mean 65.4, resp. 56.1), they also made less double faults (mean 0.9, resp. 1.3), unforced errors (mean 11.6, resp. 15.1), and achieved a higher percentage success rate of the first serve (60.3 %, resp. 57.5 %). Cross et al. (2009) analyzed the speed of serves, the number of aces and double faults at grandslam tournaments in 1991–2009 in a total of 127 men's matches. They found that the number of aces generally increased due to the increased speed of serves, while the number of double faults decreases. They also found that most aces are achieved at Wimbledon (grass courts) every year (mean 2884), and that the number of aces is gradually decreasing from the USO (mean 2490), through the AO (mean 2096), those are courts with the artificial surface, to the RG on clay (mean 1819). The order is obviously closely related to the speed of the court surface in the individual tournaments. The influence of compression (inflating – compression resistance) of tennis balls on the game characteristics of junior tennis players was examined by Kachel et al. (2015). They found that this factor does not affect the number of winners, unforced errors, double faults, or success rate of the first serve. A total of 15 game characteristics for every 127 men's matches at the RG, W and USO tournaments in 2010 and 2011 were reviewed by Tudor et al. (2014). They came to the conclusion that the number of unforced errors increased on the slowest clay surface (mean 29.4, resp. 36.0) and decreased on the grass (mean 25.6, 22.8) and on concrete (mean 36.1, resp. 24.8). This phenomenon indi-

cates an aggressive style of play on clay and more cautious on hard surfaces compared to 2010 and 2011. Similar findings have also been found by Katic et al. (2011) who compared the game characteristics of winning and defeated tennis players at Wimbledon and Roland Garros 2009. Their study shows that winning tennis players at Wimbledon have been more successful in game characteristic relating to serves and net playing. At RG especially the players who played more aggressively from the baseline and gained more winners and fewer unforced errors. Polach et al. (2016) and Janak et al. (2017) analyzed the junior's final matches at WJTF in 2013 and 2014 using the Dartfish software. The results of these authors' studies show that the decisive characteristics in the junior category are the number of winners and unforced errors, the more successful players commit a lower number of unforced errors (winning players – 88, defeated players – 103) and also get more winners (winning players – 44, defeated players – 38). It is more about a cautious style of play. The authors also found that compared with adult tennis players, juniors are more likely to gain breaks (juniors – 15/28, adults – 9/19), which suggests that junior's serve is not as important and dominant factor as in men's matches.

Comparing the published conclusions of the junior's analysis of the game characteristics, it is clear that in the age group U14 the differences between the game characteristics of male tennis players and female tennis players (winners and losers) are relatively small. The level of game characteristics of male juniors and female juniors is closely related to tactical concepts in individual matches and greater differences are evident mainly in the adult category.

CONCLUSIONS

Comparing the level of game characteristics of the winning and defeated players in both WJTF 2017 final matches showed that the winning players gained more points after first serve, second serve and in total than losers in both matches. In the first match winning player obtained more breaks and winners, while committing a significantly less unforced errors. She also played significantly more winning points at the net, because she played more variably. In the second match the number of winners was the most significant difference – winning player gained almost twice as much as the defeated player. Generally, the level of the winning players' game characteristics was higer, while in both matches different characteristics were decisive. Comparison of top junior and top adult players' game characteristics showed that WJTF 2017 winning players achieved a higher success rate of the first serve than the RG 2017 winner and also had a significantly higher success rate in the number of gained breaks. The RG winner was found to have a significantly higher ratio of winners against the defeated player than the WJTF winners. The ratio of the total points won by winning players versus the losers was higher for the WJTF than for the RG winner, which also (as three sets played) suggests a tighter match in the RG 2017 final. Difference in the level of the game characteristics between junior and adult players was not found in this study.

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References

Albamonte, M. (2011). Tennis Metrics. *ITF coaching and sport science review, 55*, 19–20.

Bedford, A., Barnett, T., Pollard, Gr. & Pollard, Ge. (2010). How the interpretation of match statistics affects player performance. *Journal of medicine and science in tennis, 15*(2), 25–29.

Brody, H. (2004). Match statistics and their importance. *ITF coaching & sport science review, 32*, 11–12.

Crespo, M., & Miley, D. (2003). *ITF advanced coaches manual.* London: ITF Ltd.

Cross, R. & Pollard, G. (2009). Grand Slam men's singles tennis 1991–2009 serve speeds and other related data. *ITF coaching & sport science review, 49*, 8–10.

Filipcic, A., Caks, K. K., & Filipcic, T. (2011). A comparison of selected match characteristics of female tennis players. *Kinesiologia Slovenica, 17(2)*, 14–24.

Filipcic, T., Filipcic, A. & Berendijas, T. (2008). Comparison of game characteristics of male and female tennis players at Roland Garros 2005. *Acta Universitatis Palackianae Olomucensis, Gymnica, 38(3)*, 21–28.

Hohmann, A., Lames, M., & Letzelter, M. (2007). *Einführung in die Trainingswissenschaft.* Wiebelsheim: Limpert Verlag.

Hui, Z., Lijuan, Y., & Jinju, H. (2010). Computer-aided game analysis of net sports in preparation of Chinese teams for Beijing olympics. *International journal of computer science in sport, 9(3)*, 53–69.

Choi, H. J., O'Donoghue, P. G. & Hughes, M. D. (2009). A comparison of whole match and individual set data in order to identify valid performance indicators for real-time feedback in men's single tennis matches. In Lees, A., Cabello, D. & Torres, G. *Fourth World Congress of Science and Racket Sports.* Madrid: SBA, 227–231.

Janak, O., Paces., J. & Zhanel, J. (2018). Analysis of the game characteristics of a final juniors match U14 at World Junior Tennis Finals – WJTF in 2014 (case study). In Zvonar, Martin; Sajdlova, Zuzana. *11th International Conference On Kinanthropology "Sport and Quality of Life"*. Brno: Masarykova univerzita, 815–825.

Kachel, K., Buszard, T. & Reid, M. (2015). The effect of ball compression on the match-play characteristics of elite junior tennis players. *Journal of Sports Sciences, 33(3),* 320–326. http://dx.doi.org/10.1080/02640414.2014.942683.

Katic, R., Milat, S., Zagorac, N. & Durovic, N. (2011). Impact of Game Elements on Tennis Match Outcome in Wimbledon and Roland Garros 2009. *Collegium Antropologicum, 35(2)*, 341–346.

Matchstat.com. Retrieved February 2, 2018 from https://matchstat.com/tennis/h2h-odds-bets/Simona%20Halpec/Jelena%20Ostapenko.

Polach, M., Zhanel, J., Paces, J. & Cernosek, M. (2016) Analysis of the game characteristic of a final juniors mach up tp 14 years at world junior tennis finals. In Zvonar, Martin; Sajdlova, Zuzana. *10th International Conference On Kinanthropology "Sport and Quality of Life"*. Brno: Masarykova univerzita, 168–178.

Sanz, D. & Terroba, A. (2012). New technologies applied to tactical analysis in tennis. *ITF coaching & sport science review, 56*, 22–23.

Schönborn, R. (2012). *Strategie und Taktik im Tennis:* Gelnhausen: Wagner Verlag.

Terroba, A., Kosters, W.,Varona, J. & Manresa-Yee, C. (2013). Finding optimal strategies in tennis from video sequences. *International Journal of Pattern Recognition and Artificial Intelligence, 27(6)*, 1–31.

Tudor, P. B., Zecic, M. & Matkovic, B. (2014). Differences between 2010 and 2011 performance indicators of tennis play at the grand slam tournaments. *Kinesiology 2014 Supplement, 46,* 101–106.

Forefoot strike, rear foot strike or running shoes. Does it matter?

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Abstract

The main aim of this article is to provide some insight into evidence-based data in running. The prevalence of a rearfoot strike (RFS) pattern is much more usual than a forefoot strike (FFS) even among elite distance runners. There has been significant pressure on runners to change their running style from RFS to FFS in recent times. Usually, this has been justified by the statement that FFS relates to a lower injury rate. Recent studies have shown however, that this statement is probably not true. Different types of strike pattern have an influence on loading different structures of the lower limbs, but the total incidence of running related injury is the same regardless of the type of foot strike pattern.

We want to provide not only an objective view on running technique but also an evidence-based view on the choice of running shoes. There are many recommendations to consider when choosing running shoes, especially in running stores, but only a few of them are supported by research.

This article is not a meta-analysis but it provides some evidence based information about running styles and running shoes.

Keywords: *forefoot strike, rearfoot strike, running, running shoes, foot strike pattern*

INTRODUCTION

There are a lot of recommendations about running technique these days, but not all of them are supported by evidence-based research. We can classify running technique according to the foot strike pattern into forefoot strike (FFS), midfoot strike (MFS) and rearfoot strike (RFS) (Lieberman, 2012). Forefoot strike is defined as a landing in which the ball of the foot hits the ground before the heel. Midfoot strike is a landing in which the point of the first contact of the foot with the ground is not only the rear third of the foot but the midfoot or entire part of the sole. Rearfoot strike is defined as a landing in which the heel hits the ground first and is followed by the ball of the foot (Cavanagh & Lafortune, 1980; Hasegawa, Yamauchi, & Kraemer, 2007; Lieberman, 2012).

It is possible to divide foot strike patterns according to the center of pressure at landing relative to maximum shoe length. This is called the foot strike index. If the foot strike index is less than 33% the pattern is a RFS, a MFS is between 34 and 66% and a FFS is 67% or higher (Cavanagh & Lafortune, 1980). However, Lieberman (2012) argues that this index is arbitrary concerning the foot's anatomy. He supposes to use the vertical ground reaction force (VGRF) instead of the foot strike index.

During running foot hits, the ground and causes an impact. It has been recognized that the RFS landings differ from FFS landings in impact peak in the VGRF and the shape of the curve of landing forces. The curve of RFS has two peaks however, the FFS curve has only one peak (Figure 1) (Lieberman, 2012).

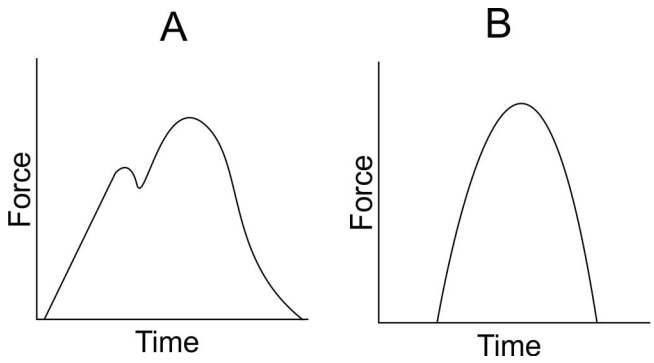

Fig. 1: Vertical ground reaction forces in the rearfoot strike (A) and the forefoot strike (B)

Many authors are using high-speed video analysis for the evaluation of the running pattern for its simplicity and effectivity (Hasegawa et al., 2007). For this reason, is the classification of the pattern based on the landing of the foot as was mentioned before.

The main aim of this article is to provide some insight into evidence-based data in running. We want to provide not only an objective view on running technique but also an evidence-based view on the choice of running shoes. There are many recommendations to consider when choosing running shoes, especially in running stores, but only a few of them are supported by research.

Pubmed, Scopus, Google Scholar, and Sport Discus were searched to identify articles for inclusion. Keywords were: *running, foot strike pattern, running technique, stride length, neutral shoes, running shoes, running economy.*

PREVALENCE OF FOOT STRIKE PATTERNS

The prevalence of foot strike patterns has been examined by many authors. Larson (2011) found that almost 90% of recreational and sub-elite runners at the 10-kilometer point of a half-marathon had a rearfoot strike pattern. De Almeida (2015) chose 514 recreational runners without injury and discovered that 95% of them had a rearfoot strike pattern. It looks like that most elite distance runners use the rearfoot strike pattern too. In the Osaka half-marathon at the 15km point, 74.9% of runners had a RFS, 23.7% used a MFS and 1.4% of runners had a FFS pattern (Hasegawa et al., 2007).

It can be argued that a RFS pattern is not natural, and is caused by wearing shoes. But foot strike pattern varies also among habitually barefoot runners in Kenya (Hatala, Dingwall, Wunderlich, & Richmond, 2013). In a group of 38 habitually barefoot runners running at their endurance speed, 72% used RFS and 24% used a MFS pattern. A FFS pattern was used very rarely, namely in 4% (Hatala et al., 2013). So, what can influence foot strike pattern? It turns out that one of the main parameters resulting in a change of foot strike pattern is running velocity. Kenya barefoot runners used RFS predominantly at velocities 5.0 m/s and less. At speeds between 5.01 and 6.0 m/s, the sample group used RFS and MFS with equal frequencies. At speeds between 6.01 to 7.0 m/s the majority used MFS. In the Hatala's group, the incidence of FFS was greatest at speeds between 6.01 and 7.0 m/s and FFS was never used by the majority of runners (Hatala et al., 2013). It seems that with higher speeds, elite long-distance runners adopt MFS and FFS more likely. This tendency is applicable to men and women runners as well (Hasegawa et al., 2007). Using only a FFS pattern is necessary for sprinters and middle-distance runners to obtain high running velocity (Ardigò, Lafortuna, Minetti, Mognoni, & Saibene, 1995). We can divide recreational road runners into three approximately equal sized groups according to their change of foot strike pattern (Forrester & Townend, 2015). The first group are runners who run

using a RFS pattern regardless of the running velocity. They have lower stride frequency and a higher stride length. The second group are runners who use RFS at a slower speed and change their pattern to FFS with increasing running velocity. The third group are runners who use FFS regardless of their running velocity (Forrester & Townend, 2015).

INJURIES AND FOOT STRIKE PATTERN

A common myth is that forefoot strike pattern is associated with lower injury rates. There is plenty of literature which refutes this myth. Switching technique is associated with altered distribution in loading between joints. However, the amount of total lower limb mechanical work or average power when running are the same. It indicates that one technique does not offer a mechanical advantage over the other (Stearne, Alderson, Green, Donnelly, & Rubenson, 2014).

During RFS technique the hip and the knee are stressed more. During FFS the foot, ankle, and calf are stressed more. There is also a difference in muscle activation between FFS and RFS. FFS runners activate their plantar flexors 11% earlier and 10% longer than RFS runners. Earlier and longer activation of the muscles increase the capacity of the passive structures to store elastic energy. If the tendon is under tension before landing, then the force of landing would cause greater storage of elastic energy. This storage of elastic energy in the connective tissue of the tendon will increase the force output of plantarflexors at the end of the stance phase. On the other hand, this increases requirements on passive structures as Achilles tendon (Ahn, Brayton, Bhatia, & Martin, 2014). Very usual among runners are Achilles tendon injuries. Almonroeder (2013) established that FFS runners experienced 11% greater Achilles tendon impulse each step in comparison to RFS runners. It is not only the type of foot strike that influences the loading of joints. Increased stride frequency and reduced stride length both have the effect of decreasing load through the knee and hip (Lenhart, Thelen, Wille, Chumanov, & Heiderscheit, 2014; Schubert, Kempf, & Heiderscheit, 2014; Willson, Sharpee, Meardon, & Kernozek, 2014).

These data show that there is a clear difference between loading structures when comparing RFS and FFS. But running injury rates don't vary between RFS and FFS. Grier (2016) conducted a study in which there were 1332 soldiers. 83% of subjects were RFS runners and 17% were FFS runners. The authors found no difference in injury risk between FFS and RFS. However, they found a difference in most often injured segments of the lower limb. In RFS runners hip and knee were more likely injured than in FFS group, on the other hand in FFS runners the Achilles tendon and calf were more likely injured than in RFS group. But the total incidence of injuries was the same in both groups. Another paper was published by Warr (2014). In their study, they tested 341 male soldiers, and they did not find FFS to be advantageous for decreasing running related injury.

Runners who are suffering running relating injuries often should consider changing running attributes as a stride length and frequency. It is simpler to choose the only attribute of the running pattern than changing the whole technique. The deficiency in running technique will cause injury more likely in runner with higher loads due to the cumulative effect.

RUNNING ECONOMY AND FOOT STRIKE PATTERN

Running economy is the aerobic demand of running at submaximal pace. It means that there is a relationship between oxygen consumption and running speed. Running economy is influenced by many factors but most studies suggest that foot strike pattern alone is not a determinant of running economy (Nichols et al., 2016). Additionally, retraining from RFS to FFS does not change the running economy in recreational runners (Roper, Doerfler, Kravitz, Dufek, & Mermier, 2017). However, change from RFS to FFS can lead to reducing patellofemoral pain which is consistent

with the findings that during RFS the knee is more loaded (Roper et al., 2017). However, there are some studies which conclude that a FFS pattern is more beneficial than RFS (Gillinov, Laux, Kuivila, Hass, & Joy, 2015), whereas, in contrast we can find studies that conclude that RFS is more economical than FFS (Gruber, Umberger, Braun, & Hamill, 2013). The results from studies investigating the effects of foot strike pattern on running economy vary, but as mentioned previously, most of the studies did not find a difference in running economy between RFS and FFS.

RUNNING SHOES

There are a wide variety of running shoes, for example motion control shoes, stability shoes, cushioned shoes or minimalistic shoes. Historically there has been a recommendation to prescribe shoes based on three basic types of foot. For flat feet or overpronating feet, a motion control shoe has typically been recommended. For normal foot, stability shoes were recommended and for high or supinated feet cushioned shoes have been recommended. The type of foot has usually been assessed by the wet footprint test during walking. However there is no association between these tests and dynamic function of the foot when running (Razeghi & Batt, 2002). According to the wet footprint test, foot pronation is a risk factor for injury. There are many studies to the contrary however (Beynnon, Renström, Alosa, Baumhauer, & Vacek, 2001; Neal et al., 2014; Nielsen et al., 2014). To the best of the author's knowledge, there are no set standards to determine the angle of pronation. Measuring pronation in the shoe has a lot of limitations, and markers on the shoe do not describe the position of the calcaneus within the shoe (Reinschmidt, Stacoff, & Stüssi, 1992). Cushioned shoes, sometimes called maximalist shoes are usually used for reducing impact loading during running. A recent study had the surprising result that high cushioned shoes increase impact loading during running (Kulmala, Kosonen, Nurminen, & Avela, 2018). Therefore, using this type of shoes for reducing impact seems to be in vain. Prescribing running shoes based on the shape of the foot has no significant effect on the incidence of running related injuries (Knapik et al., 2010).

If the wet footprint test is not reliable, how are we then able to appropriately choose running shoes? It seems that comfort is the key factor in choosing running shoes. Comfort in shoes is very individual and subjective but it can reduce the incidence of stress fractures and pain in different locations by 1.5–13.4% (Mündermann, Stefanyshyn, & Nigg, 2001). Crucial for runners is to regularly change their shoes and to rotate them regularly, which leads to a reduction in running injury risk by almost 40% (Malisoux et al., 2015). Participants in this study run, on average, approximately 19 km per week for single shoe users and approximately 33 km per week for multiple shoe users. Based on this data, it seems to be beneficial to change different types of shoes regularly, even among recreational runners who do not have very high volumes of training.

CONCLUSION

Changing foot strike technique for uninjured distance runners has no justifiable basis according to evidence-based data. If a runner suffers from running related injury often, changing attributes of the running technique such as stride frequency or stride length should be considered, rather than switching technique completely. Choosing running shoes should be led by comfort of the shoe rather than making a choice based on the type of foot. According to the research of Malisoux (2015) for distance runners whose training load is in excess of 25km per week, it is very beneficial to have more than two different pairs of shoes and to change them regularly. Changing different types of shoes leads to a significant reduction in running related injury risk. In youth athletes, it

has been shown that athletes who participate in a variety of sports have fewer injuries and play sport longer than those who specialize before puberty. For adults, it is also beneficial to do more activities than only running because it decreases the risk of overuse injuries because of the use of different muscle groups.

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References

Ahn, A. N., Brayton, C., Bhatia, T., & Martin, P. (2014). Muscle activity and kinematics of forefoot and rearfoot strike runners. *Journal of Sport and Health Science*, *3*(2), 102–112. https://doi.org/10.1016/j.jshs.2014.03.007.

Almonroeder, T., Willson, J. D., & Kernozek, T. W. (2013). The effect of foot strike pattern on achilles tendon load during running. *Annals of Biomedical Engineering*, *41*(8), 1758–1766. https://doi.org/10.1007/s10439-013-0819-1.

Ardigò, L. P., Lafortuna, C., Minetti, A. E., Mognoni, P., & Saibene, F. (1995). Metabolic and mechanical aspects of foot landing type, forefoot and rearfoot strike, in human running. *Acta Physiologica Scandinavica*, *155*(1), 17–22. https://doi.org/10.1111/j.1748-1716.1995.tb09943.x.

Beynnon, B. D., Renström, P. A., Alosa, D. M., Baumhauer, J. F., & Vacek, P. M. (2001). Ankle ligament injury risk factors: A prospective study of college athletes. *Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society*, *19*(2), 213–220. https://doi.org/10.1016/S0736-0266(00)90004-4.

Cavanagh, P. R., & Lafortune, M. A. (1980). Ground reaction forces in distance running. *Journal of Biomechanics*, *13*(5), 397–406.

de Almeida, M. O., Saragiotto, B. T., Yamato, T. P., & Lopes, A. D. (2015). Is the rearfoot pattern the most frequently foot strike pattern among recreational shod distance runners? *Physical Therapy in Sport: Official Journal of the Association of Chartered Physiotherapists in Sports Medicine*, *16*(1), 29–33. https://doi.org/10.1016/j.ptsp.2014.02.005.

Forrester, S. E., & Townend, J. (2015). The effect of running velocity on footstrike angle--a curve-clustering approach. *Gait & Posture*, *41*(1), 26–32. https://doi.org/10.1016/j.gaitpost.2014.08.004.

Gillinov, S. M., Laux, S., Kuivila, T., Hass, D., & Joy, S. M. (2015). Effect of Minimalist Footwear on Running Efficiency: A Randomized Crossover Trial. *Sports Health*, *7*(3), 256–260. https://doi.org/10.1177/1941738115571093.

Grier, T., Canham-Chervak, M., Bushman, T., Anderson, M., North, W., & Jones, B. H. (2016). Minimalist Running Shoes and Injury Risk Among United States Army Soldiers. *The American Journal of Sports Medicine*, *44*(6), 1439–1446. https://doi.org/10.1177/0363546516630926.

Gruber, A. H., Umberger, B. R., Braun, B., & Hamill, J. (2013). Economy and rate of carbohydrate oxidation during running with rearfoot and forefoot strike patterns. *Journal of Applied Physiology*, *115*(2), 194–201. https://doi.org/10.1152/japplphysiol.01437.2012.

Hasegawa, H., Yamauchi, T., & Kraemer, W. J. (2007). Foot strike patterns of runners at the 15-km point during an elite-level half marathon. *The Journal of Strength & Conditioning Research*, *21*(3), 888.

Hatala, K. G., Dingwall, H. L., Wunderlich, R. E., & Richmond, B. G. (2013). Variation in foot strike patterns during running among habitually barefoot populations. *PloS One*, *8*(1), e52548. https://doi.org/10.1371/journal.pone.0052548.

Knapik, J. J., Trone, D. W., Swedler, D. I., Villasenor, A., Bullock, S. H., Schmied, E., … Jones, B. H. (2010). Injury reduction effectiveness of assigning running shoes based on plantar shape in Marine Corps basic training. *The American Journal of Sports Medicine*, *38*(9), 1759–1767. https://doi.org/10.1177/0363546510369548.

Kulmala, J.-P., Kosonen, J., Nurminen, J., & Avela, J. (2018). Running in highly cushioned shoes increases leg stiffness and amplifies impact loading. *Scientific Reports*, *8*(1), 17496. https://doi.org/10.1038/s41598-018-35980-6.

Larson, P., Higgins, E., Kaminski, J., Decker, T., Preble, J., Lyons, D., … Normile, A. (2011). Foot strike patterns of recreational and sub-elite runners in a long-distance road race. *Journal of Sports Sciences*, *29*(15), 1665–1673. https://doi.org/10.1080/02640414.2011.610347.

Lenhart, R. L., Thelen, D. G., Wille, C. M., Chumanov, E. S., & Heiderscheit, B. C. (2014). Increasing running step rate reduces patellofemoral joint forces. *Medicine and Science in Sports and Exercise*, *46*(3), 557–564. https://doi.org/10.1249/MSS.0b013e3182a78c3a.

Lieberman, D. E. (2012). What we can learn about running from barefoot running: An evolutionary medical perspective. *Exercise and Sport Sciences Reviews*, *40*(2), 63–72. https://doi.org/10.1097/JES.0b013e31824ab210.

Malisoux, L., Ramesh, J., Mann, R., Seil, R., Urhausen, A., & Theisen, D. (2015). Can parallel use of different running shoes decrease running-related injury risk? *Scandinavian Journal of Medicine & Science in Sports*, *25*(1), 110–115. https://doi.org/10.1111/sms.12154.

Mündermann, A., Stefanyshyn, D. J., & Nigg, B. M. (2001). Relationship between footwear comfort of shoe inserts and anthropometric and sensory factors. *Medicine and Science in Sports and Exercise*, *33*(11), 1939–1945.

Neal, B. S., Griffiths, I. B., Dowling, G. J., Murley, G. S., Munteanu, S. E., Franettovich Smith, M. M., … Barton, C. J. (2014). Foot posture as a risk factor for lower limb overuse injury: A systematic review and meta-analysis. *Journal of Foot and Ankle Research*, *7*(1), 55. https://doi.org/10.1186/s13047-014-0055-4

Nielsen, R. O., Buist, I., Parner, E. T., Nohr, E. A., Sørensen, H., Lind, M., & Rasmussen, S. (2014). Foot pronation is not associated with increased injury risk in novice runners wearing a neutral shoe: A 1-year prospective cohort study. *British Journal of Sports Medicine*, *48*(6), 440–447. https://doi.org/10.1136/bjsports-2013-092202.

Nichols, R., Germano, C., Burke, M., Nolan, K., Youngs-Grand, K., & Girard, J. (2016). The effects of foot strike on running economy in distance runners: A narrative review. *Physical Therapy Reviews*, *21*(1), 32–37. https://doi.org/10.1080/10833196.2016.1193970.

Razeghi, M., & Batt, M. E. (2002). Foot type classification: A critical review of current methods. *Gait & Posture*, *15*(3), 282–291.

Reinschmidt, C., Stacoff, A., & Stüssi, E. (1992). Heel movement within a court shoe. *Medicine and Science in Sports and Exercise*, *24*(12), 1390–1395.

Roper, J. L., Doerfler, D., Kravitz, L., Dufek, J. S., & Mermier, C. (2017). Gait Retraining From Rearfoot Strike to Forefoot Strike does not change Running Economy. *International Journal of Sports Medicine*, *38*(14), 1076–1082. https://doi.org/10.1055/s-0043-110225.

Schubert, A. G., Kempf, J., & Heiderscheit, B. C. (2014). Influence of stride frequency and length on running mechanics: A systematic review. *Sports Health*, *6*(3), 210–217. https://doi.org/10.1177/1941738113508544.

Stearne, S. M., Alderson, J. A., Green, B. A., Donnelly, C. J., & Rubenson, J. (2014). Joint kinetics in rearfoot versus forefoot running: Implications of switching technique. *Medicine and Science in Sports and Exercise*, *46*(8), 1578–1587. https://doi.org/10.1249/MSS.0000000000000254.

Warr, B., Fellin, R., Frykman, P., Sauer, S., Goss, D., & Seay, J. (2014). Footstrike Patterns do not Influence Running Related Overuse Injuries in U.S. Army Soldiers: 2977 Board #263 May 30, 3. *Medicine & Science in Sports & Exercise*, *46*, 812. https://doi.org/10.1249/01.mss.0000495935.37415.aa.

Willson, J. D., Sharpee, R., Meardon, S. A., & Kernozek, T. W. (2014). Effects of step length on patellofemoral joint stress in female runners with and without patellofemoral pain. *Clinical Biomechanics (Bristol, Avon)*, *29*(3), 243–247. https://doi.org/10.1016/j.clinbiomech.2013.12.016.

Lateral differences in maximal grip strength in Czech male tennis players aged 11–12 in the context of injury prevention

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Abstract

The term laterality indicates the one-sided preference or functional advantage of the stronger, more accurate and coordinated limbs or organs and the brain hemisphere of a human body. In the preference process, more accurate, precise, coordinated and stronger side is chosen from the perspective of motoric functions. Among the general population is about 10–13% of left-handers and in certain sport fields this percentage may be higher (baseball, tennis, box etc.). The left-handed dominance in tennis is considered an advantage. Due to unilateral load, there may be an excessive side-effect in strength differences in tennis and overloading of specific muscle group could lead to an injury. The aim of the research was to identify the levels of somatic and strength characteristics and assess the lateral difference in maximal grip strength of Czech elite male tennis players. The sample consisted of male tennis players, ranging in age from 11 to 12.9 years (n = 186) who participated in the regular tests for Czech Tennis Association in years 2000–2018. Base anthropometrics were measured (height, weight) and maximal grip strength of both hands using the hand-held dynamometry (Grip D). Data came from normal distribution (statistically proven – chi-square test). The basic statistical characteristics were calculated (body height, M = 155.08 ± 7.98 cm; body weight, M = 43.45 ± 7.13 kg; strength of right hand: M = 24.88 ± 4.67 kp; strength of left hand: M = 21.70 ± 4.74 kp). It was found that 87.6% of the players (n = 163) were right-handed and the remaining 12.4% left-handed (n = 23). The assessment of the significance (Cohen's d) between the dominant (playing) hand for the right-handed and left-handed players showed small effect size (dominant hand right: MRHR = 25.11 ± 4.41 kp, dominant hand left: MLHL = 26.62 ± 5.65 kp; d = 0.30, small) in favor of the left-handed players. The difference between the dominant and the non-dominant hand showed large effect size for the right-handed (dominant hand right vs. hand left; MRHR = 25.11 ± 4.41 kp, MRHL = 21.01 ± 4.15 kp, d = 0.96, large) and medium effect size for the left-handed players (dominant hand left vs. hand right; MLHL = 26.62 ± 5.65 kp, MLHR = 23.24 ± 5.98 kp, d = 0.58, medium). The results showed that the value of 15 % level of strength laterality between dominant and non-dominant hand was exceeded for the right-handed (55.83 %) and left-handed (43.48%) groups ergo the exceeded value could be a cause of injuries. Because of this signals attention should be given during training process for optimizing the required load.

Keywords: *bilateral asymmetry, laterality, tennis, dynamometer, training*

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The Research Ethics Committee of Masaryk University has reviewed the application to conduct the research project as specified above and 21. 12. 2017 the Committee has approved this project to be conducted.

INTRODUCTION

Generally, the term laterality indicates the one-sided preference or functional advantage of the stronger, more accurate and coordinated limbs or organs (such as mainly upper and lower limbs, eyes, pelvis) and the brain hemisphere. Laterality manifests itself outwardly by giving preference to one side of the body during life, which is dependent on the movement center in the opposite brain hemisphere (eg. left hand → right brain hemisphere) controlled by cortex center. The more we used the preferred side the more economic, certain and accurate it will be (Garipuy, 2001; Loffing et al., 2014; Domino et al., 2015; Ziagkas et al., 2017). During literary review we found references to laterality in conjunction with following terms: handedness, footedness, eyedness, earedness and axis-rotation in relation to laterality manifestations. Because of the research intension we focused on the handedness issue (refers to left-hand or right-hand dominance). Handedness is divided into right-handed dominance (dextrality), left-handed dominance (sinistrality) and ambivalent sidedness (ambidexterity). The left-handedness occurs more stronger amongst men compared to women (Papadatou-Pastou et al., 2008). Preferred side may not necessarily be consistent for all tasks. In some interactive sports a higher percentage of left-handers occurs (e.g. fencing, box, baseball, cricket, ice-hockey and tennis). If we focused more on tennis, we could find a limited number of repeatedly performed motoric activities which could leads to a strength and flexibility imbalances and therefore to a possible injury. Mostly training and play load created these muscle disbalances. In tennis, injuries in the upper limbs are most often caused by the repeated excessive load of the speed-strength movement character. Alizadehkhaiyat et al. (2007) claims that muscle imbalances are defined as a failure of functional relationship between agonist and antagonist muscle group or predominance of synergist muscle group. This situation further increases joint loading and involved muscles become overloaded or weakened and may lead to an injury. Study of De Smet et al. (1997) and Pienimaki et al. (2002) say that if the injury appears (in this case tennis elbow) it can lead to a reduction in grip strength approximately about 25%. In tennis it depends on the forearm strength, especially on the grip strength which has an important role, but also on the muscular endurance because of the length of the match. So, it's important to maintain the optimal level of grip strength to prevent mainly the wrist overloading, but also elbow and shoulder joint as well (Roetert & Kovacs, 2018). Boys participated in higher physical intensity activities compared to girls after reaching the age 9 or 10 which leads to improved muscular strength (Butterfield et al., 2009). Study of Ploegmakers et al. (2013) claims that boy's grip strength grew linearly until the 12th year in both hands and after that the accelerated strength increase tendencies were observed for dominant hand. For non-dominant hand the similar tendencies were shown after reaching the 13th year. The maximal grip strength remained relatively stable during repeated measurements in this age. Because according to Häger Ross & Rösblad (2002) and Omar et al. (2015) it could be the result of an incomplete maximal strength.

During the training process players should maintain the optimal muscle balance, focus onto development of strength and endurance (both necessary for tennis) which is important for prevention and performance optimization. Because the asymmetries and strength differences could start in at early age between 11–12th year according to Ellenbecker et al. (2002) and in a longtime this process may be the cause of injuries. According to Sell et al. (2012) and Pluim et al. (2009) lower limbs (LL) injuries were 1.3 times more likely than injuries to the upper limbs (UL) in men (n = 704) during their recording period (1994–2009) at the US tennis championship. The data for the injury rate were shown per one thousand matches exposed for LL in 337 cases (which were 26.59 injury rates) vs. UL in 255 cases (which were 20.12 injury rates). Because our research was focused on the upper limbs, the list of injuries related to the upper limbs and their rate are described below. From 255 cases 93 of them were related to the shoulder/shoulder blade (7.34 injury rate), 49 of them concerned the elbow (3.87 injury rate), 74 of them were at wrist

(5.84 injury rate) and 23 of them were presence in hand, finger or thumb (1.82 injury rate). Vast majority of all injuries were associated with muscle or tendon injury (605 cases with 47.74 injury rates) and after that were joints with ligaments (29 cases with 2.29 injury rates) followed by a minor representation of skin, bone and nervous system injury types. By data from this study and others (Alizadehkhaiyet et al., 2009; Abrams et al., 2012; Rossi et al., 2014; Hayot et al., 2014) we could claim that the most observed and common injuries were concerning the shoulder, wrist and elbow and mostly included muscle or tendon type of injury. Studies of Hutchinson et al. (1995) and Silva et al. (2003) claimed that musculoskeletal injuries such as strains, sprains and cramps were the mostly reported type of injury amongst junior tennis players.

With regards to handedness, some of the tennis players (3.6% among male and female) play with an opposite hand used for tasks like writing etc. This could be as a result for sport-specific tasks (or sport-specific dominance) simply because of its advantage on the field (cross-dominance). Right-handed players have smaller tendency to ambidexterity (no social pressure). According to Grouios (2004) and Loffing et al. (2014), considering motor skills, the left-handers can benefit from weaker lateralization of the brain hemispheres for tasks using both hands (in their childhood almost everyday tasks were made for right-handed part of population). Left-handers have got a little bit of advantage in one-on-one situations in the game, due to lack of games played against them for right-handed (Loffing et al.,2012). The lateralization process has key role in technical aspects of the game, therefore it could be found connection between a player's laterality patterns and his strengths and weaknesses. Decoding these patterns could give a player advantage against his opponent and could therefore apply efficient tactical schemes (Garipuy, 2001; Domino et al., 2015; Loffing et al., 2014; Ziagkas et al., 2017).

METHODS

The aim of the study was to assess the lateral difference in maximal grip strength in Czech tennis players with regard to a possible risk of injury. The subsequent goals of the research were to (1) identify the levels of somatic and strength characteristics, (2) the rate of right-handed and left-handed players, (3) lateral differences in grip strength between the dominant and non-dominant hand. The study included male tennis players. Ages ranged between 11 and 12.9 years (n = 186, mean height with standard deviation was M = 155.08 ± 7.98 cm and mean weight with standard deviation was M = 43.45 ± 7.13 kg). Because the subjects were under the 18 years old, all participants' legal representatives signed an Informed consent. Subjects participated in the project Complex diagnostics in tennis (1999) for Czech Tennis Association in years 2000–2018. Research was approved by The Research Ethics Committee of Masaryk University. The TENDIAG 1 testing battery, 3 out of 9 research-related parts was used: base anthropometrics (height, weight) and maximal hand grip strength using the hand-held dynamometry (Grip D, Takei, Japan). Hand-held dynamometry measurement results came in kiloponds (kp). The playing (dominant) hand was queried with each player. Each subject performed two attempts with each hand parallel to the body in the standing position without touching it, wrist in the neutral position and elbow extended. As a result, the highest strength score (best attempt) was considered and recorded as peak grip strength (kp). The STATISTICA 12 and Microsoft Excel software were used for data processing. According to the fact, that the research sample was not obtain as a random selection, but intentional selection, the authors (Cohen, 1988; Blahuš, 2000; Soukup, 2013) recommend using the effect size for the assessment of mean values differences. Cohen's d was used for the assessment of the significance (effect size) of differences in mean values, which could be interpreted in agreement with author (Cohen, 1988). The scale for the Cohen's d effect size was small (d = 0.2), medium (d = 0.5) and large (d = 0.8).

RESULTS

It has been statistically proven (chi-square test, variations on goodness-of-fit) that the testing data came from a normal distribution. It was found that 87.6% of the players (n = 163) were right-handed and the remaining 12.4% left-handed (n = 23). Base statistical and anthropometric characteristics and maximal hand grip strength are presented in Table 1.

Tab. 1: Basic statistical characteristics of the sample

Sample	Male players (n = 186)			
Variables	**M**	**SD**	**min**	**max**
Age (y)	12.05	0.55	11.0	12.9
Height (cm)	155.08	7.98	139.0	178.0
Weight (kg)	43.45	7.13	30.0	74.0
SR (kp)	24.88	4.67	12.8	40.7
SL (kp)	21.70	4.74	11.4	38.0

Legend: SR ... max. strength right hand, SL ... max. strength left hand, M ... mean, SD ... standard deviation, y ... years, cm ... centimeter, kg ... kilogram, kp ... kiloponds

Table 1 showed the difference for the mean value of maximal hand strength between the right (SR = 24.88 kp) and the left (SL = 21.70 kp) regardless of whether the individual is right-handed or left-handed. In this case the right-hand score was higher. Using the Cohen's d we verified the significance of the difference in mean values for the strength (3.18 kp) of both hands. The medium effect size was shown (d = 0.68, medium). In this sample the representation of left-handed players was 12.4%. The mean percentage difference between the maximum of left and right-hand strength was 15.72% (see Table 2). Among 186 observed players, 101 of them (54.30%) had the 15% strength difference between the dominant and non-dominant hand and amongst 63 of them (33.87%) the difference was found greater than 20%.

Tab. 2: Strength difference between the right and left hand

Difference	n	%
R vs. L	163 vs. 23	15.72
> 15–19.99%	101	54.30
> 20%	63	33.87

Legend: R vs. L ... difference between right and left hand, > 15% ... strength difference greater than 15%, > 20% ... strength difference greater than 20%

Left-handed players (Table 3 and 4) have shown a greater mean value of maximal hand strength for a dominant hand compared to right-handed (M_{LHL} = 26.62 ± 5.65 kp vs. M_{RHR} = 25.11 ± 4.41 kp). Non-dominant hand has shown the same tendencies in favor for left-handed players in comparison with right-handed (M_{LHR} = 23.24 ± 5.98 kp vs. M_{RHL} = 21.01 ± 4.15 kp).

Tab. 3: Maximal strength and differences between dominant and non-dominant hand for the right-handed players

Right-handed players					
	M	**SD**	**Min**	**Max**	**Diff > 15%**
Dominant RHR (kp)	25.11	4.41	12.80	40.70	55.83
Non-dominant RHL (kp)	21.01	4.15	11.40	33.00	
Left-handed players					
	M	**SD**	**Min**	**Max**	**Diff > 15%**
Dominant LHL (kp)	26.62	5.65	18.00	38.00	43.48
Non-dominant LHR (kp)	23.24	5.98	13.90	38.00	

Legend: RHR ... dominant hand right - right hand, RHL ... dominant hand right - left hand, LHR ... dominant hand left - right hand, LHL ... dominant hand left - left hand, M ... mean strength, SD... standard deviation, Diff > 15% ... strength difference between R and L hand higher than 15 % percent, kp ... kiloponds

Both, the right-handed (55.83%) and left-handed (43.48%) groups achieved relatively high strength differences between dominant and non-dominant hand exceeding 15% level of strength laterality.

Results focused on comparison of the strength of the right-handed (RH) and the left-handed (LH) subjects (Table 3 and 4) showed small effect size differences for their dominant hand (M_{RHR} = 25.11 ± 4.41 kp, M_{LHL} = 26.62 ± 5.65 kp; d = 0.30, small) in favor of the left-handed players. The difference between the dominant (DH) and non-dominant (NDH) hand and their strength assessment showed large effect size (M_{RHR} = 25.11 ± 4.41 kp, M_{RHL} = 21.01 ± 4.15 kp, d = 0.96, large) for right-handed players and medium effect size (M_{LHL} = 26.62 ± 5.65 kp, M_{LHR} = 23.24 ± 5.98 kp, d = 0.58, medium) for left-handed players.

DISCUSSION

Our research showed 12.4% representation of left-handed individuals in tennis which agrees with some authors who claimed, that in population is about 10–13% of left-handers (Faurie & Raymond, 2004; Raymond et al., 1996). According to Bohannon (2003) grip strength was typically greater on the dominant hand than on the non-dominant hand. But he also claimed, that it depends whether the subject was right-handed or left-handed and differences might be varying widely among sides. Hand grip strength for right-handed players was found greater in their dominant hand (comply with the 10% rule), but for the left-handed players the results were more equilibrated or even higher on their non-dominant hand (Bohannon, 2003; Hepping et al., 2015). During the study we have found the same results as authors mentioned above and others (Hepping et al., 2015; Tutkuviene & Schiefenhövel 2013; Incel et al., 2002; Bohannon, 2003), who claimed – that left-handed players were more often stronger on their non-dominant against their dominant hand in comparison with their right-handed rivals.

We compared our study results with the other studies (see Table 4) where grip strength came similar. Most of them divided our 2 years category into separate ones. But some of them did not distinguish between strength in the dominant and non-dominant hand or showed only combined results for specific year (mean for right and left hand together).

Tab. 4: Hand grip strength presented in studies

Author	Age	DH	NDH
Molenaar et al. (2010)	11 yo 12 yo	19.92 kp 22.37 kp	18.33 kp 20.68 kp
Ploegmakers et al. (2013)	11 yo 12 yo	22.00 kp 24.7 kp	20.6 kp 22.9 kp
Hepping et al. (2015)	11 yo 12 yo	RH 22.5 kp; LH 19.6 kp RH 25.1 kp; LH 23.0 kp	LH 20.7 kp; RH 19.9 kp LH 23.0 kp; RH 22.7 kp
Butterfield et al. (2009)	11 yo 12 yo	22.36 kp 28.04 kp	21.27 kp 26.28 kp
Omar et al. (2017)	11 yo 12 yo	17.73 kp 21.26 kp	17.46 kp 21.05 kp
Kocher et al. (2017)	11 yo 12 yo	23.1 kp 27.6 kp	25.1 kp 29.7 kp
Kocher et al. (2018)	11 yo 12 yo	21.74 kp 24.49 kp	
Ramirez-Velez et al. (2017)	11 yo 12 yo	15.9 kp 18.1 kp	
Gomez-Campos et al. (2018)	11 yo 12 yo	18.49 kp 22.46 kp	17.25 kp 21.31 kp
Garcia-Hermoso et al. (2018)	11 yo 12 yo	17.60 kp 21.46 kp	
Fredriksen et al. (2018)	11 yo 12 yo	18.4 kp 19.9 kp	16.9 kp 19.0 kp

Legend: DH ... dominant hand, NDH ... non-dominant hand, yo ... years old, RH ... right hand, LH ... left-hand, kp ... kiloponds

These studies originated from all over the world (North America, South America, Central Europe, Eastern Europe, and Asia) and were comparable within western and eastern population. Mostly they agreed with the lowering tendency for hand grip strength amongst the children in last 2–3 decades. During our study did not appear strength drop between attempts because of incomplete maximal strength. Subjects below 12 years were able to repeat those stable attempts in comparison with older ones (13–16 years – which considered to be the strength spur). They produced more strength in a separated attempt (maximal contraction) then the next one fell. Grip strength in boys grew linearly with age in both hands until the 12th year. After that accelerated increase in strength for dominant hand occurred and for non-dominant hand we could observed the same tendencies after reaching the 13th year (Butterfield et al., 2009; Ploegmakers et al., 2013; Tutkuviene & Schiefenhövel 2013; Loffing et al., 2014; Hepping et al., 2015).

CONCLUSION

During our research it was found that out of the total of 186 players 163 were right-handed and 23 left-handed, 87.6% vs. 12.4% respectively. Observed players showed significant differences between the strength level of dominant (play) and non-dominant hand in both groups (right-handed and left-handed). Significant differences were found between the strength of the dominant right hand and the dominant left hand in favor of left-handed players. The mean difference in maximal hand strength was 15.72% (right vs. left hand). Left-handed players had a higher maximal strength in

both hands (dominant and non-dominant) while right-handed only in their right hand (dominant). The value of 15% level of strength laterality between dominant and non-dominant hand was exceeded for the right-handed (55.83%) and left-handed (43.48%) groups. Strength laterality asymmetries between limbs could lead to injury or disbalances, therefore proper exercise (or compensation) should be included as an important part of the training (by coaches and players themselves). The importance of abdominal and lower back exercises (Core stability) are crucial for various types of service helps with the stabilization process (Chow et al., 2003; Elliot, 2006) and also with the appropriate strength transfer via kinetic chain from lower limbs to upper limbs. As kinetic chain continues through the trunk to the shoulder, strength imbalances can possibly cause injury in muscles related to acceleration and deceleration processes during the game. Exercise for eccentric external rotators strength may help with the balancing the antagonist group strength (Noffal, 2003). This is crucial for athletes who perform explosive concentric and eccentric contractions on a regular basis such as tennis, because most of the tennis strokes are according to Elliot (2006) characterized by so called stretch-shortening cycle (eccentric then immediately concentric contraction). It is therefore obvious that training session should include exercise of concentric and also eccentric character.

References

Abrams, G., Renstrom, P., & Safran, M. (2012). Epidemiology of Muskuloskeletal Injury in the Tennis Player. *British Journal of Sports Medicine, 46*, 492–498.

Alizadehkhaiyat, O., Fisher, A., Kemp, G., Vishwanathan, K., & Frostick, S. (2009). Assessment of Functional Recovery in Tennis Elbow. *Journal of Electromyography and Kinesiology, 19*, 631–638.

Alizadehkhaiyat, O., Fisher, A. C., Kemp, G. J., Vishwanathan, K., & Frostick, S. P. (2007). Upper limb muscle imbalance in tennis elbow: a functional and electromyographic assessment. *Journal of Orthopaedic Research*, *25*(12), 1651–1657.

Blahuš, P. (2000). Statistická významnost proti vědecké průkaznosti výsledků výzkumu. *Česká kinantropologie*, *4*(2), 53–72.

Bohannon, R. W. (2003). Grip strength: a summary of studies comparing dominant and nondominant limb measurements. *Perceptual and motor skills*, *96*(3), 728–730.

Butterfield, S. A., Lehnhard, R. A., Loovis, E. M., Coladarci, T., & Saucier, D. (2009). Grip strength performances by 5-to 19-year-olds. *Perceptual and Motor Skills*, *109*(2), 362–370.

Cohen, J. (1988). Statistical power analysis for the behavioral science (2nd ed.). Hillsdale, NJ: Erlbaum.

Chow, J. W., Shim, J. H., & Lim, Y. T. (2003). Lower trunk muscle activity during the tennis serve. *Journal of science and medicine in sport*, *6*(4), 512–518.

De Smet, L., & Fabry, G. (1997). Grip force reduction in patients with tennis elbow: influence of elbow position. *Journal of Hand Therapy*, *10*(3), 229–231.

Domino, G., Świątkowski, P., & Matłosz, P. (2015). Characteristics and analysis of determinants for two-handed forehand in tennis. *Scientific Review of Physical Culture*. 4. 253–263.

Ellenbecker, T. S., Roetert, E. P., Bailie, D. S., Davies, G. J., & Brown, S. W. (2002). Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Medicine & Science in Sports & Exercise*, *34*(12), 2052–2056.

Elliott, B. (2006). Biomechanics and tennis. *British journal of sports medicine*, *40*(5), 392–396.

Faurie, C., & Raymond, M. (2004). Handedness frequency over more than ten thousand years. *Proceedings of the Royal Society of London B: Biological Sciences*, *271*(Suppl 3), S43–S45.

Fredriksen, P. M., Mamen, A., Hjelle, O. P., & Lindberg, M. (2018). Handgrip strength in 6–12-year-old children: The Health Oriented Pedagogical Project (HOPP). *Scandinavian journal of public health*, *46*(21_suppl), 54–60.

Garcia-Hermoso, A., Cofre-Bolados, C., Andrade-Schnettler, R., Ceballos-Ceballos, R., Fernández-Vergara, O., Vegas-Heredia, E. D., … & Izquierdo, M. (2018). Normative Reference Values for Handgrip Strength in Chilean Children at 8–12 Years Old Using the Empirical Distribution and the Lambda, Mu, and Sigma Statistical Methods. *Journal of strength and conditioning research*, *00*(0), 1–7.

Garipuy, C. (2001), The use of laterality in tennis training, *ITF Coaching & sport science review* 23, 3–5.

Gómez-Campos, R., Andruske, C. L., de Arruda, M., Sulla-Torres, J., Pacheco-Carrillo, J., Urra-Albornoz, C., & Cossio-Bolaños, M. (2018). Normative data for handgrip strength in children and adolescents in the Maule Region, Chile: Evaluation based on chronological and biological age. *PloS one*, *13*(8), e0201033.

Grouios, G. (2004). Motoric dominance and sporting excellence: Training versus heredity. *Perceptual and motor skills*, *98*(1), 53–66.

Häger-Ross, C., & Rösblad, B. (2002). Norms for grip strength in children aged 4–16 years. *Acta Paediatrica*, *91*(6), 617–625.

Hayot, Ch., Vigouroux, L., Rossi, J., Monsabert, B., G., Barla, Ch., & Berton, E. (2014). Measurements of tennis players specific forearm muscle force imbalance to assess the potential risk of lateral epicondylitis. *Procedia Engineering, 72*, 174–179.

Hepping, A. M., Ploegmakers, J. J., Geertzen, J. H., Bulstra, S. K., & Stevens, M. (2015). The influence of hand preference on grip strength in children and adolescents; a cross-sectional study of 2284 children and adolescents. *PloS one*, *10*(11), e0143476.

Hutchinson, M. R., Laprade, R. F., Burnett, Q. M., Moss, R., & Terpstra, J. E. F. F. (1995). Injury surveillance at the USTA Boys' Tennis Championships: a 6-yr study. *Medicine and science in sports and exercise*, *27*(6), 826–831.

Incel, N. A., Ceceli, E., Durukan, P. B., Erdem, H. R., & Yorgancioglu, Z. R. (2002). Grip strength: effect of hand dominance. *Singapore medical journal*, *43*(5), 234–237.

Kocher, M. H., Oba, Y., Kimura, I. F., Stickley, C. D., Morgan, C. F., & Hetzler, R. K. (2018). Allometric Grip Strength Norms for American Children. *Journal of strength and conditioning research*, *00*(0), 1–11.

Kocher, M. H., Romine, R. K., Stickley, C. D., Morgan, C. F., Resnick, P. B., & Hetzler, R. K. (2017). Allometric Grip Strength Norms for Children of Hawaiian Lineage. *The Journal of Strength & Conditioning Research*, *31*(10), 2794–2807.

Loffing, F., Hagemann, N., & Strauss, B. (2012). Left-handedness in professional and amateur tennis. *PLoS One*, 7(11), e49325.

Loffing, F., Sölter, F., & Hagemann, N. (2014). Left preference for sport tasks does not necessarily indicate left-handedness: sport-specific lateral preferences, relationship with handedness and implications for laterality research in behavioural sciences. *PloS one*, *9*(8), e105800.

Molenaar, H. M., Selles, R. W., Zuidam, J. M., Willemsen, S. P., Stam, H. J., & Hovius, S. E. (2010). Growth diagrams for grip strength in children. *Clinical Orthopaedics and Related Research®*, *468*(1), 217.

Noffal, G. J. (2003). Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and nonthrowers. *The American journal of sports medicine*, *31*(4), 537–541.

Omar, M. T., Alghadir, A. H., Zafar, H., & Al Baker, S. (2018). Hand grip strength and dexterity function in children aged 6–12 years: A cross-sectional study. *Journal of Hand Therapy*, *31*(1), 93–101.

Omar, M. T. A., Alghadir, A., & Al Baker, S. (2015). Norms for hand grip strength in children aged 6–12 years in Saudi Arabia. *Developmental neurorehabilitation*, *18*(1), 59–64.

Papadatou-Pastou, M., Martin, M., Munafò, M. R., & Jones, G. V. (2008). Sex differences in left-handedness: a meta-analysis of 144 studies. *Psychological bulletin*, *134*(5), 677.

Pienimäki, T., Tarvainen, T., Siira, P., Malmivaara, A., & Vanharanta, H. (2002). Associations between pain, grip strength, and manual tests in the treatment evaluation of chronic tennis elbow. *The Clinical journal of pain*, *18*(3), 164–170.

Ploegmakers, J. J., Hepping, A. M., Geertzen, J. H., Bulstra, S. K., & Stevens, M. (2013). Grip strength is strongly associated with height, weight and gender in childhood: a cross sectional study of 2241 children and adolescents providing reference values. *Journal of physiotherapy*, *59*(4), 255–261.

Pluim, B. M., Fuller, C. W., Batt, M. E., Chase, L., Hainline, B., Miller, S., … & Wood, T. O. (2009). Consensus statement on epidemiological studies of medical conditions in tennis, April 2009. *British journal of sports medicine*, *43*(12), 893–897.

Ramírez-Vélez, R., Morales, O., Peña-Ibagon, J. C., Palacios-López, A., Prieto-Benavides, D. H., Vivas, A., … & Izquierdo, M. (2017). Normative reference values for handgrip strength in Colombian schoolchildren: the FUPRECOL study. *The Journal of Strength & Conditioning Research*, *31*(1), 217–226.

Raymond, M., Pontier, D., Dufour, A. B., & Moller, A. P. (1996). Frequency-dependent maintenance of left handedness in humans. *Proceedings of the Royal Society of London B: Biological Sciences*, *263*(1377), 1627–1633.

Roetert, E. P., & Kovacs, M. (2018). *Tennis anatomy*. Human Kinetics.

Rossi, J., Vigouroux, L., Barla, C., & Berton, E. (2014). Potential effects of racket grip size on lateral epicondilalgy risks. *Scandinavian journal of medicine & science in sports*, *24*(6), e462–470.

Sell, K., Hainline, B., Yorio, M., & Kovacs, M. (2014). Injury trend analysis from the US Open Tennis Championships between 1994 and 2009. *Br J Sports Med*, *48*(7), 546–551.

Silva, R. T., Takahashi, R., Berra, B., Cohen, M., & Matsumoto, M. H. (2003). Medical assistance at the Brazilian juniors tennis circuit—a one-year prospective study. *Journal of science and medicine in sport*, *6*(1), 14–18.

Soukup, P. (2013). Věcná významnost výsledků a její možnosti měření. *Data a výzkum-SDA Info*, *7*(2), 125–148.

Tutkuviene, J., & Schiefenhövel, W. (2013). Laterality of handgrip strength: age-and physical training–related changes in Lithuanian schoolchildren and conscripts. *Annals of the New York Academy of Sciences*, *1288*(1), 124–134.

Ziagkas, E., Mavvidis, A., Grouios, G., & Laios, A. (2017). Investigating the role of ipsilateral and contralateral eye-hand dominance in tennis serve accuracy of amateur tennis players. *Journal of Physical Education and Sport*, *17*(2), 867.

The effect of the intervention dance program on the level of functional fitness and postural stability in the elderly

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ABSTRACT

Objective: The major objective of this study was to investigate the influence of six months dance intervention program on the level of functional fitness and postural stability in the elderly.
Methods: The exercise program was carried out three times a week and included 60 dance exercise sessions. 60 elderly participated in the study (67.5 ± 5.69 years), 30 in a dance intervention group (weight: 70.32 ± 13.59kg; BMI 25.95 ± 3.79 kg/m^2), 30 in a control group (weight: 76.93 ± 15.45kg; BMI 27.06 ± 3.88 kg/m^2). Three subtests (6Min Walk Test, Chair Stand Test, 8 Foot up and Go Test) were used to determine the level of functional fitness from the Senior fitness test battery; the static posturography method assessed the level of balance abilities in one position.
Results: The most meaningful results to emerge from the data are that the intervention dance program led to a post-exercise increase in the level of agility, dynamic balance and reaction speed measured by 8 Foot up Go test in the intervention group. The results indicate a statistically significant difference value in the intervention group compared to the control group between post-test results (p = 0.01). Values of the other monitored parameters were not statistically significant. The Cohen coefficient d reflects the low (8 Foot up and Go test, 6 Min Walk test) or medium value (Chair Stand test) of the intervention program›s effectiveness.
Conclusions: Our study suggests, that intervention dance program could significantly improve the level of agility, dynamic balance and reaction speed.

***Keywords*:** *aging, dance, Senior fitness test, motor abilities, balance ability*

INTRODUCTION

It has been proven by many studies (Kalvach, 2004; Eijkeren et al., 2008; Uhlíř, 2008) that any regular physical activity is an effective strategy for healthy age/aging. It is one of the most important instruments used to achieve the quality of life in the elderly. Regular physical activity in the elderly population helps to slow down the onset of involution changes. Active seniors can stay self-sufficient and independent longer. Physical activity is also crucial in increasing the resilience of the elderly to disease, preventing certain civilization diseases and reducing the risk events that can lead to death (Ellingson & Conn, 2000; Svobodová, 2017).

Including dance into the offer of physical activities broadens the range of options where everyone can find an activity to match their needs. Dancing has the potential to be an attractive physical activity that can be adjusted to fit a target population's age, physical limitations, and culture (Skotáková, Vaculíková, Sklenaříková & Grmela, 2017). In recent years many authors (Federici, Bellagamba & Rocchi, 2005; Hwang & Braun, 2015; Keogh, Kilding, Pidgeon, Ashley

& Gillis, 2009) agree that dance in many varieties and styles could be a suitable activity for the group of the elderly.

Some dance intervention programs have been proposed to improve the balance ability and reduce falls in aging (Ferrufino, Bril, Dietrich, Nonaka, & Coubard, 2011; Hui, Chui, & Woo, 2009). Other studies focus on increasing the level of endurance, coordination and joint mobility. Their findings confirm the improvement in observed parameters due to the dance intervention program (Cruz-Ferreira, Marmeleira, Formigo, Gomes & Fernandes, 2015; Zhang, Ishikawa-Takata, Yamazaki, Morita & Ohta, 2008). A positive, statistically significant effect of the dance programs on the strength of the lower limbs, which can be the limiting factor in falls, is also demonstrated in several studies (Granacher et al., 2012; Merom et al., 2016; Zhang et al., 2008).

If we count the benefits of the dance, we cannot ignore psychological and sociological influence as in the studies of Dosedlová (2012), West, Otte, Geher, Johnson & Mohr (2004) and Winkelmann et al. (2004). The social relations – fellowship among the participants of dance exercise programs, play a significant role in the quality of their lives. It is about creating pleasant experiences, positive feelings while dancing and also the pleasure of movement that the seniors themselves consider to be very important.

The aim of the contribution si to investigate the effect of the dance intervention program on the level of functional fitness and postural stability in a group of elderly. This article is one of the outputs of the project "The effect of an intensive dance-exercise intervention on cognitive functions and cerebral plasticity changes in healthy seniors and seniors with mild cognitive impairment".

In another forthcoming publication (another output of the same project) entitled "Dance-Movement Activities for Healthy Seniors and Seniors with Mild Cognitive Impairment") we monitor the impact of this dance-exercise intervention on the same parameters in seniors divided, based on MRI (magnetic resonance imaging) and psycho-tests results, into healthy seniors and seniors with Mild Cognitive Impairment.

METHODS

Participants

Our sample consisted of 60 older adults (44 women, 16 men) over the age of 60 (67.5 ± 5.69 years). Elderly participants were recruited using the snowball technique from several sources. A cooperating organization which provided education for the elderly (U3A, Senior academy, ...) were addressed, recruitment was also carried out free advertising in community newsletters and key places (libraries or local authorities).

Inclusion criteria

Based on a structured interview all participants were non-smokers, without any serious diseases that would impede the implementation of dance and movement activities in the specified scope and duration. None of the participants was engaged in a regular sports activity that is more frequently practiced or more demanding than our intensive dance-exercise intervention.

All participants were asked to sign an informed consent form approved by the Ethics Committee of Masaryk University, Brno. The Ethic committee application number was 13/2015.

The participants were randomly divided in 1 : 1 ratio. Half of the group (24 women, 6 men) underwent a 6-month dance-exercise intervention; the second half (20 women, 10 men) was a control group. Participants were asked to maintain their usual daily regimen with the same amount of physical activity and normal daily lifestyle. The descriptive characteristics (age, BMI, weight, number of men and women) of the study sample are shown in Table 1.

Tab. 1: Descriptive characteristics of the study sample

	Experimental group		Control group	
	M	*SD*	*M*	*SD*
Age	68.24	5.00	67.19	6.70
BMI	25.73	3.60	27.20	3.90
Weight (kg)	70.02	13.70	77.03	15.20
	N	*%*	*N*	*%*
Male	6	20	10	33.3
Female	24	80	20	66.6

Note: M – mean, SD – standard deviation, N – number, % – percentage, BMI – body mass index

Methods

Three tests from the Senior fitness test (SFT) battery determined the level of functional fitness and one test on the "FootWork Pro" stabilometric platform assessed the level of postural stability. All three controlled functional tests were performed in a gym, the static posturography test and body composition measurements (BMI characteristics) were carried out in a laboratory. Body composition measurements were found out using the direct segmental multi-frequency bioelectrical impedance analyzer (Inbody 230).

All participants participated in the testing two times (two identical experimental tests and measurements before and after the six months of the intervention program). Firstly, the anthropometric characteristics were found out, followed by static posturography and functional tests. All tests and measurements lasted about 40 minutes.

Senior Fitness Test (SFT) was created to evaluate the individual components of functional fitness in older adults. Subsequent tests assessing the level of motor abilities that can be improved due to dance intervention program and that are also closely related to performing daily tasks were chosen.

- 30 Chair stand test: assessing the level of the strength of lower limbs,
- 6 Minute Walk test: assessing the level of endurance,
- 8 Foot up and Go test: assessing the level of agility, dynamic balance and reaction speed (Rikli & Jones, 2013).

Static posturography allows a precise assessment of the static balance level. Due to measurements on the "FootWork Pro" stabilometric platform, the precise results indicating the foot pressure layout and its changes in feet during the measurement and center of pressure (COP) movements can be assessed and visualized (Amcube, 2015). Lower numerical values indicate the minor deviation of the center of gravity. We measured the center of pressure trajectory (COP), the center of gravity deflection in forward (DF) and right-hand directions (DR). For assessing the level of balance ability we used one standardized subtest:

For assessing the level of balance ability, we can use one standardized subtest:

- "Broad posture": the standing position with legs width of the pelvis, arms along the body, eyes open – holding the position for 30 s

Intervention program

The intervention program was conceived as "a world tour." Dances like polka, Irish dance, African dance, Greek dance and tango were performed. More famous dances such as Polka and Irish dance have been taught first. Later, more demanding dances were included in terms of both motor and rhythm.

The exercise program was carried out three times a week and included 50 dance exercise sessions. Each session (60 minutes) contained parts of dance choreography, preparatory and general exercises focused on developing a good posture, a breathing and relaxation exercises. An experienced trainer and an assistant led the individual lesson.

After each dance-movement class, feedback from the participating seniors was obtained using a standard evaluation sheet for each lesson. The evaluation included the opinions of the participants on the musical accompaniment, on the dance activity and also on the point of view of their physical and mental state during the whole class. The evaluation sheet contained four closed descriptive characteristics with a scale from 1 "strongly disagree" to 6 "strongly agree." The part of the evaluation was also the opened sentence: "I would recommend..." which offered participants to write their comments and recommendations.

Compliance with the intervention was registered and calculated as a percentage of the sessions attended. Subjects whose attendance was lower than 60 % were not included in the data analyses.

The more detailed description of the unit:

The introductory part lasting about 10 minutes consisted of warm-up (e.g., movements around the gym performed on rhyme of the music, gait in different positions – on toes, on heels, on inner or external parts of feet, on bent knees...), mobilization exercises and dynamic stretching of main muscles with tendency to become shortened.

In the main part (30 min) steps of dance choreography were taught. Steps were gradually linked into the short sequence and repeated several times concerning seniors' individual needs. After completing the new part, the sequences taught in previous lessons were repeated, and the whole routine was formed and repeated several times. At the end of the main part, the mastered dances were replayed too. To raise the level of difficulty, we introduced new stimuli, such as the initial layout of participants. The final part was aimed at balance exercises (using balance equipment – fit balls, over balls, bosu, ladder), and on strengthening exercises (targeted, e.g., on muscles responsible for a good posture and muscles with the tendency on weakness). All workouts could be alternated with respect to individual particularities of each participant.

The final part included the stretching and short relaxation including respiratory exercises.

Statistical analyses

For analysis of obtained data, we used IBM SPSS Statistics 25 software. The data were evaluated using descriptive statistics: arithmetic mean and standard deviation. The data were not normally distributed; therefore Wilcoxon and Mann-Whitney U test were used. To identify the statistical significance of the differences between pre-test and post-test in both groups the Wilcoxon sign rank test was used. Mann-Whitney U test was applied to the significant results, to identify if the significance survives between groups comparison. Statistical significance was set at $p \leq 0.05$. The Cohen coefficient d, representing the effect size, was assessed to compare the effect of the intervention dance program on all monitored variables.

RESULTS

Table 2 shows the descriptive statistics (mean, standard deviation) and the statistical significance values of individual Senior fitness tests and postural stability measured before and after the intervention dance program in the intervention and the control group.

Tab. 2: Descriptive statistics functional fitness and balance values in intervention and control groups

	Intervention group			Control group		
	Pre-test	**Post-test**		**Pre-test**	**Post-test**	
	M ± SD	*M ± SD*	*p-value*	*M ± SD*	*M ± SD*	*p-value*
SFT						
6 Min Walk (m)	588.16 ± 77.4	622 ± 63.79	**0. 000***	574.5 ± 78.28	601.79 ± 90.85	**0.01***
Chair Stand (number)	16.40 ± 3.73	18.30 ± 3.58	**0.03***	15.66 ± 3.53	16.14 ± 4.31	0.79
8 Foot up Go (s)	4.93 ± 0.99	4.64 ± 0.80	**0.01***	5.06 ± 0.90	5.17 ± 1.39	0.82
LB						
COP (cm2)	2.65 ± 1.47	2.78 ± 2.76	0.26	2.08 ± 1.47	2.58 ± 2.76	0.42
RD (cm)	1.54 ± 0.72	1.39 ± 0.58	0.22	1.25 ± 0.54	1.48 ± 0.86	0.31
FD (cm)	2.23 ± 0.99	2.16 ± 1.09	0.20	1.98 ± 0.65	2.01 ± 1.02	0.76

*Note: M – Mean, SD – standard deviation, SFT – Senior fitness test, LB – level of balance, COP – Center of pressure, RD – Center of gravity, deflection in the right-hand direction, FD – Center of gravity deflection in the forward direction, p-value – statistical significance, * $p \leq 0.05$*

The table 2 shows that both groups increased significantly the level of aerobic endurance measured by 6 Min Walk test in comparison with the pre-test (experimental group p = 0. 000, control group p = 0. 001).

The tendency to improve we can also observe in the Chair Stand test assessing the level of strength of lower limbs and in the level of agility, reaction speed and dynamic balance measured by 8 Foot-Up-and-go Test. The intervention group increased the level of these abilities significantly (p = 0.03 in Chair stand test, p = 0.01 in 8 Foot-Up-and-go Test). In the control group there is the only slight, non significant, enhancement (p = 0.79 in Chair stand test, p = 0.82 in 8 Foot-Up-and-go Test).

Regarding postural stability there were no statistically significant changes in post-test compared with pre-test in either group after 6 months.

The effectiveness of the intervention dance program: SFT and the level of balance

For greater clarity, the obtained results of the level of functional fitness and postural stability will be interpreted separately.

Table 3 presents the results of the effectiveness of the intervention dance program in Senior fitness tests and balance level indicated by p-value (statistical significance) and Cohen coefficient *d* (Effect size).

Tab. 3: The effectiveness of the intervention dance program: SFT and the level of balance

		p-value		Cohen's d	
		experimental group	control group	experimental group	control group
SFT					
	6 Min Walk (m)	0.28		0.2	
	Chair Stand (number)	0.21		0.5	
	8 Foot up Go (s)	**0.01***		0.4	
LB					
	COP (cm^2)	0.18		0.0	
	RD (cm)	0.23		0.1	
	FD (cm)	0.30		0.1	

Functional fitness

The results (Table 3) show that the intervention dance program affected the most the level of agility, reaction speed and dynamic balance measured by 8 Foot-Up-and-go Test. In the intervention group, there was a significant change from the pre-test, and the result was also statistically significant compared to the change of the control group (***p* = 0.01**). The Cohen's *d* value reaches 0.4 that reflects a low size effect.

Both groups increased the level of aerobic endurance measured by 6 Min Walk test in comparison with the pre-test, but the result is not statistically significant ($p = 0.2$). The value of Cohen's *d* indicates a low size effect (0.2).

The same tendency we can observe in the Chair Stand test assessing the level of strength of lower limbs. Intervention group improved the level of this ability, but the result is not statistically significant compared to the control group ($p = 0.21$). Cohen's coefficient *d* value exceeds 0.5 that indicates the medium level of effect size.

Postural stability

Based on the results (Table 3) we can confirm there are no statistically significant changes in any monitored parameters (COP, RD, FD) in the "broad posture" test that finds out the level of static balance. The value of Cohen coefficient *d* in all reliable (COP, RD, FD) indicates a low effect.

DISCUSSION

Recently, the quality of life in senior age is often discussed (Ellingson & Conn, 2000, Von Bonsdorff, 2016). Due to the aging of the population, the necessity of regular physical activity in the elderly is often mentioned (Kalvach, 2004, Eijkeren et al., 2008). The appropriate physical activities can slow down the aging process and thus to contribute to increase or to maintain the good level of the quality of life.

In our research, the statistically significant values of **8 Foot up and Go test** showed the increasing level of this monitored parameter in the intervention group compared to the control group ($p = 0.01$, Cohen's $d = 0.4$). The research of Kattenstroth et al. (2010) suggests the same effect of the dance intervention program on the experimental group in comparison with the con-

trol group. 8 Foot up and Go test evaluates the level of agility, dynamic balance and reaction speed. These abilities are used in day-to-day activities, in fast body position changes while, e.g., working in the kitchen or shopping. The increasing level of these abilities in our intervention group could be caused by frequent direction changes during choreography, by the necessity of space orientation to follow the choreography and also by using some balance demanding positions.

Although the resulting values of **6 Min Walk test** did not reveal any statistically significant changes (p = 0.28, Cohen's d = 0.2) in the intervention group compared to control group, we have to mention the growth of the level of endurance ability in the intervention group. This positive tendency may be due to the fact that the main part of the session lasted for 30 minutes and the steps, dance sequences or already mastered dances were replayed many times. The results of the control group could be influenced by the season in which the measurements took part. The post-test measurements were held in spring, when seniors are engaged in gardening or starting to walk in the countryside. The positive effect of the dance intervention programs on the endurance ability in seniors is mentioned in many types of research (Cruz-Ferreira et al., 2015; Hui et al., 2009). Similarly, Shanahan et al. (2016) in the results of their study suggest that the regular participation of seniors in dance sessions is associated not only with the increasing level of endurance ability but also by raising of balance ability and with many health benefits and also by improving the quality of life.

The result of **the Chair stand test**, assessing the level of lower limbs strength, did not show any statistically significant value (p = 0.21) compared to the control group. Cohen's coefficient d value indicates the medium level of effect size (Cohen's d = 0.5). Even though the dance intervention program was not specifically aimed at developing the level of lower limb strength, the experimental group was able to improve this parameter. The growing tendency could result from the use of dance steps and some exercises in the final part of the session on bent knees. Due to this fact, the level of lower limbs strength could increase – the similar results we can see in Kattenstroth at al. (2013) research. Six months of dance intervention program led to improving the level of this monitored parameter in the experimental group, unlike the control group that worsened in this test. The positive, statistically significant effect of the lower limb dance programs is also demonstrated in studies of Zhang et al. (2008) or Merom et al. (2016). The sufficient level of the strength ability is necessary e.g., climbing stairs, rising from the chair, getting out of the car and also plays a crucial role in fall prevention.

Concerning the level of static balance assessed by **"broad posture" test,** we did not find out any statistically significant differences any monitored parameters (COP, RD, FD). The level of effect size in all reliable (COP, RD, FD) indicates a low effect. Unlike our research, another study (Sofianidis et al. 2009) has shown an increasing level of balance ability due to the dance intervention program (the Greek dance). The positive effects of Caribbean dance on the level of static balance, joint mobility, strength and coordination is mentioned in the study of Federici, Bellagambam & Rocchi (2005). According to Koegh et al. (2009) the main benefit of dance in the elderly is to improve the level of balance ability and reduce the risk of falls.

The study limitations

The pre-test results could be caused by the ignorence of the tests. In post-test measurements the learning effect could positively influence the results. Furthermore, the different level of motivation of the tested sample was observed. This fact could be affected by the current mental and physical state of mind. The results could also be influenced by the season in which the measurements took part. The post-test measurements held in spring, when seniors are engaged in gardening or starting to walk in the countryside. We can assume that their fitness level may be affected by this fact.

CONCLUSION

Our study suggests, that intervention dance program significantly improved the level of agility, dynamic balance and reaction speed. The level of aerobic endurance, the same as the level of leg strength did not reveal any statistically significant enhancement. However, in both mentioned parameters (aerobic endurance and the lower limb strength) we could see a slight improvement. Based on the results there are no statistically significant changes in the level of postural stability. Even if the dance intervention program did not have a more significant effect on the level of all tested parameters, we must state that only a slight improvement or a steady level of functional fitness and postural stability is a positive result in this age.

Apart from the importance of maintaining the level of physical fitness in senior age at a sufficient level, the positive impact of dance on psychological and sociological parameters must not be neglected. It is precisely the effect of the dance program on the chosen psychological characteristics and their link with the change in the quality of life of seniors, or life satisfaction, could be another topic of the research work.

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REFERENCES

Cruz-Ferreira, A., Marmeleira, J., Formigo, A., Gomes, D., & Fernandes, J. (2015). Creative Dance Improves Physical Fitness and Life Satisfaction in Older Women. *Research on Aging*, *37*(8), 837–855. https://doi.org/10.1177/0164027514568103.

Dosedlová, J. (2012). *Terapie tancem*. Praha: Grada Publishing a. s.

Ellingson, T., & Conn, V. S. (2000). Exercise and quality of life in elderly individuals. *Journal of Gerontological Nursing*, *26*(3), 17–25.

Federici, A., Bellagamba, S., & Rocchi, M. B. L. (2005). Does dance-based training improve balance in adult and young old subjects? A pilot randomized controlled trial. *Aging Clinical and Experimental Research*, *17*(5), 385–389.

Ferrufino, L., Bril, B., Dietrich, G., Nonaka, T., & Coubard, O. A. (2011). Practice of Contemporary Dance Promotes Stochastic Postural Control in Aging. *Frontiers in Human Neuroscience*, *5*. https://doi.org/10.3389/fnhum.2011.00169.

Granacher, U., Muehlbauer, T., Bridenbaugh, S. A., Wolf, M., Roth, R., Gschwind, Y., … Kressig, R. W. (2012). Effects of a Salsa Dance Training on Balance and Strength Performance in Older Adults. *Gerontology*, *58*(4), 305–312. https://doi.org/10.1159/000334814.

Hui, E., Chui, B. T., & Woo, J. (2009). Effects of dance on physical and psychological well-being in older persons. *Archives of Gerontology and Geriatrics*, *49*(1), 45–50. https://doi.org/10.1016/j.archger.2008.08.006.

Hwang, P. W.-N., & Braun, K. L. (2015). The Effectiveness of Dance Interventions to Improve Older Adults' Health: A Systematic Literature Review. *Alternative therapies in health and medicine*, *21*(5), 64–70.

Kalvach, Z. (2004). *Geriatrie a gerontologie.* Praha: Grada Publishing, 2004. ISBN 80-247-0548-6.

Kattenstroth, J.-C., Kolankowska, I., Kalisch, T., & Dinse, H. R. (2010). Superior Sensory, Motor, and Cognitive Performance in Elderly Individuals with Multi-Year Dancing Activities. *Frontiers in Aging Neuroscience*, *2* (31). https://doi.org/10.3389/fnagi.2010.00031.

Kattenstroth, J.-C., Kalisch, T., Holt, S., Tegenthoff, M.& Dinse, H. R. (2013). Six months of dance intervention enhances postural, sensorimotor, and cognitive performance in elderly without affecting cardio-respiratory functions. *Frontiers in Aging Neuroscience*, *2* (31). https://doi.org/10.3389/fnagi.2013.00005.

Keogh, J. W. L., Kilding, A., Pidgeon, P., Ashley, L., & Gillis, D. (2009). Physical Benefits of Dancing for Healthy Older Adults: A Review. *Journal of Aging and Physical Activity*, *17*(4), 479–500. https://doi.org/10.1123/japa.17.4.479.

Merom, D., Mathieu, E., Cerin, E., Morton, R. L., Simpson, J. M., Rissel, C., … Cumming, R. G. (2016). Social Dancing and Incidence of Falls in Older Adults: A Cluster Randomised Controlled Trial. *PLOS Medicine*, *13*(8). https://doi.org/10.1371/journal.pmed.1002112.

Pávková, J. (2008). *Pedagogika volného času: [teorie, praxe a perspektivy výchovy mimo vyučování a zařízení volného času*. Praha: Portál.

Rikli, R. E., & Jones, C. J. (2013). *Senior fitness test manual* (2nd ed). Champaign, IL: Human Kinetics.
Shanahan, J., Coman, L., Ryan, F., Saunders, J., O'Sullivan, K., Ni Bhriain, O., & Clifford, A. M. (2016). To dance or not to dance? A comparison of balance, physical fitness and quality of life in older Irish set dancers and age-matched controls. *Public Health*, *141*, 56–62. https://doi.org/10.1016/j.puhe.2016.07.015.
Skotáková, A., Vaculíková, P., Sklenaříková, J., & Grmela, R. (2017). The effect of dance interventions at the level of chosen physical abilities in elderly people. Review. In *Sport and quality of life 11th International Conference on Kinanthropology, 29. 11.–1. 12. 2017*. Brno: Masarykova univerzita.
Sofianidis, G., Dimitriou, A.-M., & Hatzitaki, V. (2017). A Comparative Study of the Effects of Pilates and Latin Dance on Static and Dynamic Balance in Older Adults. *Journal of Aging and Physical Activity*, 25(3), 412–419.
Svobodova, L. (2017). Dance Contribution to Improving Physical Activity and Health. *8th International Scientific Conference on Kinesiology*, 307–311.
Uhlíř, P. (2008). *Pohybová cvičení seniorů.* Olomouc: Univerzita Palackého v Olomouci.
Van Eijkeren, F. et al. (2008). Nordic walking improves mobility in Parkinson's disease. *Movement disorders*. Retrieved from: https://doi.org/10.1002/mds.22293.
Von Bonsdorff, M. B. (2016)**.** Midlife work ability and mobility limitation in old age among non-disability and disability retirees. *BMC Public Health*, doi: 10.1186/s12889-016-2846-y.
West, J., Otte, C., Geher, K., Johnson, J., & Mohr, D. C. (2004). Effects of Hatha yoga and African dance on perceived stress, affect, and salivary cortisol. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine*, *28*(2), 114–118. https://doi.org/10.1207/s15324796abm2802_6.
Winkelmann, A., Tharicharu, J., Lissner, P., Beauchet, O., Gold, G., & Kressig, R. W. (2004). Exercise promotion among geriatric in-patients: Tai Chi and dance. *Medecine Et Hygiene*, *62*(2484).
Zhang, J.-G., Ishikawa-Takata, K., Yamazaki, H., Morita, T., & Ohta, T. (2008). Postural stability and physical performance in social dancers. *Gait & Posture*, *27*(4), 697–701. https://doi.org/10.1016/j.gaitpost.2007.09.004.
Amcube. (2015). Footwork Pro Pressure Plate, Pressure Measurement. Retrieved from 18. říjen 2018, z http://www.amcube.co.uk/products/footwork-pro-pressure-plate/.

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SOCIAL SCIENCES

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"Olympism" and Olympic Education in Greek Antiquity

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Abstract

This paper deals with basic points which comprise Olympic and "sport" education in the Greek antiquity. Until the emergence of professionalism in ancient athletics was the essence of "sport" education and Olympism the areas known as free "sport", nudity, construction of "sports" buildings, organizing of many games and relation of society to the Olympic winners as well as leading the citizens to cultural and philosophical ideals. The education itself to the Olympic Games and "sport" had an important role in ancient Greece. Victory in the Panhellenic Games was very important not only for the victors as individuals, but also for their lineage and the city-state. Each victor entered the next level, which was close to the heroes and gods. They acquired semi-divine status and the homages for them by all society and mainly by the city-states were greatly important for cultural outputs and conception of all society. The influence of victors on youth was huge and this influence was one of the most important educational parts of all ancient Greek culture. The winners of great Panhellenic Games, especially the winners of the Olympic Games or περιοδονίκοι (periodonikoi), were the best role models with big cultural power and the best examples for youth. Successes of ancient athletes supported sport education of young Greek boys, thus also the military training and this conception created better warriors and defenders of the city-states.

Key words: *Games, Greek antiquity, nudity, olympism, olympic education, sport buildings, winners.*

INTRODUCTION

This contribution deals with basic points which comprise Olympic and "sport" education in the Greek antiquity. The use of the word Olympism for antiquity is problematic because it was created afterwards, but there were many similar tendencies among them. Especially the name itself is derived from ancient Olympia, where the Olympic Games had their origin. Furthermore, the education itself to the Olympic Games and "sport"[1] had an important role in ancient Greece.

Victory in the Panhellenic Games (Olympia, Delphi Isthmos, Nemea) was important not only for the winners as individuals, but also for their lineage and the city-state. Many tyrants, often from Magna Graecia, mainly from Sicily, used this to promote their own political regime; therefore sometimes they also bribed the gifted ἀθληται (*athlétai*) or victors to move and compete on the games for their name and community.

METHODOLOGY

This paper is a historical contribution. The data was gained mainly from primary sources, relevant professional literature and ancient arts.

Used methods were gathered from the primary and secondary sources. The methods that were used were comparation method, biography method, progressive method, direct and indirect methods.

[1] Or rather the ἀγών (*agon*).

As the way of processing data, results from primary and professional literature and ancient arts, as well as criticism of the sources, interpretation and synthesis were compared.
Sections of the connection between Olympism and Olympic Education in ancient Greece
The importance of the Panhellenic Games and "sport" led to a great state support, which was manifested mainly in the following sections:

1. free "sport",
2. nudity as a substance of *ισονομία* / ***δημοκρατία***[2],
3. construction of "sports" buildings,
4. organizing of many all-Greek and local games,
5. promotion and support of the winners.

At the same time, these areas were basic for the Olympic education in Greek antiquity and each *πόλις* (*polis*) placed considerable emphasis on them, because "sport" was associated with *τῑμή* (*time*, honour) and other virtues, which spread through Greek society, from religion to everyday life and from art to politics and warfare. Mentioned areas above and upbringing to the true types / ideals of Greek culture were the essence of the "Olympism" and Olympic education in Greek antiquity until the uprise of the professionalism in"sport".

Free "sport"

Theoretical instruction was often held in ancient Greece in private schools and it was defrayable, so it depended on the parents of the boys what education they were able to provide them with. These schools were not to be open after sunset and before dawn. But that was not a rule for all Greece; the opposite was e.g. Sparta, where private schools did not exist. Beyond theoretical and musical education here was also *γυμνικός* (*gymnikos*) education, that contained running, jumping, wrestling, discus throw, javelin and swimming. The *παλαίστρᾱ* (*palaistra*) was for fourteen years old boys and unlike other schools, the *παλαίστρᾱ* was free. After completing of this education, young boys from wealthy families could continue in further education; they had a choice of philosophy, rhetoric, geometry, astronomy, politics, lawmaking, art of war and higher *γυμνικός* (Cambiano, 2005; Šílený, 1947; Zamarovský, 2003).

The reason was to allow access to all sports fields and to make sport free so even the poorest could participate. But the main reason for the big expansion of "sport" in Greece was the need for excellent physical preparation of Greek aristocracy as defenders of the homeland (in a sense of their dual identity – protection of their own *πόλις* and protection of Greece) against the external and internal enemies. In addition to alien attempts to subjection the Greeks, there was also a great danger by slaves, whose number was often higher than the number of freemen and semi-freemen. In physical violence "*and in a weapon, held by a muscular and trained hand, was the most effective guarantee of the unlimited obedience of the exploited men and lordly welfare*" (Sábl, 1960, p. 12: translated from the Czech). Without support of "sport", physical exercises and military training, this ruling class would be destroyed.

From the above-mentioned reasons and not only from it, "sport" and physical exercises were free for the Greeks. The Greeks had to pay for education and acquirement, but not for "sport", if they had time, they could go to the ***γυμνάσιον*** or the *παλαίστρά* and exercise whenever. This situation is not very realistic nowadays, because modern states and countries will never support sports so much as long as the commerce, the *πλεονεξίά* (*pleonexia*) and the *ὕβρις* (*hybris*) prevails here.

[2] *Isonomia* / *demokratia*.

Nudity like a substance of *ισονομία / δημοκρατίᾱ*

Ancient Greeks competed naked. Originally, athletes had their flank and waist covered by a loincloth, so called *ζῶμα*, *διάζωμα* or *τρίβων*[3], but later they removed it (Golden, 2005, p. 131). According to the legend, it was because of the runner Orsippus/ Orhippus of Megara (and after him also because of Acanthus, a long-distance runner from Sparta) in 8th century B. C. at Olympia, whose *διάζωμα* fell during the race; but he continued in the running *ἀγών* and won. The *ἀθληται* gradually followed his example and nudity became a rule (Newby, 2006; Potter, 2012). The source of this legend was Orsippus›s tomb with Simonides's epigram (Hyde, 1921). According to other sources, mainly the Spartans expanded this practice. At the beginning of the archaic period the Spartans wore a light garment during the exercise, which they undressed later. Artistic displaying of the naked Spartans and Greek *ἀθληται* was a realistic depiction of the reality; it was not only artistic and heroic depictions. The introduction of nudity had also something to do with Greek mythology and rituals, its sense was largely religious (Jirásek, 2009); it was understood as an expression of culture and not as something to be ashamed of – to be ashamed was a sign of barbarism. Its significance and meaning was given by a set of values attributed to nudity, cultural and social environment (Jirásek, 2009). Modern historians derive the origin and genesis of nudity from prehistoric hunting, initiating of young boys and admiring of a male body (Golden, 2005, p. 111–112).

The meaning of nudity was not only religious and practical, but also symbolic; here the inequality was deleted. An ordinary naked young man or any man competing against a naked aristocrat was equal to him at this moment, there was nothing unnatural that would make them different. An aristocrat could be equal to a common slave if they clashed in the *gymnasion* (*γυμνάσιον*). The men were not separated by their expensive dress or badges of dignity and their roles, but only by their own body shape, strength, speed, endurance and dexterity; when the *ἀγών* started, they were separated only by their own *ἀρετή*. Also the last boy could compete with the noblest and defeated him in run, *πάλη* (*pale*) or *παγκράτιον*[4]. The ισονομία was the best fulfilled in the ***γυμνάσιον***, in the place of the clash of people where at the same time everyone was socially *ἴσος* (*isos*). The *γυμνάσιον* become an important means of increasing of human pride and equality. We can observe the first elements of the *δημοκρατίᾱ* not in the field of society in general, politics, philosophy, or science, art, *paideia* (*παιδεία*)[5], but in the field of ancient physical exercises through nudity.

The importance of nudity in Greek world was confirmed also by the significance of the term for nudity itself, *γυμνός*, *gymnos* (traditionally was the term *γυμνός* understood as naked, meaning unarmed, which also refers to the concept of Homer's expression ***γυμνός***, as "without weapon"). This term was also a part of the name of some festivities like for example the Gymnopaedia and the basic of the term for a trainer (***γυμναστής***, *gymnastés*) and a name for the main Greek "sport" competitions (*γυμνικός ἀγών*, *gymnikos agon*).

Construction of "sports" buildings

"Sports" buildings were an important, inherent and essential part of Olympic education in the antiquity. These were the *στάδια*, the *ἱππόδρομοι*, the *παλαίστραι* and the *γυμνάσια*.

The basic construction of Greek "sport" was the *στάδιον*, which formed a race track of a rectangular shape at one end, the track was semicircularly rounded and had different lengths: the Olympic στὰδιον measured 192,27 meters, the Delphic had 177,6 meters, Isthmian had 181,2

[3] Spartan short coat.

[4] *Παγκράτιον*, *pankration*, was combination of *πάλη* and *πυγμή* (*pygme*).

[5] The word *παιδεία* (a game) was derived from the word *παῖς*, *pais* (a child). The opposite was the term *σπονδή*, spondé (serious) as the activities which were practiced by adults (Cambiano, 2005). It was actually about upbringing, the life struggle of the soul for self-liberation from the ignorance of the supreme good, which is the trellage on the way to true bliss – Plato understood this ignorance as a source of all evil (Jaeger, 1986).

meters, Athenian had 184,9 meters, Miletian had 177,4 meters, Aiginian had 196,8 meters, attic measured 164 meters, ... (Kössl et alii, 1982; Prach, 1998; Zamarovský, 2003, p. 55), and the *ἱππόδρομος*[6], which was built for equestrian races. Its length was various, but one circle measured approximately 1125–1200 meters.

Other construction associated with Greek "sport" was the *γυμνάσιον*. Its part was the *παλαίστρᾱ*, an open and covered running track where was a place for long jumps, throws and boxing, a place for ball games and premises for a body care and hygiene as dressing rooms, bathrooms, swimming pools, massage rooms etc. The γυμνάσιον included also a buffet; later were its parts swimming pools and a spa. Hermes the god was the inventor of this building (according to the myth) and here he had many sculptures (here were also the statues of the god Eros). The *γυμνασίαρχος* was responsible for the *γυμνάσια* (Golden, 2005, p. 73). Since 100 B. C. each *γυμνάσιον* was equipped with the *hypocaustum* (special central heating). In each (even small) city were usually several of these buildings (e.g. the Academy, the Lyceum, the Cynosarges – also for the underprivileged citizens (Grexa, 2009; Kössl et alii, 1982; Olivová, 1988; Zamarovský, 2003). The *γυμνάσιον* was to develop the *ἀρετή* of the *ἀθληται*, there were also lessons for teenagers, who were twelve years old. The *ἀθληται* in the *γυμνάσιον* exercised and strengthened naked, only lubricated with oil. Entrance to the γυμνάσιον was a sign of social differentiation. Its main development was associated with increasing leisure time (*σχολή*) of free (also poorer) inhabitants, who visited it often after their work, *ἀσχολία* (Grexa, 2008). The *γυμνάσιον* at Olympia was situated in the west and there were two backyards. The *ἀθληται* in Olympia were preparing for competitions here. Vitruvius described the *γυμνάσιον* in more details: "*In palaestris peristylia quadrata sive oblonga itasunt facienda, uti duorum stadiorum habeant ambulationis circumitionem, quod Graeci vocant δίαυλος, ex quibus tres porticus simplices disponantur, quarta, quae ad meridianas regiones est conversa, duplex, uti, cumtempestates ventosae sint, non possit aspergo in interiorem partempervenire. Constituantur autem in tribus porticibus exhedrae spatiosae, habentessedes, in quibus philosophi, rhetores reliquique, qui studiis delectantur, sedentes disputare possint*" (Vitr. 5.11.1–2).[7] The running track in the *γυμνάσιον* was called *ξυστός* , *xystos*, (from *ξύω*, adjust); it referred to Heracles, who weeded out the bush in Olympia because of runing (Sábl, 1968).

The *παλαίστρᾱ* was a part of the *γυμνάσια*, but sometimes it could be situated alone. Its name is derived from a Greek verb *παλαίω* (*palaio*), I wrestle (*πάλη*, wrestling). Here were also the *αὐληται* (*auletai*, fluteplayer), who accompanied the *ἀθληται* with music (Bouzek & Ondřejová, 1989).

Organizing of many all-Greek and local games

In ancient Greece there were organized many games. The most famous of them were the Great Panhellenic games at Olympia, Delphi, Isthmos and Nemea and also the Great Panathenia. But there were also a number of larger and smaller local games.

We also know, for example, about the Boedromia as the celebration of the victory of Theseus over the Amazons or to the honour of Apollo Boedromios (Hurry to help in distress), the Heracleia in Marathon, Thebs, Argos, Samos, Syros). In Argos took place e.g. the Sthenia and the Heraean Games; in Megara the games to honor Apollo, the Pythaea and the Alcathoa, the son of Pelops; in Eleusis the games to honor the goddess Demeter; in Rhodos the games the Tlepolemia to honour

[6] From the *ἵππος*, the horse and the *δρόμος*, run or race track.

[7] "*I think it best to set forth the traditional way, and to show ob long peristyle in a palaestra should be so formed that the circuit of it makes a walk of two stadia, a distance which the Greeks call the δίαυλος. Let three of its colonnades be single, but let the fourth, which is on the south side, be double, so that when there is bad weather accompanied by wind, the drops of rain may not be able to reach the interior. I think it best to set forth the traditional way, and to show ob long peristyle in a palaestra should be so formed that the circuit of it makes a walk of two stadia, a distance which the Greeks call the δίαυλος. Let three of its colonnades be single, but let the fourth, which is on the south side, be double, so that when there is bad weather accompanied by wind, the drops of rain may not be able to reach the interior*" (translation by M. H. Morgan, 1914).

Tlepolemus, the son of Heracles and Astydameia, the founder of settlements on the Rhode Island, who died before Troy; in the spring there was a feast of the god Helios, the Helieia (a part of these games were also *μουσικός* and *γυμνικός ἀγών* and the winners received a wreath from white poplar branches; in Delos took place the Delia and the Apollonia or the lesser Delia (these games took place also in Lesbos); in Lesbos (same as in Naxos, Tenedos and Chios) took place the Dionysia; in Thebes was the Iolaea or Iolaia to honour Iolaus, a friend of Heracles; in Epidaurus took place the Asklepia. The games were also in Ephesus, Smyrna, Puzzuoli, Macedonia, Cyrene, Sicily etc. In Plataea took place the Eleutheria (celebrated every five years as a celebration of the victory over Persia, an important race was *ὁπλείτης* here), in Lebadeia in Boeotia was celebrated the Basileia (as a celebration of the defeat of the Spartans at Leuctra in 371 B. C.; this festival was also in the other places) and the Trophonian. After the Battle of Actia, there were held the Actia Games. In Piraeus in Athens, in Sparta (for girls) and in Eleusis took place the Dionysia. Games were held also in Salamis, Pergamon, Tanagra, Koroneia (the Pamboeotia – the all-boeotians games), Amykles (the Hyakinthia), Sparta (the Carnea, the Leonidaia, the Urania). The games founder was also Alexander the Great and the Diadochi, e.g. the Demetria, the Alexandria, the Eumenia, the Ptolemaia, the Seleukeia, the Philataireia, the Attaleia etc.; likewise also the Romans (Sábl, 1960).

Promotion and support of the winners

Νίκη, nike, in ancient Greece, was not only a victory itself, but also Greek goddness, the daughter of Pallas (Combat), the Titan, and Styx (Hatred), her sister was Bia (Force) and her brothers were Kratos (Strength) and Zelos (Emulation/Endeavor). In the war between gods and titans she fought for Zeus (Hes., *Th.* 383–400). The goddness was often depicted as standing or a flying creature. She held a winner's wreath or a ribbon in her hands and brought this to the victors. Thus, she was the nikephoros, "bringer of victory" (Weiler, 2012, p. 22).

The success of ancient Olympic victors was something godlike. With the victory at Olympia, ancient athletes entered into the significance level, which was similar as the stratum of the gods and demigods. Equivalent of this great glory was only possible to find on the field of warfare. On the battlefield ancient Greeks could gain the collective glory. This collective glory and individual glory gained from the great games, mainly at Olympia, was something more than ordinary parts of Greek lives. Here, nothing was as highly valued as fame and inside of fame was really immortality (Drees, 1968, p. 101).[8] The victors gained a great fame and they were hailed with a hymn to Heracles by Archilochus of Paros at Olympia (Scheiner, 1891, p. 165). The celebration of the victors with hymns, etc. was a favourite part of this act – e.g. Xenophon of Corinth[9], the winner of the foot-race and pentathlon in 464 BC (79th Olympic Games) was welcomed at home by singing before the city gate and then by the hymn before the temple of Apollo, which was lead and created by Pindar. Here, we can mention also warlike (e.g. *ἀνδρεία*[10], *ἀριστεία*[11]) and sports (e.g. *ἀρετή*[12], *καλοκάγαθία*) ideals, which were equally the basic ethical ideals that created all society in Greek antiquity and were strongly connected with fame. Sport and Olympia were parts of the Greek miracle. The importance of the Olympia's victories played an important role in the

[8] "*When they died they went down to their joyless existence among the shades. Their only hope of immortality therefore was to perform some great deed which would live on in the minds of men. The deed was not important in itself. What mattered was that it should be celebrated by the world*" ... "*Their names lived on when they themselves were dead*" (Drees, 1968, p. 101).

[9] It is possible, that famous Myron's Discobolus was the statue of Xenophon of Corith (Kouřil, 2015, p. 120–121).

[10] *Andreia* was derived from the term *ἀνδρός*, man; courageousness, bravery, red-blooded power; fortitude displayed in the struggle.

[11] *Aristeia* was a Greek term for unusual valiant behaviour in the battle, heroism, valor, daring, rare proof of courage; as compared to the term *aristeion*, *ἀριστεῖο*. Thus, heroism and also honor, reward, victorious prize for the biggest valour in the battle (Kouřil, 2016, p. 15; Prach, 1998, p. 86).

[12] *Arete* = excellence, athleticism, proficiency.

propagation of each *πόλις* (*polis*) and its political system. Demonstration of their power and superiority was also important for the education of the youths. The winner's example and successes were emulated by others, especially by the youth. This trend was supported and promoted by the elites. The elites understood very well these principles and they knew that the public celebration of the victors and the advantages provided to them were the best educational examples for young people. The relationship of the ancient Greek culture and society to the Olympic winners was the basis of Olympism and Olympic education in antiquity. Thus, the transition from the status of an ordinary person / *ἀθλητής* to the highest human level under the gods and demigods or mythological heroes was highlighted.

The reward (*ἆθλον*, *athlon*[13]) in the most famous and the greatest ancient Greek games was a wreath – an olive wreath at Olympia, a celery or parsley wreath at Nemea, a laurel wreath at Delphi, and a pine wreath at Isthmia (Paus. 5.7.6–7, 8.48.2–3, 10.7.8; Pind., *I.* 2.15–17; Pind., *O.* 13.33–34; Plut., *Mor.* 676f; Plut., *Quaes. Conv.* 5.3.1). The winner also received a palm branch and a red ribbons symbolizing his victory, which were tied around his head and arm or leg. The olive wreath, called *κότινος* (*kotinos*), was made from the sacred olive tree, which the Greeks named Kallistefanos ("donor of the beautiful wreaths"). Either the goddess Pallas Athena gave the tree to the Greeks or Heracles planted it there (Zamarovský, 2003). The Greeks believed that this wreath had a supernatural power and the victory provided protection by Zeus himself. The *κότινος* also contained a huge honor and peak of earthy bliss. The winners could be also honored in the form of festive poems (epinikions) and a statue could be built in their hometown or in the place of their victory, or in both (Kössl et alii, 1982; Newby, 2006). The triple victors were allowed to erect realistic statues, called *iconica*.[14] The significance of the statues of the prominent people, especially the winner from Olympia confirms a funny story about an excellent Greek athlete, Theagenes of Thasos, who (when he was 9 years old) stole the bronze statue of a god from *αγορά* (*agora*). However, later, he was an Olympic victor himself and had several statues made. One of his statues, after his death, fell and killed one of Theagenes'enemies, who was walking to this statue and was flogging it everyday (Golden, 2005, p. 163).

Each Olympic Games was named after the victors of the *δρόμος*, *dromos* (Drees, 1968, p. 102; Schöbel, 1965, p. 116). The winners could eat for free (paid by the state) until the end of their life (in the *πρυτανεῖον*, *prytaneion*) and hold important political, religious, etc., positions in the state. In the struggle of battle (in the *φάλαγξ*, *falanx*) victors were stationed in honorable places. Victors also had a special honorary place in the theatre (Athen., *Deipnos*. 6.237) and during festivals.

The Olympic victor was the best man similar to a Homeric hero; in *ἆθλα ἐπί Πάτροκλωι* only the best heroes competed and won. Exmaples include: Diomedes, the king of Argos (*συνωρίς*), Epeius (*πυγμή*), Aias/Ajax the Great – Odysseus (*πάλη*), Odysseus (*δρόμος*), Diomedes – Aias/Ajax the Great (*ὁπλομαχίᾱ* with *δολιχόσκιος ἔγχος/δόρυ*), Polypoetes (*δίσκος*), Meriones (*τοξικός*), Agamemnon (*ἄκον – ἧμα*) (Hom., *Il.* 23).

The winners could choose to create the epinikion at the expense of their own, their family or *poleis* (*πόλεις*) and in which he was often filiationed with god or gods. These were also one of the appropriate means of youth education (the Olympic Education). Their most famous author was Pindar (others were Bacchylides and Simonides), and in almost every Olympic epinikions, Pindar celebrates the winner and his family or *πόλις*. The winner thus became an ideal example for young boys, the role model and one of the best citizens, who spreads the glory not only his own and his family but also his *πόλις*.

[13] Originally, it was a specification for a loot in the battle.

[14] *"Effigies hominum non solebant exprimi nisi aliqua inlustri causa perpetuitatem merentium, primo sacrorum certaminum victoria maximeque Olympiae, ubi omnium, qui vicissent, statuas dicari mos erat, eorum vero, qui ter ibi superavissent, ex membris ipsorum similitudine expressa, quas iconicas vocant"* (Plin., *NH* 34.9.4).

"*Τυνδαρίδαις τε φιλοξείνοις ἁδεῖν καλλιπλοκάμῳ θ' Ἑλένᾳ*
κλεινὰν Ἀκράγαντα γεραίρων εὔχομαι,
Θήρωνος Ὀλυμπιονίκαν ὕμνον ὀρθώσαις, ἀκαμαντοπόδων
ἵππων ἄωτον" (Pind., *O.* 3.1–4a).[15]

"*ἐγὼ δὲ συνεφαπτόμενος σπουδᾷ, κλυτὸν ἔθνος*
Λοκρῶν ἀμφέπεσον μέλιτι εὐάνορα πόλιν καταβρέχων" (Pind., *O.* 10.101a–103).[16]

The Olympic victory had for the winner a tremendous prestige; just as important for the athlete's *πόλις* – as the name of the city-state was next to the name of the winner. The *πόλις* through its *ἀθληταί* gained political significance and influence and at Olympia its official delegations / ambassadors (*θεωρόι*[17]) had the opportunity to sign agreements of the international significance.

For the winners spoke their performance, movement; they did not need to boast with external features like wealth or political power. Their wealth was something higher than ordinary things. Their movement leading to victory was "*the result of the dialogue with the Gaia*" (Hogenová, 2000, p. 150). After the ceremonial procession, the winners were hosted in the *πρυτανεῖον*. Taxes were largely forgiven to them in their birthplace and given honor similar to kings and gods. Some of them were receiving monthly or annual allowance and later, some famous winners received payment by the organizers of lesser games when they participated in these events. The *πόλεις* were extremely proud of their Olympic victors and a lot of cities pampered them and supported and subsidizing the trainings and travels of these men or their other promising and gifted athletes (Pleket, 2012, p. 132–133). The famous winners were also often released by the enemy after a lost battle (Bouzek & Ondřejová, 1989); it was an example of famous *παγκρατιαστής* (*pankratiastes*, pankratist) Dorieus, the son of Diagoras, who was captured and released by the Athenians (Paus. 6.7.1–7; Thuc. 3.8.1). The victors were also the leaders of some state expedition (e.g. Euthycleus of Locri, Gaius Perelius Aurelius Alexander). The winners were sought by the rulers of some *πόλεις* and empires as suitable husbands for their daughters (Osborne, 2010) or they were friends of kings and elites (e.g. Milo, Dexippus). The winner was dressed in purple[18] and he rode a chariot with white horses, through not a gate, but a newly made hole in the wall. It was to refer to the fact that this missing part of the wall filled the bodies of the winners who covered it and protected it against enemy attack (Tyrš 1968). For example Suetonius mentioned that this homage was utilized by Nero, the Roman emperor (Suet., *Nero* 25). Exainates from Akragatos was accompanied to the city by 300 two-team chariots with white horses (Diod. Sic. 12.82.1, 13.33.1; Scheiner, 1891, p. 166). The victor's entrance to the city was simultaneously a triumphal procession (similar to the Roman triumphs[19]) with flowers and twigs (*φυλλοβολία, fyllobolia*: Kefalidou, 1999, p. 96; Trianti & Valavanis, 2015, p. 130) – assurance of fertility and strong genus of victors. This shower of flowers and leaves probably also occured at Olympia and the victor was lifted and carried on

[15] "*I pray that I may be pleasing to the hospitable sons of Tyndareus and to Helen of the beautiful hair while I honor renowned Acragas by raising my song in praise of Theron's victory at Olympia won by the choicest of horses with untiring feet*" (translation by D. A. Svarlien, 1990).

[16] "*While I, earnestly lending my hand, have embraced the famous tribe of the Locrians, showering with honey their city of fine men*" (translation by D. A. Svarlien, 1990). Also e.g. Pind., *O.* 2.52–56; 7.20–27, 76–88; 11.16–20; 13.1–5; 14.17–24.

[17] From *θεωρῶ*, to observe, to be a spectator or a messenger at a feast.

[18] Purple was used for a high status. With the ancient Olympic victors there was lots of symbolism – purple and red color, wreaths, the *φυλλοβολία*, etc.

[19] For the Greeks, the victory at Olympia was more important than the triumphs over the Romans – "*Hoc est apud est Graecos, quoniam de eorum gravitate dicimus, prope maius et gloriosius quam Romae triumphasse*" (Cic., *Flac.* 13.31).

the shoulders of friends and spectators during the procession. The first steps of the winner led to the main temple of the city-state where he sacrificed and devoted to the gods his wreath. The procession continued also to the *αγορά* and victor's home. In Sparta, the winners had the right to march and fight next to the king. This was illustrated by the example of a Spartan wrestler who refused to lose in the final when to him there was offered a huge sum of money as a bribe. When they asked him after the race what he has now from his victory, he said that now he can fight in the battlefield before his king (Sábl, 1960, p. 149–150). In Alexandria, the winners became the members of the Musaeum (it could be said that it was some kind of an academy of science and art). In Athens, the victors received 500 drachmas (Plut., *Solon* 23.5), in Sybaris 100 drachmas, and later, according to Dio Chrysostom (*De Gloria* 1), the winners could received even 5 talets[20] (= 30 000 drachmas)[21]. For victors who came from Athens and according to Solo's census, this point was important not only because of the money but also for the reason that the possession of 500 drachmas meant that the man belonged to the highest class of society. In many cities the victors could eat for free until the end of their life in the *πρυτανεῖον*. "Sporting" buildings were named after them and to most of them were offered an important position in the religious or city administration. A lot of the winners were worshiped as heroes, either during their life (e.g. Euthymos of Locri[22] as son of god of the local river) or when they died (e.g. Theagenes of Thasos as son of Heracles, Polydamas of Skotoussa, Phillipos of Croton, Kleomedes of Astypalia). According to Bacchylides the winner could have every woman. The victor's names were on a roll of fame of each city-state and winners received special symbols of the city-states (different for each *πόλις*). Several victors also received honorary citizenship of other *πόλεις*, and some of them were called "the citizens of all the world" (Drees, 1968, p. 106; Sábl, 1960, p. 149–150). Kings were allowed to have special coins made to commemorate their victories (Drees, 1968, p. 102), e.g. Gelon of Syracuse, Phillip II of Macedon. A very interesting fact is that Gelon did this after his victory at Olympia in 488 BC in *tethrippon* but not after his victory in the important battle of Himera (480 BC[23]). In ancient Greece, many legends were created about the victors (e.g. Koroibos, Milo, Theagenes, Euthymos) as well as about other great people: Homer, Empedocles, etc. According to Plato (*Rep.* 425D) and in his ideal state, the winner could be the guardian and this was a great honor – to be the guardian and the Olympic winner.

In regard to advantages and money, it is possible to compare the victors to present football stars (Zamarovský, 2000). However, as Thomson (1952) noted, although the winners received considerable honors, they must not want too much or even want to become gods and thus to be subject to *ὕβρις* (*hybris*). The winner with the honors was only one, the first, the other competitors fell into oblivion. In contrast to that the original Homers' warriors-*ἀθληται* were awarded with prizes in the *Ilias*, even if they did not win.[24]

The organization of such a glamorous welcome in the *πόλις* had one big advantage – increasing the interest in physical activities and raising the love of "sport" for the youth. That is how the *πόλις* guaranteed the trained defenders of their homeland. This also had a very strong educational impact on the youth. The relationship to the Olympic winners, thus the transition from the status of an ordinary person to the status in which the *ἀθληται* entered, were basis of the Olympic education. Youths were inspired by the best of the examples, which were reflected by the *ἀριστείᾱ*

[20] 1 talent was 26,2 kg of silver.

[21] At this time, 1 drachma was the price of 1 sheep and 500 drachmas was equal to the annual profit from the manor.

[22] He saved a girl and killed a black daemon with wolf's skin and a horrible gaze.

[23] This battle took place in the same day as the more famous battle of Salamis.

[24] This was also seen in other games, e.g. the Great Panathenia, where the winner received the best prize, but others received some smaller prizes – the second, third and even the fourth and fifth place.

πρόμαχοι (*aristeia promachoi*[25]) and also by the *ἀριστείᾱ ὀλυμπιονῑκαί* (*aristeia olympionikai*) with this jointed collective and individual glory. As the basis of Olympism and Olympic education in antiquity, and without a doubt, we can name the relationship of ancient Greek culture and society to the Olympic victors.

The best Greek *ἀθληταί*, who achieved victories in all great Greek games – the Olympian, the Pythian, the Isthmian and the Nemean – received the honorary title the *περιοδονῑκης* and they were celebrated by all contemporaries. The winners of the Panhellenic Games were also elites warriors or commanders. Spartan victors fought next to their kings (Garlan, 2005). As ideal examples we can show the best of the Greeks *ἀθληταί*, the wrestler Milo of Croton, called "the king of wrestlers", who was six times the *περιοδονῑκης* (Olivová, 1988: p. 119; Sábl, 1960). At Olympia he won seven times (once as a junior at the age of 14), at Delphi also seven times, at Nemea nine times and at Isthmos ten times (Olivová, 1979). Before the end of his athletic career, Milo took part in a war against neighboring Sybaris, where he commanded the right wing, was dressed in lion›s skin and armed with a club to remind others of Heracles. He strongly helped to defeat the enemy (Miller, 2004; Newby, 2006; Potter, 2012; Sábl, 1968). Significant soldiers from Messenia were the *ὀλυμπιονῑκαί* Androclus, the victor of *δρόμος* from 3rd Olympic Games, who died in defense of his country against Sparta, and Fanas, the victor of *δόλιχος* (*dolichos*) from 26th Olympic Games (Paus. 4.4.4; Golden, 2005: 10; Sábl, 1960). Another famous commander in the 7th century BC was Phrynon of Athens, a double winner in *παγκράτιον*. We can name the commander Alcibiades of Athens, the victor of *τέθριππον* from the 91st Olympic Games, and pentathlete and the champion of disk throw Phayllus of Croton, who bought and armed a warship and alongside the Athenians he fought against the Persians and died at Salamis in the year 480 BC. We can also mention Philip II of Macedon, the father of Alexander the Great. Military and "sport" were closely linked in the antiquity, and so Olympic education and Olympism were dependent on both. All "sport"-military education led to the education of an ideal citizen in the sense of the education to "sport"-military and cultural ideals as the *ἀνδρείᾱ*, the *ἀρετή*, the *ἀριστεύα*, the *ἁβροσύνη*, the *καλοκἀγαθία*, the σωφροσύνη, the *τῑμή*[26], etc.

CONCLUSION

Until the emergence of professionalism in ancient athletics was the essence of "sport" education and Olympism the areas known as free "sport", nudity, construction of "sports" buildings, organizing of many games and relation of society to the Olympic winners as well as leading the citizens to cultural and philosophical ideals like e.g. the *ἀνδρείᾱ*, the *ἀρετή*, the *ἀριστεύα*, the *ἁβροσύνη*, the *καλοκἀγαθία*, the *σωφροσύνη*, the τῑμή. But the strongest argument and the ideal of the youth was definitely the status of the Olympic champion, his transition to this status and the relationship of the whole society to him. The victory at Olympia was not only an olive wreath, a red ribbon, a palm branch and the *φυλλοβολία* or a statue and an epinikion for some of them, but also a banquet at Olympia and a public announcement of the winner's name, family and the *πόλις*, free food at the expense of the city-state, a place in a cult or other important position after the end of his career, friendship with prominent persons and marriage with their daughters, likewise the protection after the fight when it was honest for the Olympic winner to be released without the ransom or for the Spartans honorable place next to the king in marching and struggle and especially the triumphal entry into the *πόλις* through a new hole in the walls. This last part

[25] *Promachoi*, sg. *πρόμαχος* (*promachos*) – ahead/combatant in first line; anterior warrior. Πρόμαχος was also famous epithet of Greek goddness Athena.

[26] *Andreia, arete, aristeia, habrosyne, kalokagathia, sophrosyne, time.*

of the honors to the winners was similar to Roman triumphs; a celebration of the one – the best – had to act the most powerful on the youth and thus it means the best way to educate children.

References

Primary Sources

Athen., *Deipnos*. = Athenaeus, *Deipnosophists*, vol. 3, Books 6–7. Transl. by C. B. Gulick (1929). Cambridge: Harvard University Press.

Cic., *Flac.* = M. Tullius Cicero, M. Tulli Ciceronis Orationes. Ed. by A. Clark (1909). Oxford: Typographeo Clarendoniano.

D. Chr. = Dionis Prusaensis Chrysostomum, *Quae Exstant Omnia*, Vols I & II. Ed. by J. de Arnim (1893). Berlin: Weidmann.

Diod. Sic. = Diodorus Sicilus, *Library of History*, volume V, Books 12.41–13. Transl. by C. H. Oldfather (1950). Cambridge: Harvard University Press.

Hes., *Th.* = Hesiod, Theogony. In: Hesiod, *The Homeric Hymns and Homerica*. Ed. & Transl. by H. G. Evelyn-White (1914). Cambridge: Harvard University Press & London: William Heinemann.

Hom. *Il.* = Homeros, *Homer's Ilias, zweiter Teil : Gesang XI–XXIV*. Ed. E. Naumann (1898). Leipzig: Velhagen & Klasing.

Hom. *Il.* = Homer, Ílias. Transl. R. Mertlík (1980). Prague: Odeon.

Paus. = Pausanias, *Cesta po Řecku I*. Transl. H. Businská (1973). Prague: Svoboda.

Paus. = Pausanias, *Cesta po Řecku II*. Transl. H. Businská (1974). Prague: Svoboda.

Paus. = Pausanias, *Pausanias Description of Greece*, 4 Volumes. Ed. & Transl. by W. H. S. Jones & H. A. Ormerod (1918). Cambridge: Harvard University Press & London: William Heinemann.

Pind., *O.* = Pindar, *The Odes of Pindar*. Ed. & Transl. by J. Sandys (1937). Cambridge: Harvard University Press & London: William Heinemann.

Pind., *O.* / *I.* = Pindar, *Odes*. Transl. by D. A. Svarlien (1990). New Haven: Yale University Press.

Plat., *Rep.* = Plato, The Republic. In: Plato, *Plato in Twelve Volumes*, Vols. 5 & 6. Transl. by P. Shorey (1969). Cambridge: Harvard University Press & London: William Heinemann.

Plin., *NH* = Gaius Plinius Caecilius Secundus, *C. Plini Secundi Naturalis Historiae, libri XXXVII, Vol. V. Libri XXXI – XXXVII*. Ed. by K. Mayhoff (1897). Lipsiae: B. G. Teubner.

Plut., *Mor.* = Plutarch, Quaestiones Convivales. In: Plutarch, *Moralia*. Ed. G. N. Bernardakis (1892). Leipzig: Teubner.

Plut., *Quaes. Conv.* = Plutarch, Quaestiones Convivales. In: Plutarch, *Plutarch's Morals*. Transl. by W. W. Goodwin (1874). Boston: Little, Brown, and Company & Cambridge: Press Of John Wilson and son.

Plut., *Solon* = Plutarch, Lycurgus. In: Plutarch, *Plutarch's Lives*, Vol. 1. Transl. by B. Perrin (1914). Cambridge: Harvard University Press & London: William Heinemann.

Suet., *Nero* = Gajus Suetonius Tranquillus, *Životopisy dvanácti* císařů. Transl. by B. Ryba (1966). Prague: Státní nakladatelství krásné literatury a umění.

Thuc. = Thucydides, *History of the Peloponnesian War*, Volume 1. Ed. & Transl. by B. Jowett (1881). Oxford: Clarendon Press.

Vitr. = Vitruvius Pollio, *On Architecture*. Ed. F. Krohn (1912). Lipsiae: B.G. Teubner.

Vitr. = Vitruvius, *The Ten Books on Architecture*. Transl. by M. H. Morgan (1914). Cambridge: Harvard University Press & London: Humphrey Milford. Oxford University Press.

Secondary Sources

Bouzek, J. & Ondřejová, I. (1989). *Periklovo Řecko*. Prague: Mladá fronta.

Cambiano, G. (2005). Cesta k dospělosti. In: Vernant, J.-P. (Ed.). Řecký člověk a jeho svět. Prague: Vyšehrad, pp. 77–103.

Drees, L. (1968). *Olympia: Gods, Artists and Athletes*. London: Pall Mall Press.

Garlan, Y. (2005). Člověk a válka. In: Vernant, J.-P. (Ed.). Řecký člověk a jeho svět. Prague: Vyšehrad, pp. 47–85.

Golden, M. (2005). *Sport in the Ancient World from A to Z*. London: Taylor & Francis e-Library.

Grexa, J. (2008). Kalokagathia – staroveký ideál a novoveká realita. In: Šíp, R. (Ed.). *Kalokagathia: ideál, nebo flatus vocis?* Brno: Masarykova univerzita & Paido. Pp. 33–41.

Grexa, J. (2009). *Přehled světových dějin sportu*. Brno: Masarykova univerzita.

Hogenová, A. (2000). *Areté: Základ olympijské filozofie*. Prague: Karolinum.

Hyde, W. W. (1921). *Olympic Victor Monuments and Greek Athletic Art*. Washington: Carnegie Institution.

Jaeger, W. (1986). *Paideia: The Ideals of Greek Culture, volume III: The Conflict of Cultural Ideals in the Age of Plato.* New York/ Oxford: Oxford University Press.

Jirásek, I. (2009). Nahota v kontextu pohybové kultury. In: *Tělesná kultura, vol. 32, no 2*. Olomouc: Faculty of Physical culture, Palacký University, pp. 7–19.

Kefalidou, E. (1999). Ceremonies of AthleticVictory in Ancient Greece: an Interpretation. In: Decker, W.; Ebert, J.; Sinn, U. & I. Weiler (Eds.). *Nikephoros: Zeitschrift für Sport und Kultur im Altertum*, 12. Jahrgang. Hildesheim: Weidmann. Pp. 95–119.

Kössl, J. et alii (1982). *Malá encyklopedie olympijských her*. Prague: Olympia.

Kouřil, J. (2015). K problematice antického pentathlonu. In: Suchý, J. et al. (Eds.). *Scientina Movens 2015 : Sborník příspěvků z mezinárodní studentské vědecké konference.* Prague: Faculty of Physical Education and Sport, Charles University. Pp. 117–126.

Kouřil, J. (2016). Athlétai a sportovní tituly antického světa. In: *Tělesná kultura*, 2016, roč. 39, č. 1, Olomouc: Palacký University, pp. 15–26.
Miller, S. G. (2004). *Ancient Greek Athletics*. New Haven & London: Yale University.
Newby, Z. (2006). *Athletics in the Ancient World*. London: Bristol Classical Press.
Olivová, V. (1979). *Lidé a hry: Historická geneze sportu*. Prague: Olympia.
Olivová, V. (1988). *Sport a hry ve starověkém světě*. Prague: Artia.
Osborne, R. (2010). *Dějiny klasického Řecka*. Prague: Grada Publishing.
Pleket, H. W. (2012). The Reward of the Ancient Athlete. In: Petermandl, W. & C. Ulf (Eds.). *Nikephoros: Journal of Sports and Culture in Antiquity (Special Issue 2012: Youth – Sports – Olympic Games)*. Hildesheim: Weidmann. Pp. 131–134.
Potter, D. (2012). *The Victor's Crown: How the Birth of the Olympics and the Rise of the Roman Games Changed Sport For Ever*. London: Quercus.
Prach, V. (1998). Řecko-český slovník. Prague: Vyšehrad.
Sábl, V. (1960). *Od Olympie k Římu 1960: Z dějin olympijských her*. Prague: Sportovní a turistické nakladatelství.
Sábl, V. (1968). *Hrdinové antických olympiád: Olympijské příběhy a pověsti*. Prague: Olympia.
Scheiner, J. E. (1891). *Dějiny cvičení tělesných, díl I: Tělesná cvičení ve starém věku*. Prague: own edition.
Schöbel, H. (1965). *Olympia un seine Spiele*. Leipzig: Sportverlag.
Šílený, T. (1947). Život v antickém Řecku. Prague: Jednota českých filologů v Praze.
Thomson, G. (1952). *Aischylos a Athény: O původu umění ve starověkém Řecku*. Prague: Rovnost.
Trianti, I. & Valavanis, P. (2015). Olympia. Athens: Papadimas Ekdotiki.
Tyrš, M. (1968). *Hod olympický*. Prague: Olympia.
Weiler, I. (2012). Victory and "Bringer of Victory" Nike and *Nikephoros*. In: Petermandl, W. & C. Ulf (Eds.). *Nikephoros: Journal of Sports and Culture in Antiquity (Special Issue 2012: Youth – Sports – Olympic Games)*. Hildesheim: Weidmann. Pp. 21–22.
Zamarovský, V. (2003). *Vzkříšení Olympie*. Prague: Euromedia Group – Knižní klub – Erika.

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BMI Indicators in Children with Intellectual Disabilities

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Abstract

Currently, obesity in people with intellectual disabilities, whose daily lives are to a certain degree affected by their impairment, is increasingly becoming the focal point of attention. However, there is a lack of scientific data for children with intellectual disabilities.

The aim of this research is to determine whether children with intellectual disabilities are prone to obesity, whether obesity is gender- and age-specific, what is the distribution of intellectual disabilities in boys and girls and whether any level of intellectual disability shows a higher proclivity to obesity.

The method employed was comparative and qualitative research approached deductively. For the collection of BMI indicators, InBody analyser was used to measure the data of 49 children attending two special needs primary schools.

The findings of the research show that the BMI values of more than a half of children with intellectual disabilities in all assessed groups is within norm. Boys are estimated to have a lower BMI in middle adolescence than in early adolescence and school age. Girls are highly likely to have a higher BMI in late adolescence than in middle and early adolescence. In boys, obesity is associated with early adolescence and mild to moderate level of intellectual disability, whereas in girls with middle adolescence and mild level of intellectual disability.

***Key words*:** *children with intellectual disabilities, special elementary school, the BMI indicator, levels of intellectual disabilities, obesity.*

INTRODUCTION

Childhood obesity is considered one of the most pressing public health issues of today. Its prevalence is continuously rising. Unfortunately, no consensus as to how this problem should be resolved has been reached yet. Obesity has mostly been regarded as a matter of personal and parental responsibility. The intervention of governments usually lies in laying down normative regulations as to what constitutes a healthy diet and what food should be prepared in schools (Duramy, 2018). It has been found out that childhood obesity is more prevalent in children who have been exposed to high levels of stress and as a result suffer from behavioural issues, learning difficulties, emotional problems and somatization (Tanu et al., 2018). In the Czech Republic, the number of obese children in primary schools is on the increase. Whilst 20 years ago, only 4 % of children were obese, nowadays the percentage is 14 % for obesity and 25 % for overweigh. The most common factors are a bad lifestyle and poor eating habits (Eurozprávy, 2008).

Intellectual disability (ID) is an umbrella term for congenital handicap of intellectual abilities which are manifested as an inability to understand and adapt to one's surroundings (Vágnerová, 2004, p. 289). Intellectual disability in an individual is seen as a limitation in intellectual functioning and adaptive behaviours (*Švarcová*, 2000, p. 28). According to Valenta and Müller (2003, p. 10), intellectual disability is a developmental mental disorder manifesting in lower intelligence. It is demonstrated especially as a deficit in cognitive, speech, motor and social abilities. In terms of IQ, intellectual disabilities can be divided into mild (50–69), moderate (35–49), severe (20–34) and profound (below 20), (NICM, 2014).

Individuals with mild ID are comparable with children at the age of 9 to 12. They can be educated at special needs primary schools. Speech is used functionally in day-to-day situations. Individuals with mild ID are able to hold a conversation and respond in a clinical interview despite the delay in speech development. Most of them manage to master self-care, i.e. eating, getting dressed, hygiene, bladder and bowel control and practical household chores.

Individuals with moderate ID are comparable with children of pre-school age, i. e. 3–6 years old. The development of cognitive and language skills is considerably delayed. Learning occurs solely on the practical level and includes mastering self-care activities and basic skills (ALFABET, 2014). Some pupils are able to attain the grounding in reading, writing and maths under the tutelage of a qualified teacher. Self-care and fine motor skills also develop with delay. Adults with moderate ID are able to carry out simple manual work under supervision. They are not able to live a life completely independent of support and instruction. This degree of disability is characteristic of noticeable differences. Some individuals attain a higher level of sensory motor skills or are capable of social interaction, for example a simple conversation, whilst others are not able to communicate their basic needs (Švarcová, 2000, pp. 28–29).

Individuals with severe intellectual disability have a considerable motor skills impairment or other associated handicaps which are characteristic of a clinically significant damage to or a defective development of the central nervous system (ALFABET, 2014). Even though education possibilities are somewhat limited, experience shows that an early and systematic expert treatment can lead to the development of motor and cognitive skills, communication skills, self-care and overall improvement in the quality of life. Nevertheless, people with severe ID remain dependent on daily supervision and support (Švarcová, 2000, p. 29).

The causes of ID may occur in prenatal, perinatal or postnatal development of an individual. In the prenatal stage (before the birth of a child), the cause could be substance abuse, undernourishment, injury, maternal infections, for example toxoplasmosis, rubella or syphilis. Smoking also constitutes a significant risk factor. In the perinatal stage (during childbirth or immediately afterwards), the cause might be prematurity, low birth weight and hypoxia. In the postnatal stage (after birth up to 2 years of age), the cause may constitute childhood infections, such as acquired meningitis and encephalitis, whooping cough, chicken pox and hepatitis. ID may also be the consequence of a head injury or drowning. Further factors leading to ID may include poverty resulting in insufficient medical care. Genetic dispositions also play an important role causing conditions such as phenylketonuria (congenital metabolic disorder) or Down syndrome (ALFABET, 2014).

People with intellectual disabilities have a shorter lifespan and a higher mortality in comparison with the general population (Bittles et al., 2002); (Patja et al., 2000). Conditions such as epilepsy, osteoporosis, motion disorders, obesity, intestinal motility disorders and hyperlipidemia are more often found in people with intellectual disabilities (Tyler et al., 2010). According to Havercamp, Scandline & Roth (2004, pp. 418–426) and Cooper, Melville & Morrison (2004, pp. 414–415), this population also has a worse state of health and concurrently difficult access to primary healthcare.

The school age period (6–9 years of age) is characterised by fast growth in height followed by a period of slow growth. Children are exposed to life-changing events. They start attending school and take part in different social interactions. They have to subject themselves to activities which are not necessarily perceived as attractive (schoolwork) and follow a stricter timetable. Further characteristics include cooperation, competition, accepting objective reality at face value and dependence on the leadership of parents and teachers (Vágnerová, 2000, p. 207). Early adolescence stretches between the ages of 10 and 13. It is at this stage that sexual maturation commences and in most adolescents is also completed. Cognitive processes also undergo a tumultuous development. Furthermore, psychological and social changes significantly mark this period, for example adolescents showed an increased interest in the opposite sex. Middle adolescence encompasses the ages between 14 and 16 years. Young people make a conscious effort to differentiate themselves from the adult population by adopting eccentric hairstyles, by listening to distinctive music and taking

up idiosyncratic interests, thus seeking to connect with their peers. Searching for their identity, individuality and authenticity is also typical. In girls, the growth finishes around their 15 years of age, while in boys it continues up to 18. Late adolescence encompasses the ages between 17 and 20 years. Most adolescents are finishing their education and seek to pursue their careers. Social aspects of identity tend to gain on importance, for example the need to belong and share with others (Pavlas, 2011, pp. 56–57).

An increased body weight, which is more common in people with intellectual disabilities, is a significant risk factor for the onset of certain diseases (Melville, Hamilton, Miller & Boyle, 2007); (Rimmer & Yamaki, 2006). According to Melville, Hamilton, Miller & Boyle (2007), the prevalence of obesity is 15–50 % for women and 2–45 % for men (pp. 223–230). The risk of obesity appears to be especially high in women, people with Down syndrome and people with mild ID (Melville, Hamilton, Miller & Boyle, 2007); (Hsieh, Rimmer & Heller, 2014). Stancliffe et al. (2011) underscores the need to assess living arrangements during the obesity risk factor analysis (pp. 401–418). People living in institutional environments have the lowest prevalence of obesity and people living in their own homes experience the highest prevalence of obesity (Melville, Hamilton, Miller & Boyle, 2007); (Stancliffe et al., 2011).

All cited authors reference to the BMI scale of the WHO. The BMI was developed as a tool for estimating the risk of disease. The higher the BMI, the higher the risk for certain medical conditions. Being overweight or obese means a higher risk of premature death, cardiovascular disease, high blood pressure, arthrosis, certain kinds of cancer and diabetes (WHO, 2018).

The goal of this study, which is part of the project Healthy Community (HC-ZAS), is to determine whether children with intellectual disabilities are prone to obesity, whether obesity is gender- and age-specific, what is the distribution of intellectual disabilities in boys and girls and whether any level of intellectual disability shows a higher proclivity to obesity.

METHODOLOGY

Participants

The study participants were pupils of Primary school for children with special needs in Otrokovice and the Special Needs and Practical School in Zlín in June 2017. In total, 53 children took part in the research. Four children were excluded from the study due to their health impairment which made them unfit for the BMI scanning.

Table 1 shows the classification of participants by age according to Pavlas (2011, p. 54).

Tab. 1: The characteristics of participants by age

Age group	Age	Girls	Boys	Total girls	Total boys	Average age
School age 6–9 years	6 years	0	0	3	7	8.3
	7 years	0	1			
	8 years	2	3			
	9 years	1	3			
Early adolescence 10–13 years	10 years	1	3	8	11	11.7
	11 years	2	1			
	12 years	1	5			
	13 years	4	2			
Middle adolescence 14–16 years	14 years	3	3	9	7	15.0
	15 years	3	1			
	16 years	3	3			
Late adolescence 17–20 years	17 years	0	0	3	1	18.8
	18 years	2	0			
	19 years	0	1			
	20 years	1	0			
Total	**–**	**23**	**26**	**49 children**		**13.5**

As can be seen from the table, participants comprise 10 school-age children, 19 pupils in early adolescence, 16 pupils in middle adolescence and 4 pupils in late adolescence. There was a total of 49 participants, 23 of whom were girls and 26 of whom constituted boys. In terms of gender, the group well-balanced. As regards age, participants ranged between 7 and 20 years old. All pupils participated with the consent of their parents. The ethical consensus was guaranteed.

Table 2 shows the distribution of ID levels within the assessed group. As can be seen, there is a slight prevalence of mild to moderate level of ID.

Tab. 2: The characteristics of participants according to the number of boys and girls in age categories and level of intellectual disabilities

The level of intellectual disabilities	School age 6–9 years	Early adolescence 10–13 years	Middle adolescence 14–16 years	Late adolescence 17–20 years	Total
Mild level of disabilities	4 boys 1 girl	6 boys 4 girls	2 boys 4 girls	0 boys 0 girls	**12 boys** **9 girls**
Moderate level of disabilities	3 boys 2 girls	5 boys 4 girls	4 boys 3 girls	0 boys 2 girls	**12 boys** **11 girls**
Severe level of disabilities	0 boys 0 girls	0 boys 0 girls	1 boy 2 girls	1 boy 1 girl	**2 boys** **3 girls**

Data collection and processing

The InBody 230 analyser, which provides accurate results of body composition (fat, active body mass and water), was used for the detection of obesity. InBody uses the method of 8-point tactile electrodes which enable to measure the body in segments. In the picture below (Figure 1), we can see the example of the BMI scanning taken at one of the special needs primary schools. The

data collection took place in the school's gym and was carried out within the space of two days at two different schools, one day each. Both institutions cooperated well, and the participating children looked forward to the measurement.

Fig. 1: BMI scanning with InBody230

BMI is an index of body weight which is commonly used to indicate underweight, normal weight and obesity. There are universal BMI ranges for the adult population which are not age- or gender-specific. However, there are no standardized ranges for children between the ages 5 and 19. In children, BMI changes with sex and age. It is calculated as for adults and then compared with z-scores and percentiles. Based on the measured BMI value, one of five categories is allotted by age and sex. The categories are as follows obesity, overweight, normal and thinness. The child then can be assigned to one of these groups (Figure 2, Figure 3). BMI is defined as a person's weight in kg divided by the person's height in meters (kg/m^2). The ratio is expressed by the formula (WHO, 2018):

$$BMI = \frac{weight\ in\ kilograms}{(height\ in\ meters)^2} .$$

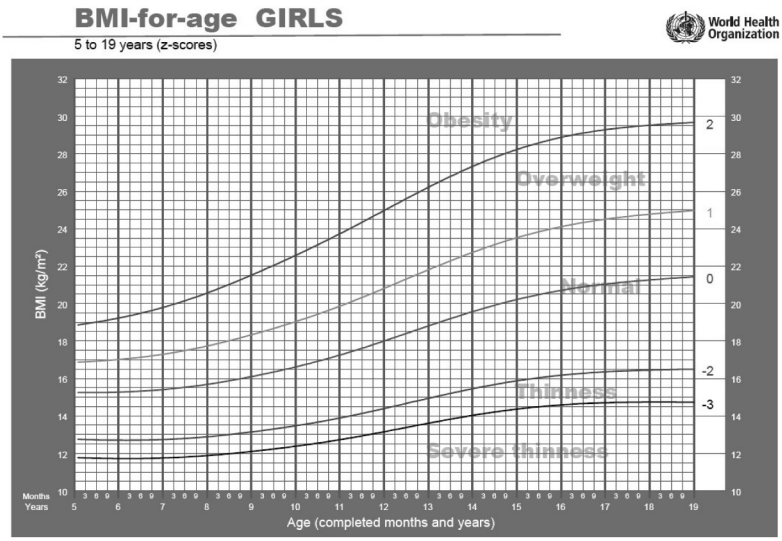

Fig. 2: Chart of BMI for age in girls

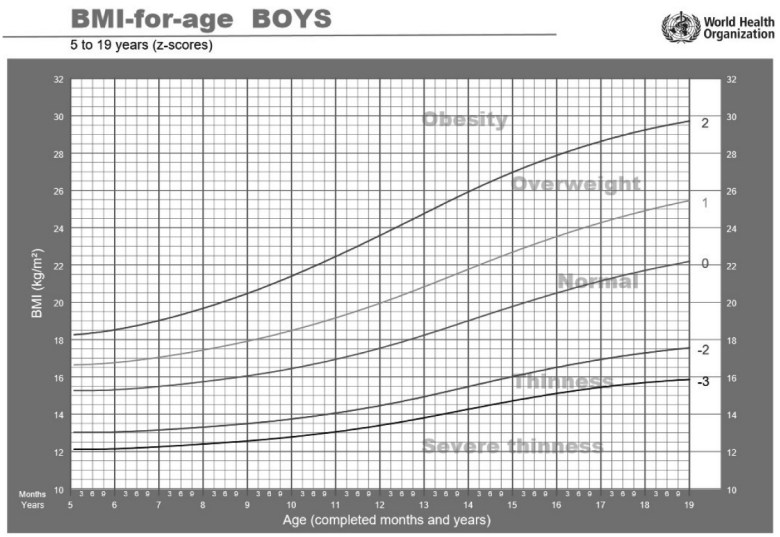

Fig. 3: Chart of BMI for age in boys

RESULTS

The results are presented as follows:
a) BMI indicator in relation to age,
b) BMI indicator in relation to gender,
c) BMI indicator in relation to the level of intellectual disabilities.

a) BMI indicator in relation to age

As can be seen in Figure 4, nearly all age groups are distributed across the BMI indicators. The lowest representation can be found in underweight. Most children exhibit normal weight. The only category showing the same percentage of normal weight and obesity is early adolescence.

School-age children and early adolescents fall into underweight with 2 %, middle adolescents make up 4 %. There is no prevalence of underweight in late adolescence. Normal weight is made up by school age with 12 %, by early adolescence with 18 %, by 22 % with middle adolescence and by 8 % with late adolescence. Obesity is most prevalent in early adolescence with 18 %. School-age children and middle adolescents are represented with 6 % each. There is no incidence of obesity in late adolescence.

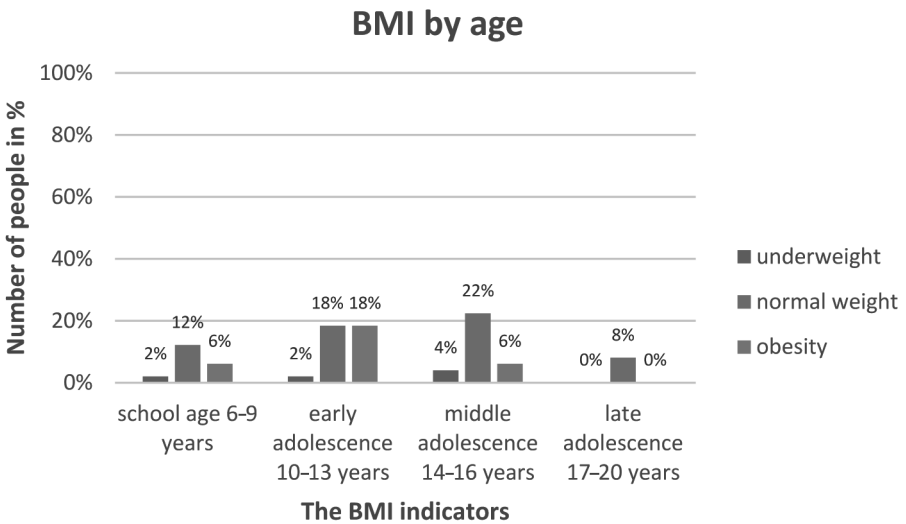

Fig. 4: BMI indicators by age

Figure 5 shows the distribution of BMI indicators within the whole group. The prevalence of obesity constitutes 31 %, whereas normal weight is representative of 31 %. Underweight occurs rarely (8 %).

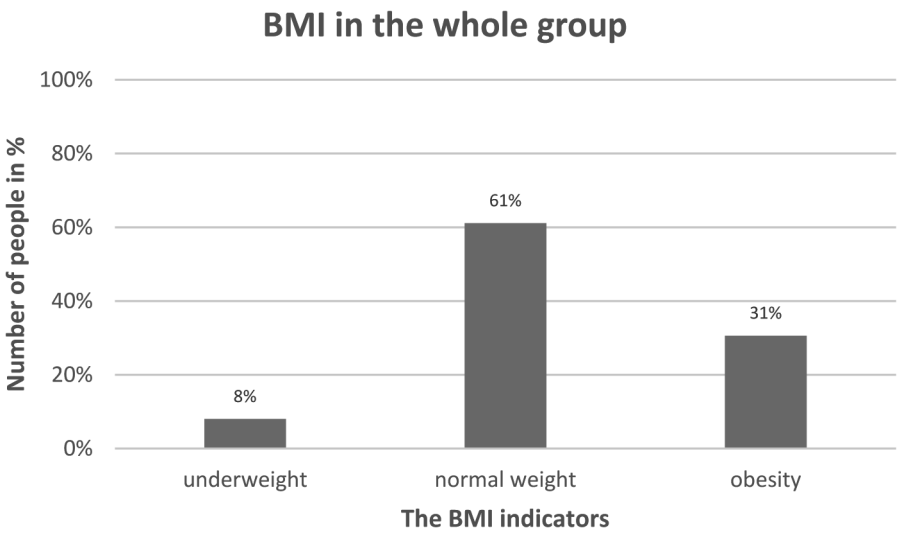

Fig. 5: BMI indicators in the whole group

b) BMI indicators in relation to gender

As is apparent from Figure 6 the incidence of underweight is associated with school age and middle adolescence with 14 %. It can be further inferred that with older age, BMI approaches normal weight.

In school-age boys both normal weight and obesity constitute 43 %. Early adolescence is the only category in which obesity is the most prevalent with 64 %, whereas normal weight is represented by 36 %. Middle adolescence is markedly representative of normal weight with 71 %. The incidence of obesity and underweight is significantly lower with only 14 % for both BMI indicators. Late adolescence is represented only by normal weight.

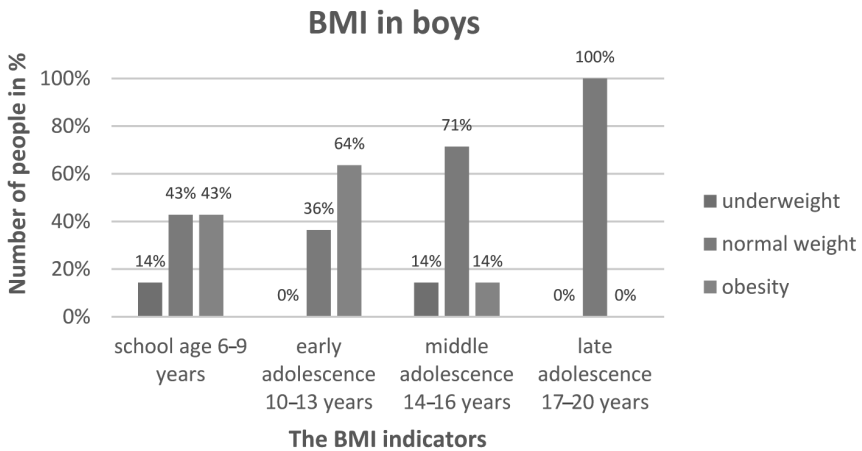

Fig. 6: BMI indicators in boys

As can be seen from Figure 7 all age groups in girls show dominant prevalence of normal weight. All school-age girls as well as late adolescents exhibit normal weight. Obesity is associated with 25 % of girls in early adolescence and 33 % in middle adolescence. Underweight is represented by 13 % in early adolescence and 11 % in middle adolescence.

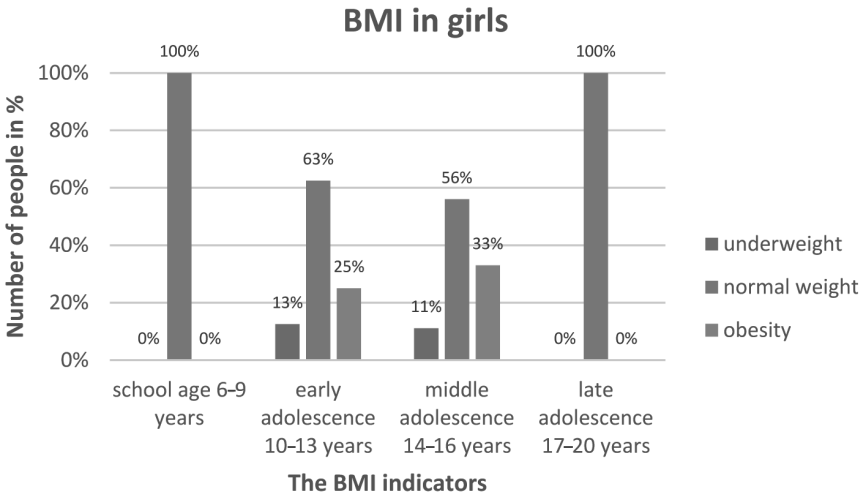

Fig. 7: BMI indicators in girls

c) BMI indicators in relation to the level of intellectual disabilities

Figure 8 shows that mild ID is distributed across three age groups. It is associated with 57 % of school-age boys, 55 % of boys in early adolescence and 29 % of boys in middle adolescence. Moderate ID is also typical of the first three age groups and is represented by 43 % of school-age boys, 46 % of boys in early adolescence and 57 % in middle adolescence. The incidence of severe ID in middle adolescence is as low as 14 % as compared to 100 % in late adolescence.

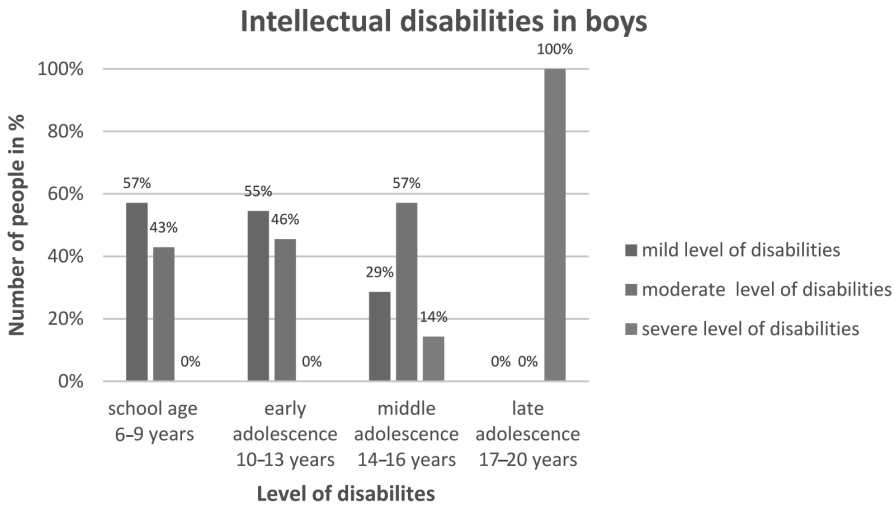

Fig. 8: ID levels in boys

Table 3 shows mean BMI values in boys in relation to the level of their disability. Obesity is associated solely with early adolescence. It is prevalent in boys with mild as well moderate level of ID. Underweight is associated with mild ID in middle adolescence. Normal weight can be found in school-age boys with mild to moderate ID, in middle-adolescent boys with moderate and severe ID and in late-adolescent boys with severe ID.

Tab. 3: BMI values in boys by ID levels

The level of intellectual disabilities in boys	Average BMI			
	School age 6–9 years	Early adolescence 10–13 years	Middle adolescence 14–16 years	Late adolescence 17–20 years
Mild level of disabilities	16,8 (normal)	21,7 (obesity)	15,3 (underweight)	–
Moderate level of disabilities	18,1 (normal)	22,7 (obesity)	22,1 (normal)	–
Severe level of disabilities	–	–	18,9 (normal)	21,5 (normal)

As it is apparent from Figure 9 similarly to boys, obesity in girls is associated with middle adolescence, in which it constitutes 22 %, and late adolescence with 33 %. As regards ID levels, 67 % of school-age girls exhibit moderate ID, whilst the remaining 33 % show mild ID. Mild and moderate ID are equally distributed among girls in early adolescence with 50 % respectively. Middle adolescence is made up by 45 % of girls with mild ID and 33 % of girls with moderate ID. Late adolescence is dominated by 68 % of girls with moderate ID.

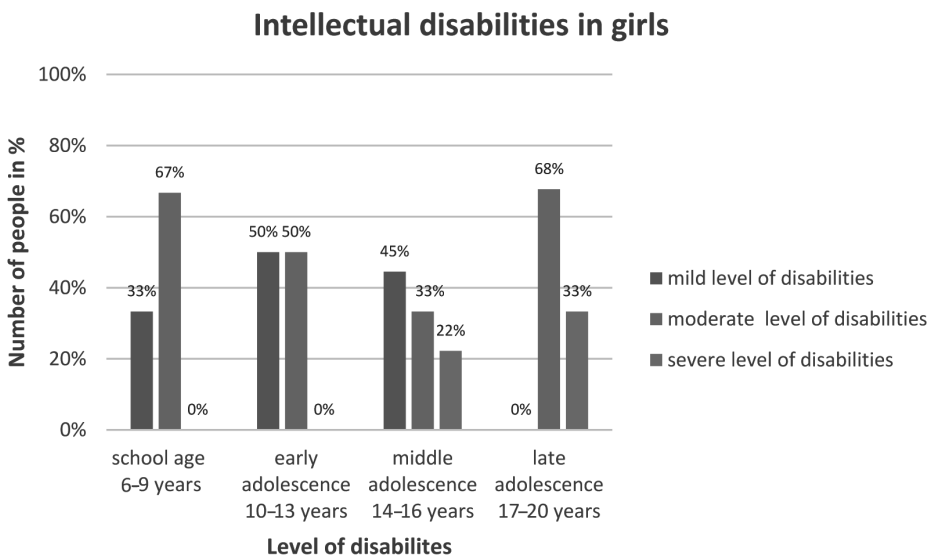

Fig. 9: ID levels in girls

Table 4 shows mean BMI values in girls by the level of their disabilities. Normal weight is associated with all school-age girls and early-adolescent girls with mild to moderate ID. The prevalence of obesity can be found only in girls with mild ID in middle adolescence in contrast to girls with moderate and severe IDs in the same age group who fall into normal weight. Girls with moderate and severe ID in late adolescence have normal weight.

Tab. 4: BMI values in girls by ID levels

The level of intellectual disabilities in girls	Average BMI			
	School age 6–9 years	Early adolescence 10–13 years	Middle adolescence 14–16 years	Late adolescence 17–20 years
Mild level of disabilities	16,4 (normal)	20 (normal)	26,8 (obesity)	–
Moderate level of disabilities	16,9 (normal)	20,5 (normal)	17,8 (normal)	23,8 (normal)
Severe level of disabilities	–	–	23 (normal)	21,4 (normal)

DISCUSSION

It is interesting that the same findings made for adults are also valid for children with intellectual disabilities. In the adult population, many studies have determined a correlation between obesity and mild ID (Melville, Hamilton, Miller & Boyle, 2007). Rimmer & Yamaki (2006) have arrived at the same conclusion. We have also observed the same tendency in both genders. In boys, obesity is prevalent in early adolescence and in girls it occurs in middle adolescence and is associated with mild ID. One of the reasons why this correlation has not been identified for the same age in both genders might be the fact that girls mature 1–2 years faster than boys (Pavlas, 2011, pp. 56–57). As a result, obesity in boys with mild ID is associated with late adolescence rather than middle adolescence.

The finding that women are more prone to obesity than men (Melville, Hamilton, Miller & Boyle, 2007), which is also supported by Hsieh, Rimmer & Heller (2014), has not been observed in our assessed group for early adolescence, where obesity is associated with nearly 64 % as compared to only 25 % of girls. This significant disproportion may again be linked to the differences in development between both genders. It is possible that girls at this age seek out a more active lifestyle than boys, for example they may attend after school clubs which focus on physical exercise.

The above-mentioned argument that women have a higher proclivity to obesity than men (Melville, Hamilton, Miller & Boyle, 2007), as also advocated by Hsieh, Rimmer & Heller (2014), has been confirmed for middle adolescence in our research. In this category, only 14 % of boys show obesity, while in girls the percentage is considerably higher (33 %). At this age, obesity is influenced by physiological differences between men and women rather than intellectual disabilities. During puberty, boys experience an increase in muscle mass caused by higher testosterone levels. In girls, estrogen causes fat build-up in the area of hips and buttocks.

The proportion of fat is considerably higher in women than men. In adulthood, women have, on average, 27 % of body fat as compared to 15 % of body fat in men. The percentage of visceral fat is four-fold greater in women than in men (3 %). Visceral fat protects internal organs and plays a vital part in healthy bodily processes. The amount of fat naturally increases with age in both genders (*ČSOB*, 2017).

Despite the positive finding that there is 61 % prevalence of normal weight in contrast to that of 31 % of obesity in children with ID, the sad true remains that obesity is on the increase and will probably continue rising. This conclusion can be inferred from the comparison of presented findings with publicly available data on the prevalence of obesity in the general childhood population in the in the Czech Republic which shows an increase from 4% to 14 % over the last twenty years and 25% of children at primary schools have overweight (Eurozprávy.cz, 2018).

According to experts, the cause of obesity lies in a bad lifestyle and poor eating habits (Eurozprávy, 2018). Considering that lunch options in school canteens are a subject of strict state regulation and supervision, the main role in childhood obesity is probably played by the family. The need to take family setting into account within the obesity risk factors analysis is also pointed out by Stancliffe et al. (2011).

CONCLUSION

In total, 49 children in the period of school-age, early adolescence, middle and late adolescence participated in the research. More than half of them have a normal weight (61 %) and proclivity to obesity have only one third (31 %) children.

The differences in BMI values among boys can be characterized by the fact that underweight is prevalent only at school age and middle adolescence (14 %). The most notable difference in normal weight can be identified between age groups early adolescence and middle adolescence, in which case middle adolescence shows a 35 % increase. Consequently, boys in middle adolescence are estimated to exhibit lower BMI than in early adolescence, i.e. they will become slimmer. Obesity in boys is associated with early adolescence (64 %).

The differences in BMI values among girls are characteristic of the fact that underweight and obesity are only associated with early and middle adolescence. Girls in middle adolescence demonstrate a decrease in underweight by 2 %, in obesity by 3 % and increase in normal weight by 4 %. There is a prevalence of normal weight in late adolescence. Consequently, it can be inferred that girls will exhibit a lower BMI value in late adolescence than they did in the previous two stages. In other words, they will become slimmer. Obesity among girls is associated with middle adolescence (33 %).

Both genders show prevalence of mild and moderate levels of ID.

In boys, obesity is associated with early adolescence and both mild as well as moderate IDs, whereas in girls, obesity is associated with middle adolescence and mild ID.

References

Bittles, A. H., Petterson, B. A., Sullivan, S. G., Hussain, R., Glasson, E. J., & Montgomery, P. D. (2002). The influence of intellectual disability on life expectancy. *The Journals of Gerontology*, 57, 470–472.

Cooper, S. A., Melville, C., & Morrison, J. (2004). People with intellectual disabilities. *Journal of BMJ, 329*, 414–415.

Duramy, B. F. (2018). Childhood obesity and positive obligations: a child rights-based approach. *Journal of Seattle University Law, 42*, 87–128.

Eurozprávy.cz (2018). *Obézních dětí v* Česku *přibývá: za 20 let jich je dvakrát tolik.* Retrieved from https://eurozpravy.cz/domaci/spolecnost/235777-obeznich-deti-v-cesku-pribyva-za-20-let-jich-je-dvakrat-tolik/ (accessed December 29, 2018).

ČSOB (2017). *Rozdíly mezi muži a* ženami. Retrieved from https://www.csobnazdravi.cz/news/dil-4-rozdily-mezi-muzi-a-zenami/ (accessed January 6, 2019).

Havercamp, S. M., Scandline, D., & Roth, M. (2004). Health disparities among adults with developmental disabilities, and adults not reporting disability in north Carolina. *Journal of Public Health Reports, 119*, 418–426.

Hsieh, K., Rimmer, J. H., & Heller, T. (2014). Obesity and associated factors in adults with intellectual disability. *Journal of Intellect Disabilities*, *58*, 851–863.

ALFABET (2014). *Mentální postižení.* Retrieved from https://www.alfabet.cz/informace-o-typech-zdravotniho-postizeni/mentalni-postizeni (accessed November 11, 2018).

Melville, C. A., Hamilton, S., Hankey, C.R., Miller, S., & Boyle, S. (2007). The prevalence and determinations of obesity in adults with intellectual disabilities. *Journal of Obesity, 8*, 223–230.

NICM (2014). *Klasifikace mentálního postižení.* Retrieved from http://www.nicm.cz/klasifikace-mentalniho-postizeni (accessed December 29, 2018).

Patja, K., Iivanainen, M., Vesela, H., Oksanen, H., *& Ruoppila, I. (2000). Life expectancy of people with intellectual disability: a 35-year follow up study. Journal of Intellect Disabilities, 44, 591–599.*

Pavlas, I. (2011). *Výkonová motivace a interpersonální potřeby.* Ostrava: Pedagogická fakulta Ostravské univerzity v Ostravě.

Rimmer, J. H., & Yamaki, K. (2006). Obesity and intellectual disability. *Journal of Mental Retardation and Developmental Disabilities Research Reviews, 12*, 70–82.

Stancliffe, R. J., Lakin, K. C., Larson, S., Engler, J., Bershadsky, J., Taub, S. Fortune, J. & Ticha, R. (2011). Overweight and obesity aboung adults with intellectual disabilities who use intellectual disability/developmental disability services in 20 U.S. *The American Journal on Intellectual and Developmental Disabilities, 116*, 401–418.

Švarcová, I. (2000). *Mentální retardace: Vzdělávání, výchova, sociální péče*. Praha: Portál.

Tanu, G., Manju, M., Rajesh, S., & Vandana, J. (2018). Psychopathology and stress in Indian overweight and obese children: a case control study. *Journal of Indian Association for Child and Adolescent Mental Health, 14,* 46–59.

Tyler, C. V., Schramm, S., Karafa, M., Tang A. S., & Jain, A. (2010). Electronic Health Record analysis of the primary care of adults with intellectual and other developmental disabilities. *Journal of Policy and Practice in Intellectual Disabilities, 3, 204–210.*

Vágnerová, M. (2000). *Vývojová psychologie: dětství, dospělost, stáří.* Praha: Portál.

Vágnerová, M. (2004). *Psychopatologie pro pomáhající profese* (3rd rev. ed.). Praha: Portál.

Valenta, M., & Müller, O. (2003). *Psychopedie.* Praha: Parta.

WHO (2018). *Body mass index – BMI.* Retrieved from http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi (accessed December 27, 2018).

STUDENT SECTION

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Application of the Double Diamond framework to prepare the communication strategy of a great sports event

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Abstract

Any sports event is characterized by the process of planning, organization and implementation and evaluation itself. This system applies to both single and repetitive, small or larger sports events. The planning process itself applies to all components – sports, technical, financial, process-law, and marketing communications.

There are several marketing communication goals, but they all focus on end-users, fans, their desires, needs and interests in each sporting event. To maximize the benefits of marketing communications, careful preparation and a creative concept in the editorial plan must be prepared.

Different procedures are used to prepare the communication strategy. This article aims to introduce the universal Double Diamond framework, which was used to prepare the communication strategy on the web and social medias for the World Cup in biathlon in Nové Město na Moravě held from December 20 to December 23, 2018, to familiarize with the possibilities of using social tools networks and to present the results achieved with these instruments.

This study describes the framework theoretically and then shows possible practical outputs from the whole process.

Keywords: *sport, sports event, fans, biathlon, marketing, marketing communication, communication strategy, double diamond*

INTRODUCTION

Marketing communication involves the sharing of meaning, information and concepts from the source and the receiver about the products and services through the devices of promotion through advertising, publicity, salesmanship and sales promotion (Rohini, 2018).

According to Přikrylová & Jahodová (2010) there is a several objectives of marketing communications: provide information, create and stimulate demand, different your product or service, emphasize the benefit and value of the product, build and grow a brand or strengthen corporate image.

With the rise of internet communications and mostly social networks, there is growing demand for regular and immediate awareness of the fans. They are usually looking information on the event's website and Facebook page.

Biathlon in the Czech Republic experienced a huge boom mainly thanks to the performance of Czech representatives like Gabriela Koukalová (born Soukalová), Ondřej Moravec, Michal Šlesingr or Veronika Vítková (Hanči, 2017). World Cup races in the year 2016 visited 123,500 fans in four days (Líbal & Mikeš, 2016).

And a similar visit was also expected in December 2018. Especially this enormous interest of fans has prompted the need for quality communication through web sites and social networks. The entire communication strategy on the web, Facebook and Instagram was created to activate biathlon fans before the start of World Cup competitions in Nové Město na Moravě and provide them information about important aspects related to the arrival and the actual stay in Vysočina Arena.

The whole communication concept was created through the Double Diamond framework.

METHODS

Double diamond (Figure 1) is a framework of managing divergent and convergent thought models to create a flow between research, development and design techniques and is also used to create communication strategies (Nessler, 2018; Stubbs, 2018).

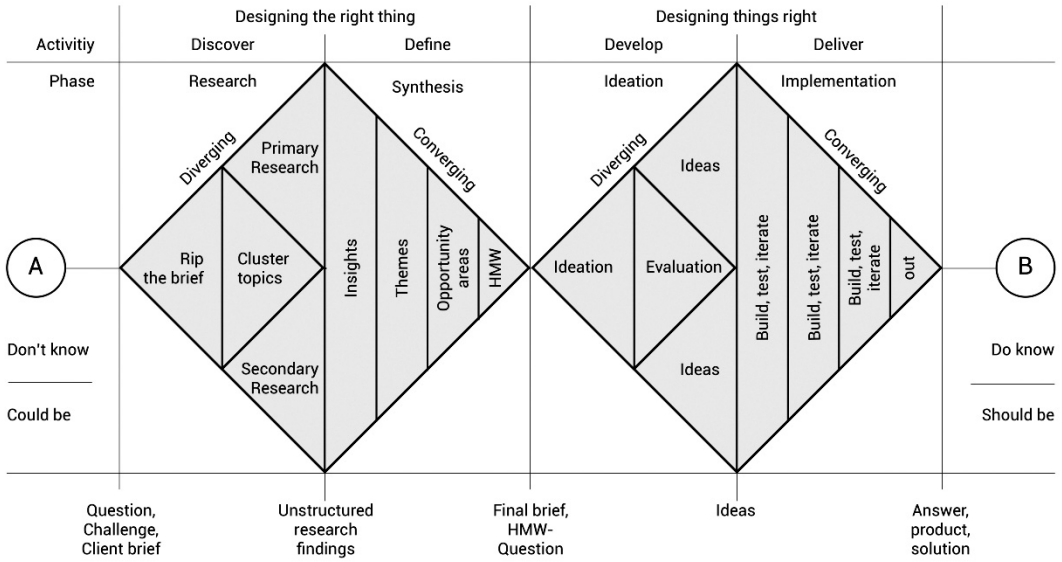

Fig. 1: Double Diamond framework (Nessler, 2018)

As can be seen in the figure, the framework consists of four phases:
- Research Phase,
- Synthesis Phase,
- Ideation Phase,
- Implementation Phase.

Research Phase (Discover) is the first step of the whole process and is based on a written brief describing the starting situation, description of goals, costs, tools, timing and responsible persons. Another part of this phase is also research – marketing mix, definition of our customer or clients, position on the marketing, our competitors etc. The following research methods were also used for this phase: desk research – evaluation the web data from Google Analytics and statistics from Facebook page and Instagram page and also evaluation competitor's qualitative data (the quality of web site, amount of Facebook status and Instagram pages, used tools), and traffic analysis.

The second is **Synthesis Phase (Define)** and starts with definition of personas (personas are archetypical users whose goals and characteristics represent the needs of a larger group of users) (Babich, 2017). For definition of personas were used brainstorming and brainwriting. In case of misunderstanding, the Dot voting was used for clear solution. Dot voting is marketing method that is used when the team needs to choose one option from multiple options (Zbiejczuk Suchá, 2018). The next step of this phase was definition Customer journey map. Customer journey map describes the customer's experience on every single communication channel we used (Boag, 2018). Important part of customer journey is also an empathy map (Figure 2). An empathy map is a collaborative tool teams can use to gain a deeper insight into their customers. Much like a user

persona, an empathy map can represent a group of users, such as a customer segment (Bland, 2016). The last step of Synthesis Phase was to define How might we questions. These questions define the specific opportunities and tasks we are trying to solve in next phase of this framework (Libdesign, 2018).

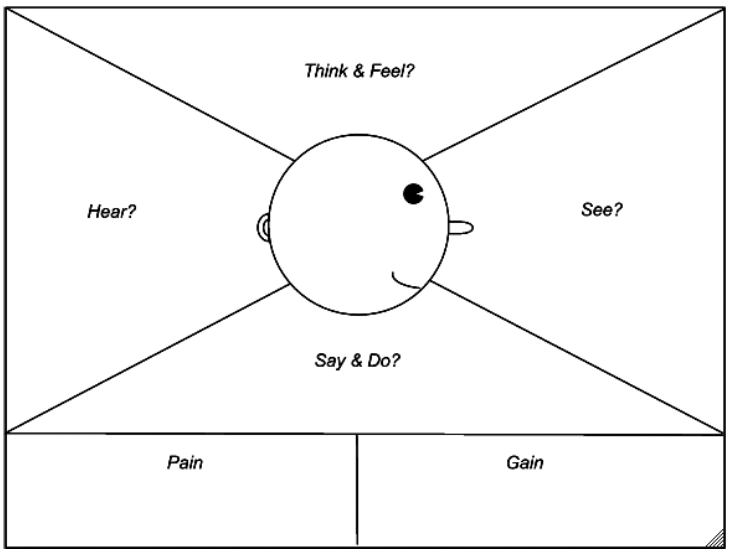

Fig. 2: Empathy Map (Bland, 2016)

After defining How might we questions, we approach **Ideation Phase (Develop)**. This creative phase is primarily about finding answers to HMW questions. A few rounds of brainstorming and brainwriting were used like a research method. Process for generating creative ideas and solutions through intensive and freewheeling group discussion. Every participant is encouraged to think aloud and suggest as many ideas as possible, no matter seemingly how outlandish or bizarre. Analysis, discussion, or criticism of the aired ideas is allowed only when the brainstorming session is over and evaluation session begins (BusinessDictionary, 2019). Brainwriting is a technique similar to brainstorming, but the general process is that all ideas are recorded by the individual who thought of them. They are then passed on to the next person who uses them as a trigger for their own ideas (Mycoted, 2019). The decisions and the final draft of communication strategy was created through Dot voting.

The last phase of Double Diamond is called **Implementation Phase (Deliver)**. This phase is about concretizing individual elements of every strategy we have chosen to create. It contains several rounds of suggestions, testing and approving posts, graphics, voting, etc. All suggestions were then put into a detailed editorial plan and applied to individual communication channels.

RESULTS

The assignment of the entire project was to create a communication strategy from November 1st to December 24th for Biathlon NMNM, its website (www.biathlonnmnm.cz) and social medias Facebook (https://www.facebook.com/biathlonnmnm/) and Instagram (https://www.instagram.com/biathlonnmnm.cz/).

The main goal was to activate fans on social networks and to provide enough information through the website. Partial goals for social networks were defined:

- Increase the average organic reach to a post on the Facebook from current 630 users to the least 5,000 users.
- Increase the average response to a post on the Facebook from current 10 to the least 300.
- Increase the followers on the Instagram page from 800 to the least 2,000 followers.
- Gain the organic responses to a post on the Instagram to the least 200.

According to several brainstorming a brainwriting activities (Figure 3), the whole strategy was created for these personas:

Šárka

- Age: 15
- Job: student
- Marital status: single
- User of social media: very active
- Hobbies: friends, dance, skiing,
- Biathlon fan – active participate with her family and friends. She wants to see all information and photo with her favorite athletes Martin Fourcade and Johannes Thingnes Boe. She is waiting for autographs and photos after the race.

Radim

- Age: 21
- Job: student
- Marital status: single
- User of social media: very active
- Hobbies: active athlete, mostly winter sports and jogging
- Biathlon fan – active participate during the races, buying merchandise, follower of all social media about biathlon, he wants to have all information about current situation, arrangement, athletes etc.

Monika

- Age: 27
- Job: Receptionist in the fitness center
- Marital status: single
- User of social media: very active
- Hobbies: recreational athlete, education, books
- Biathlon fan: huge fan, active participant with a whole family and her boyfriend – they spend all four days in Nové Město na Moravě, buying merchandise. She is follower of all social media, but she is active just on Instagram. She wants to see biathletes and backstage, that fans can't see.

Petra
- Age: 35
- Job: financial accountant
- Marital status: married
- User of social media: passive
- Hobbies: family, friends, skiing
- Biathlon fan: passive participant, she visits the races with a family, organizes a whole trip and stay in Nové Město na Moravě. She takes care of her children who love biathlon as well as her husband. She needs to know all information about traffic and parking, accommodation, race program, also history of races etc.

Martin
- Age: 43
- Job: marketing manager
- Marital status: married
- User of social media: active
- Hobbies: friends, music, cheering on big sports events
- Biathlon fan: big, he wants to know all necessary information including news about Czech team and the biggest stars of world biathlon. He visits the races with his friends, he wants to enjoy the great atmosphere in Vysočina Arena.

We also excluded two personas from the process, due to low social activity on social network, because that we had to focus on the goal of the entire strategy. But these personas could be included in other marketing activities.

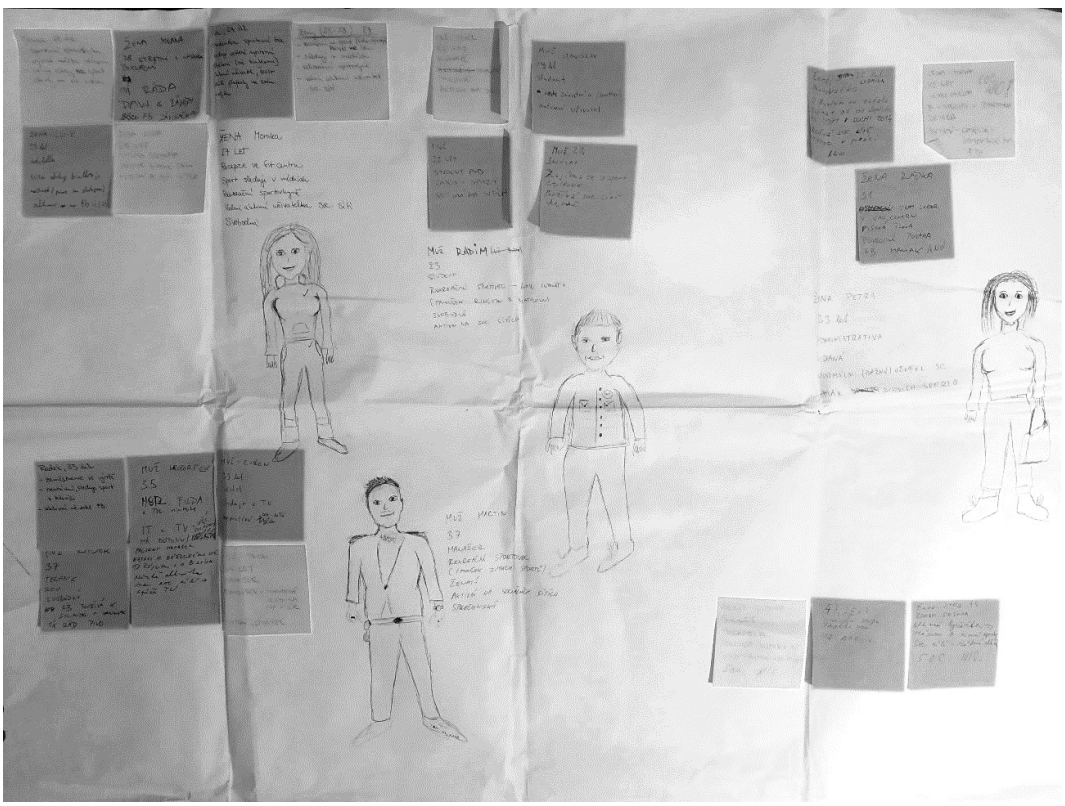

Fig. 3: Creating personas

After personas definition, the customer journey was created. The entire customer journey (Table 1) is tailored to the needs of the project – the goals and especially the personas.

Tab. 1: Customer journey

	Awareness	Consideration and purchase	Acquisition	Service and care
What are they doing on social network?	• high contribution reach • sharing, comments from friends • hashtags • recommended posts	• program search and schedule • search for information about transportation, parking and accommodation • what to take to the arena	• search for information about tickets, arenas, and tribunes • online ticket purchase • online purchase of promotional items	• return ticket information • message response • ticket delivery
Empathy Map	• interest • enthusiasm • a new opportunity • curiosity	• understanding • curiosity • surprise • search • confusion • surprise	• enthusiasm • joy • enjoyment • entertainment	• satisfaction • positive feedback • annoyance in case of non-compliance
What do we want people to do there?	• to gain awareness • raising interest • brand search	• easy orientation • available information • raising positive feelings • quality presentations	• simple purchase of tickets • buying merchandising • quality service and product • discounts for partners • experience from the atmosphere	• immediate answers • immediate receipt of tickets • good information • true information • friendliness
Opportunities we have	• great sharing of posts • viral video • stories of representatives • stories about biathlon events in the Vysočina Arena	• video with invitations of representatives • an article with information on what to take with to take • virtual map of the premises • virtual parking map	• purchase directly on Facebook • share your NMNM experiences • activating partnerships with partners	• direct messages on Messenger • informing fans through the app

The next step was to define "How might we questions" (HMW). After several rounds of brainwriting, 20 possible creative ideas were created. With the help of Dot voting, they were determined HMW questions:

1. How might we use social media tools to get the great fans interaction on social media?
2. How might we increase engagement on social media with the help of Czech representation?
3. How might we give our fans enough information?

After defining HMW questions, the creative process followed. Each question was devised with several ideas (Figure 4).

Fig. 4: Creative process

Created strategies:
HMW q. 1

- Emoji voting – example: a favorite color combination of a new hat
- Comments – example: write us your comments about what favorite song you want to sing at the stadium together
- Connection Instagram and Facebook to direct share photos and stories – example: countdown of 10 day before the start of the race (Figure 5)
- Cross posting of videos made by International Biathlon Union (IBU) – example: course overview with Eva Puskarčíková (Figure 6)
- Videos – example: favorite NMNM song
- Using hashtags – examples: #nmnm2018, #biathlonnmnm, #celebratingbiathlon (Figure 5)
- Stories voting on Instagram through a survey or scale (Figure 7)

Fig. 5: Countdown sample
Source: Instagram page biathlonnmnm.cz

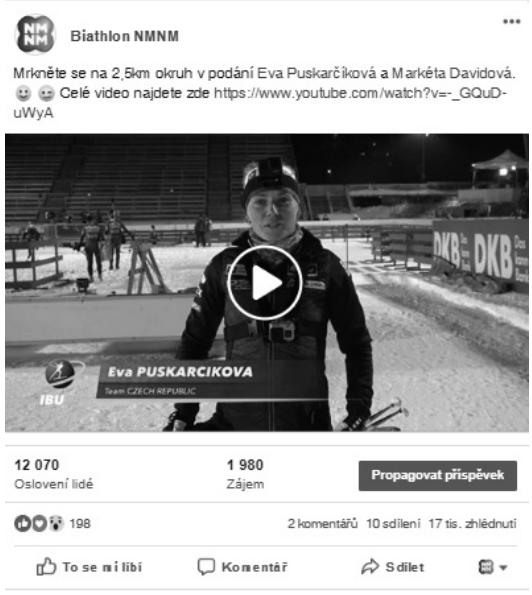

Fig. 6: Cross posted video made by IBU
Source: Facebook page Biathlon NMNM

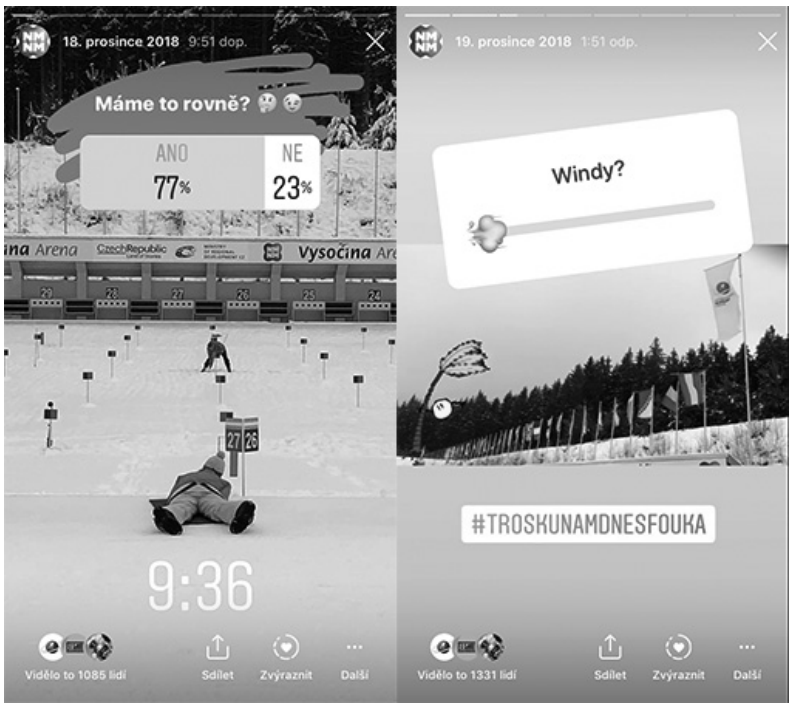

Fig. 7: Stories samples

Source: Instagram page biathlonnmnm.cz

HMW q. 2

- Interview with Czech representative
- Creating an invitation from the Czech team for Czech fans
- Leaving Instagram profile to Czech representatives for one day
- Marking Czech or other athletes in posts or stories

HMW q. 3

- Creating a virtual parking map
- Writing an article about what to take and to do in Vysočina Arena
- A series of articles about historical events in Vysočina Arena
- Writing an article about snow storage and track preparation
- Creating a Biathlon FunCard and sharing for fans

All ideas from strategies were transformed to the posts and stories on Facebook and Instagram, and to the articles on the website. Each specific post was insert into the editorial plan (Figure 8). According to this plan were all posts published until December 24th.

Datum	Typ příspěvku / Poznámka	Zodpovědnost	Příspěvek	Fotky / Video / Odkaz
20. 11. 2018	Nalákání před SP - přesně měsíc do startu	Michal Jilka	Přesně za měsíc se otevřou brány Vysočina Areny před úvodním závodem v NMNM. Tak se na to pojďme naladit. Volume doprava! NMNM...	
21. 11. 2018	Stavba tribun - fotky dodá Honza	Michal Jilka	Tribuny nám postupně rostou Už máte vytipované své místo k fandění? #biathlon #biathlonworld #biathlonnmnm #tribuny #makame	
22. 11. 2018	Informace k lístům	Michal Jilka	Předčasný vánoční dárek - i to bude pro mnoho fanoušků letošní světový pohár v NMNM! Pořiďte i vy sami sobě, svým známým nebo přátelům unikátní zážitek ve Vysočina Areně. Třetí kolo SP bude opět svátkem biatlonu, tak buďte u toho! Volné lístky najdete https://www.ticketlive.cz/cs/event/biatlon-2018	https://www.ticketlive.cz/cs/event/biatlon-2018
23. 11. 2018	Článek - shrnutí předchozích ročníků	Karel Halberštát	V roce 2008 zářil na Mistrovství Evropy v Novém Městě na Moravě Michal Šlesingr. V juniorských kategoriích o sobě zase dali vědět Veronika Vítková a Anton Šipulin. A víc se dočtete v následujícím článku https://www.biathlonnmnm.cz/2018/11/23/na-mistrovstvi-evropy-2008-na-vysocine-zarili-slesingr-vitkova-ci-sipulin/?fbclid=IwAR0v0Jn7bs8U1UehuiQ-05x2mz3mqzXaAufPlytcTrHrh0ZHyZHBCH31dNM	https://www.biathlonnmnm.cz/2018/11/23/na-mistrovstvi-evropy-2008-na-vysocine-zarili-slesingr-vitkova-ci-sipulin/?fbclid=IwAR0v0Jn7bs8U1UehuiQ-05x2mz3mqzXaAufPlytcTrHrh0ZHyZHBCH31dNM
24. 11. 2018	FAN CARD - vytvořit QR kód skrz tag (přidat ?=facebook, do dalšího ?=instagram, do dalšího ?=web) a vložit jak na web, tak na Facebook, tak na Instagram - najdou tam veškeré novinky, informace, apod.	Michal Jilka	Chcete mít nejaktuálnější informace o českém biatlonu ve vašem chytrém telefonu? Stáhněte si pomocí QR kódu nebo následujícího odkazu do vaší mobilní peněženky naši FanCARD a mějte veškeré novinky a důležité aktuality ihned po ruce! https://get.yourpass.eu/537504d0-9a85-48e6-a29d-4ec1012ab2da?tag=facebook	https://get.yourpass.eu/537504d0-9a85-48e6-a29d-4ec1012ab2da?tag=facebook

Fig. 8: Illustration of editorial plan

After the end of the World Cup in the biathlon in Nové Město na Moravě, the evaluation of the selected strategies followed. According to data from Facebook and Instagram, the chosen strategies were successful:

Partial goal 1: Increase the average organic reach to a post on the Facebook from current 630 users to the least 5,000 users – according to data from Facebook (Figure 9), we increased the average organic reach to more than 15,000 users.

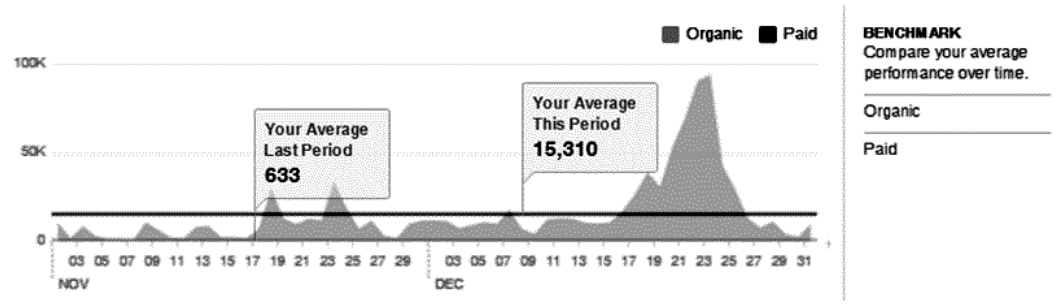

Fig. 9: Organic reach between November 1st and December 31st
Source: data from Facebook Biathlon NMNM

Partial goal 2: Increase the average response to a post on the Facebook from current 10 to the least 300 – according to data from Facebook (Figure 10), we increased the average response to almost 500 per post.

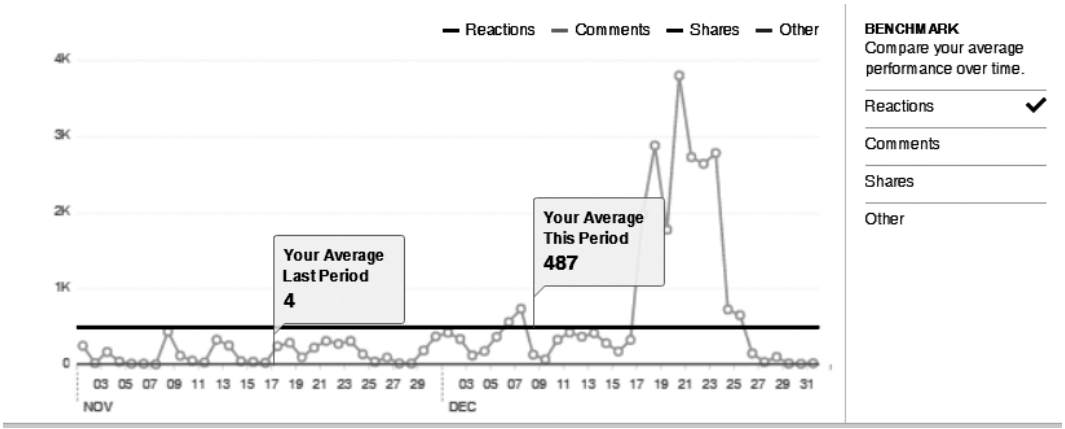

Fig. 10: Average reactions to a post between November 1st and December 31st
Source: data from Facebook Biathlon NMNM

Partial goal 3: Increase the followers on the Instagram page from 800 to the least 2,000 followers – according to data from Instagram (Figure 11), we increased the number of followers from 800 to more than 2,200 (data from January 2nd). On January 13th, the profile has a total of 2,510 followers.

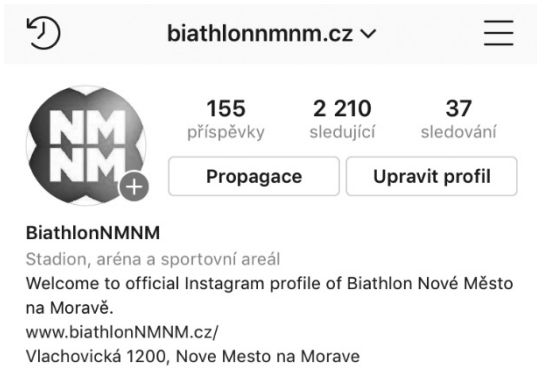

Fig. 11: The number of followers on Instagram on January 2nd
Source: Instagram page biathlonnmnm.cz

Partial goal 4: Gain the organic responses to a post on the Instagram to the least 200 – according to image data from Instagram (Figure 12), between November 1st and December 24th were published 47 posts, 13 posts received a lower response than required 200. That means 72,34 % of posts reached the goal.

Fig. 12: Posts data biathlonnmnm.cz on January 2nd
Source: Instagram page biathlonnmnm.cz

CONCLUSION

This study presents the Double Diamond framework as one of the best options for creating a communication strategy. Apart from the precise methodological description, it also illustrates concrete examples of individual steps of this framework.

The framework is consists of four phases: Research phase, Synthesis phase, Ideation phase and Implementation phase. An important part of the whole process is a facilitator, who moderates, determines and monitors the time span of individual tasks and coordinates the colleagues. This communication strategy involved a total of four people.

Even prior to launching the strategy, it is necessary to set goals that will define the success of the project. Each communication strategy is based on a detailed analysis of the internal and external environment. In the case of focusing on the internet, we can use input data from tools like Google Analytics and individual social media reports. The often-neglected part of communication strategies are precisely defined customers to whom communication is directed. In this case – the personas, who are complemented by a customer journey.

The creative part of the model then offers a variety of opportunities to differentiate from its own previous strategies and to differentiate itself from the competition.

It is also necessary to consider the time-consuming implementation of individual strategies. Just as it was in this case, several ideas were created that could not be realized due to time requirements. All approved ideas are then placed in an editorial plan and ready for publication.

References

Babich, N. (2017). *Putting Personas to Work in UX Design*. Retrieved from https://theblog.adobe.com/putting-personas-to-work-in-ux-design-what-they-are-and-why-theyre-important/.

Bland, D. (2016). *What Is an Empathy Map?* Retrieved from: https://www.solutionsiq.com/resource/blog-post/what-is-an-empathy-map/.

Boag, P. (2018). *Customer Journey Mapping: Everything You Need to Know*. Retrieved from: https://www.sailthru.com/marketing-blog/written-customer-journey-mapping-need-to-know/.

Business Dictionary (2019). *Brainstorming – definition*. Retrieved from: http://www.businessdictionary.com/definition/brainstorming.html.

Hančl, J. (2017). *Biatlonový Boom v České republice. Co za tím stojí?* Retrieved from https://www.isport365.cz/zprava/biatlonovy-boom-v-ceske-republice-co-za-tim-stoji.

Libdesign (2018). *Jak bychom mohli?* Retrieved from http://libdesign.kisk.cz/metody/jak-bychom-mohli.

Líbal, K., & Mikeš, P. (2016) *Fanoušci byli úžasní, rozplýval se v Novém Městě suverén Fourcade*. Retrieved from https://www.denik.cz/zimni_sporty/fanousci-byli-uzasni-rozplyval-se-v-novem-meste-suveren-fourcade-20161219.html.

Nessler, D. (2018). *How to solve problems applying a Design Thinking, UX, HCD or any Creative Process from scratch V2*. Retrieved from https://uxdesign.cc/how-to-solve-problems-applying-a-uxdesign-designthinking-hcd-or-any-design-process-from-scratch-v2-aa16e2dd550b.

Přikrylová, J., & Jahodová H. (2010). *Moderní marketingová komunikace*. Praha: Grada Publishing, a. s.

Rohini, S. (2018). *Marketing Communication: Concept, Objectives, Process, Golden Rules and Components*. Retrieved from http://www.businessmanagementideas.com/marketing/marketing-communication/marketing-communication-concept-objectives-process-golden-rules-and-components-business-marketing/17662.

Stubbs, A. (2018). *Double Diamond Model Expanded.* Retrieved from https://medium.com/@austin_57472/double-diamond-model-expanded-9fbcaa897d48.

Zbiejczuk Suchá, L. (2018). *100 metod*. Retrieved from http://100metod.cz/.

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Influence of Relative Age Effect on competitive shooters of clubs SSK Dukla Hradec Králové and SSKP Kometa Brno

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Abstract

This article deals with the issue of Relative Age Effect (RAE), which enables the exploration of differences and links between the expected and observed distribution of birth date of athletes based on their date of birth. It is expected that into the elite choice are chosen athletes, who were born in the beginning of the year. Therefore, athletes born in last months of year are disadvantaged. In this article, RAE was tested by the means of chi-squared test in Goodness-of-fit test and Kolmogorov-Smirnov test. Afterwards, Cramer's V was used for more accurate estimation of a potency of the association between expected and observed distribution. By the usage of methods previously mentioned it was found out that in selected sport clubs, the results of RAE are not statistically confirmed, however, different connections, which cannot be left unnoticed, were observed. In the conclusion, there is stated that even though it is not obvious on the fleeting glance, the junior category in more influenced by RAE than the senior category. This fact is as such affected also by the nature of shotgun shooting, it emphasizes overall physical condition and physique rather than separate physical and age details of a shooter.

Keywords: *birthdate, athlete talent, juniors, seniors, skeet, shotgun, trap, national team, RAE, shooting, Czech,*

INTRODUCTION

The issue known as Relative Age Effect (RAE) was first studied by Green and Simmons (1962), who conducted a research of pupils at the elementary school level. They found out that pupils who were born in the first half of the year got higher grades than the rest of the class. The issue was introduced into sport field by authors Barnsley, Thompson, and Barnsley (1985), who confirmed the overrepresentation of players who were born in the first quartal (Q_1) over players born in the last quartal (Q_4). The research was conducted on the ice-hockey players of different age and categories (NHL, WHI, OHL).

The sport which uses the RAE with the highest frequency is football, where for example the authors Deprez, Vaeyens, Coutts, Lenoir, and Philippaerts (2012) found out, that the influence is statistically important in the age categories U10–U19. However, the most notable influence was proven in the category U10–U11. The influence of RAE was observed in the players of FIFA U17 World Cup Emirates 2013 and it was found out that the influence of RAE was statistically important in qualifying tournament, but not in final round (Andrade-Souza et al., 2015).

It cannot be stated that if the number of elite players born in the first half of the year (Q_1, Q_2) surpasses the number of players born in the second half of the year (Q_3, Q_4), they are more talented.

On the base of literary research containing more than 140 publications we found out that in sport shooting there has not been any study of RAE. As the most similar sport in which RAE was tested was chosen tennis, based on its sensorimotor features. In this sport, the influence of RAE in multinational junior tournament in the years 2012–2016 (Bozděch et al., 2017) was confirmed. Different influence based on sex was confirmed by Filipcic (2001), when he found out that the influence of RAE was confirmed among boys in categories U12, U14, U16 (not

confirmed in category U18), but among girls it was confirmed in categories U12 and U14 (not confirmed in categories U16 and U18). What is interesting about the conclusion of the study conducted by Loffing, Schorer, and Cobleye (2010) is that they found out that the influence of RAE is statistically important among the players of ITP with the dominant right hand, but not among the players with the dominant left hand. Agricola et al. (2015) researched the influence of RAE on sport successfulness, but no connections between the sport successfulness and the date of birth were found. Thanks to different conditions and systems for the identification of athlete talents, there may be observed various conclusions connected to the influence of RAE in various categories. For example, Pacharoni, Aoki, Costa, Moreira, and Massa (2014) found out that the influence of RAE is significant in the junior level, but not in the professional level of Brazilian players ITP. Ulbricht, Fernandez-Fernandez, Mendez-Villanueva, and Ferrauti (2015) reached the opposite conclusion, when they found out that in Germany the influence of RAE grew with each following level (age and performance), what may be an effect of talent programs which exist in Germany from the category U12.

SHOOTING SPORTS IN GENERAL

According to Paulík (2006), the right choice of athletic talents is one of the main and key questions of today's sport. By the right choice, it is possible to shorten significantly the development of athlete in given sport or sport discipline. At the same time there is a need to calculate with the fact, that every population provides a complete talent spectrum for every sport. National sport federations and clubs then create the criteria for selection of these talents.

Málek (1989) describes the fact that shotgun shooting, which got into the general public opinion in 18th century as a popular activity among higher levels of society. It is a part of modern Olympic Games since its establishment in 1900, even though at the time as shooting and not as shotgun shooting. Since that time the shotgun shooting has developed. Not only as a sport in general, but also its disciplines as well (skeet, trap, doubletrap). Nowadays it is not only a sport for rich people. Sport clubs are trying to provide suitable conditions for everyone, who wants to engage in this sport. If everyone had an opportunity to try shotgun shooting, there would be no talent wasted.

According to Bedřich (2006), sport training is long-term matter and this phenomenon needs to be considered during the choice of athletic talents. Achieving of maximal sport performance has always been preceded by a long-term preparation for pressure, not only physical but also mental. In every case should be regarded with the specifics and rules of the particular sport discipline together with basic principles of sport training.

Shotgun shooting is a sport which considerably lacks systematic concept in the choice of talents and given sport area is overall not very explored. Current practice of the choice of starting players depends only on the trainer, who asses the talent. Trainer takes into consideration the somatotype of athletes, physical condition and mental condition. Based on the fact that given sport is performed with a gun, in the case of shotgun shooting sport gun is certain mental maturity and physical condition of a starting athlete required. Because of this reason are only very rarely accepted athletes younger than 12. As the mental and physical requirements are so high for starting athletes, the choice of talents is considerably restricted. This is the reason why it is necessary to pay attention to every factor which may influence the choice of talent, as in our case the influence of Relative Age Effect.

METHODOLOGY

The compilation of data was obtained with the consent of leaders of two top Czech sport shooting clubs. The respondents were chosen by the athletes of these clubs, who form together the Czech National Team in the year 2016/2017 (n = 35). Median of birth in Czech National Team is 1994. Particularly, it is a club Kometa Brno (n = 26, 11 men, 6 women) which fall within the department of Ministry of the interior based in Brno and club Dukla Hradec Králové (n = 9, 7 men, 2 women) which fall under the army resort, with place of operation in Hradec Králové.

The whole group is formed by several sub-categories. These sub-categories are formed of disciplines of shotgun shooting, age and sex. The disciplines are skeet and trap. Younger shooters are in junior categories (category up to 20 years included) and senior category, or rather men and women (category from 21 years). Senior category of men is divided into representative categories A, B, C; and these sub-categories have special criteria of division. For the purposes of the study is used the whole category, senior men category. On the contrary, for the purposes of the study was created the category which divides group into athletes who participated in prominent multinational competitions, such as European Championship, World Championship, World Cup and Olympic Games (ME, MS, SP, OH) and into shooters, who have not taken part such competition.

Researched data were statistically analyzed by the mean of chi-squared test (χ^2) in verification of Goodness-of-fit and Kolmogorov-Smirnov test (KS). We observed distribution (date of birth in Q_i) and compared it with the expected distribution (number of children born in Czech Republic in 1994 in Q_i), which we obtained from the publicly available database (data.un.org), it is as follows: Q_1 = 26.35%; Q_2 = 27.97%; Q_3 = 24.32%; Q_4 = 21.37%. For more accurate assessment of the influence of RAE was apart from χ^2 test calculated also Cramer's V (V), mainly for the purpose of assessing the power of association with expected and observed distribution. For our degree of freedom (df = 3) has according to Cohan (1988) the following interpretation: small (V < 0.17), medium (V < 0.29), or large effect (V ≥ 0.29).

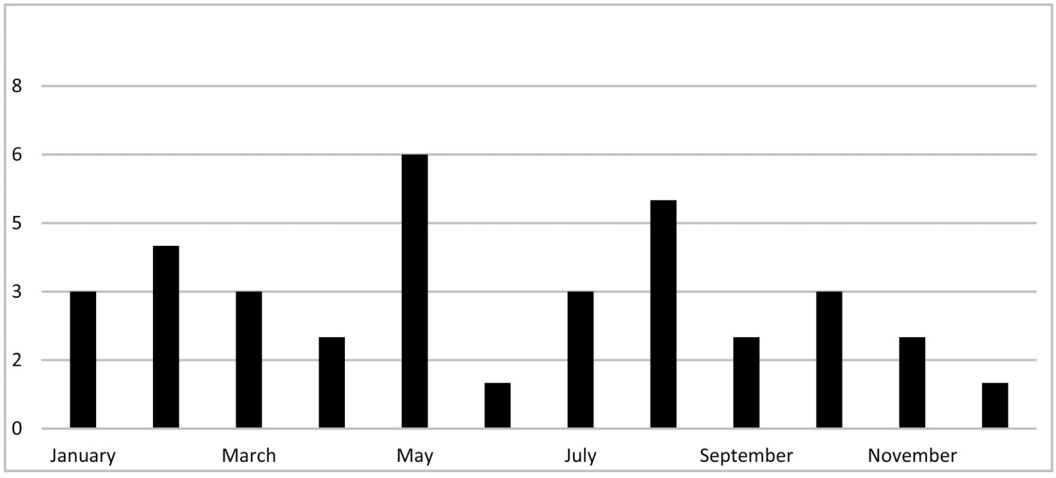

Fig. 1: Distribution of Date of Birth of Dukla Hradec Hrálove and Kometa Brno Divided into Months.

In the figure 1, you can see the division of the whole observed group (n = 35) by months.

AIM OF STUDY

Research questions for the study are the following:

Is the influence of Relative Age Effect provable in the whole observed group?

What is the difference in the influence of Relative Age Effect on the categories of junior and senior?

What is the influence of Relative Age Effect on shooters who represented the Czech Republic in European Championship, World Championship, World Cup and Olympic Games?

RESULTS

Influence of RAE on the Whole Observed Group

Methodology concerning RAE issue uses the date of birth division based on quarters (Q_i), which is displayed in the following table 1. This table contains the division of the whole group (n = 35) in individual quarters (Q_i). The table consists of chi-squared test and Cramer's V.

Tab. 1: Influence of RAE on Players of Club Dukla and Kometa Brno.

	Q_1	Q_2	Q_3	Q_4	n	χ^2	p	V	ES
Absolute	10	9	10	6	35	0.68	0.88	0.08	Small
Relative	28.57%	25.71%	28.57%	17.14%	100%				
Relative	S_1 = 54.28%		S_2 = 45.71%		100%	–	–	–	–

Note. Q_i = quarters; S_i = semester; χ^2 = chi-squared test; p = p-value; V = Cramer's V; ES = effect size.

It is noticeable that the lowest value in the tracked group in the table 1 is in the Q_4, however, based on chi-squared test (χ^2), its influence is statistically not important (p = 0.88). The associated influence in between the selected variables were Cramer's V negligible (V = 0.08).

Influence of RAE on different age categories

In the following table 2, the influence of RAE on the categories of junior and senior may be observed. Due to not fulfilling the conditions necessary for chi-square test the Kolmogorov-Smirnov test was used instead of Goodness-of-fit test.

Tab. 2: Effect of RAE on the Categories of Junior and Senior.

Category		Q_1	Q_2	Q_3	Q_4	n	D_{max}	CV
Junior	Absolute	3	6	6	0	15	0.212	0.338
	Relative	20.00%	40.00%	40.00%	0.00%	100%		
Senior	Absolute	7	3	4	6	20	0.088	0.294
	Relative	35.00%	15.00%	20.00%	30.00%	100%		

Note. CV = critical values (0,05) for $D_{max.}$

In the table 2 there can be observed that the lowest value in junior category is in Q_4 (Q_4 = 0; i.e. 0.00%) and vice versa, the highest value in senior category is in Q_1 (Q_1 = 7; i.e. 35.00%). Nevertheless, with the Kolmogorov-Smirnov test there was not indicated the influence of date of

birth neither in junior category (D_{max} = 0.212 < CV = 0.338) nor senior category (D_{max} = 0.088 < CV = 0.294). According to the result of Kolmogorov-Smirnov test there can be further stated, that the influence of RAE (although insignificant) is stronger in junior category (D_{max} = 0.212) than in senior category (D_{max} = 0.088).

The last table of this study contains only shooters (n = 28), who participated in competitions European Championship, World Championship, World Cup and Olympic Games (later ME, MS, SP, OH).

Tab. 3: Influence of RAE in the Category of shooters, who Participated in Top Competitions (ME, MS, SP, OH).

	Q_1	Q_2	Q_3	Q_4	n	χ^2	p	V	ES
Absolute **Relative (Q_i)**	9 32.14%	6 21.43%	7 25.00%	6 21.43%	28 100%	0.79	0.85	0.10	Small
Relative (S_i)	S_1 = 53.57%		S_2 = 46.43%		100%	-	-		-

Table 3 shows certain influence of date of birth in number of shooters in certain quarters (Q_i) as well. The highest value can be observed in Q_1 (Q_1 = 9; i.e. 32.14%). According to chi-squared test these values are statistically negligible (p = 0.85) and according to Cramer's V the association between variables is negligible (V = 0.10).

DISCUSSION

The results obtained show, that the influence of RAE in shotgun shooting is statistically negligible. Nevertheless, there is noticeable difference in between junior and senior categories. The force of the influence of RAE is higher on junior level than on senior level.

This fact is partially in accordance with Coutts, Kempton and Vaeyens (2014), who studied the influence of RAE in Australian draft in the highest league AFL in years 2001–2012. It showed significant influence of RAE among players below and above 20 years. Just as in our study was the influence of RAE in younger category more powerful (< 20 years χ^2 = 28.7; ≥ 20 years χ^2 = 8.0).

This fact partially corresponds with study by Coutts, Kempton, and Vaeyens (2014), who researched the influence of RAE in Australian.

In contrary, Ubricht et al. (2015) found out that the influence of RAE in Germany is more significant in every next performance group, players (U1–U18) who were born in Q_1 had the following representation in various performance levels: registered players 24.3%, players in ladder ITP 29.6%, regional selection 38,1%, national selection 42.1% (expected number 24.7%). In other words, the influence is exactly the opposite to our findings. One of the possible explanations are countless centers for talented youth in Germany, into which there are chosen the players in young age.

With a similar size of study group worked Camacho-Cardenosa et al. (2018), who researched the influence of RAE in handball (23 males and 24 females, 13.26 ± 0.44 years). Their values of women's group (χ^2 = 0.89; p = 0.35) were comparable with our calculated value of χ^2 in the whole group (χ^2 = 0.68; p = 0.88) and among the participants of top-level competitions (χ^2 = 0.79; p = 0.85). In the men's group the authors found even lesser influence of RAE than in women's group (χ^2 = 0.064; p = 0.8).

CONCLUSION

In the whole group (n = 35) was not observed by the mean of chi-squared test any significant difference between expected and observed value (χ^2 = 0.68; p = 0.88), therefore there was no influence of RAE. Next, the RAE influence in junior category (n = 15) and senior category (n = 20). Based on Kolmogorov-Smirnov test (KS), the influence of RAE is not significant neither in junior category (D_{max} = 0.212 < CV = 0.338) nor senior category. (D_{max} = 0.088 < CV = 0.294). Even though none of categories (junior, senior) according to KS test showed expected distribution of the date of birth, we can state that the junior category is more likely to be influenced by the RAE than the senior category.

Then, we researched the influence of RAE among sport shooters, who represented the Czech Republic on a multinational level (ME, MS, SP, OH) and we found out that according to chi-squared test the influence of RAE is not significant (χ^2 = 0.79; p = 0.85) the association between the variables is none (df = 3; V = 0.1).

Even though from an objective point of view the influence of RAE is evident, none of our tests found out statistically important influence of the date of birth in sport shooters in any category. These results are not surprising, as one of the criteria for the influence of RAE is the competition (which is numerous enough) in the category. Moreover, we consider the advantages resulting from the date of birth of relatively older athletes who were born in the first half of the year, such as height and weight, are not so fundamental for shotgun shooters. Even from the recruitment of athletes the importance is put on the physical construction and physical readiness of the body to absorb back pressure. Despite the fact that this work consists of only a small observed group from which the general conclusions are difficult to obtain, it consists of approximately 30% of all registered Czech shooting athletes and 90% of the Czech National Team. Based on not proving the influence of date of birth in all observed criteria of our group we assume that the current method of choice of shooting athletes does not need to be adjusted in order to eliminate the influence of RAE.

References

Agricola, A., Psotta, R., & Abdollahipour, R. (2015). Relativný efekt veku na súťažnú úspešnosť v tenise u dětí staršieho školského veku. *Telesna Kultura*, *38*(1), 30–43.

Andrede-Souza, V., Moniz, F., & Teoldo, I. (2015). Relative age effect in FIFA U17 Emirates 2013 World Cup: analysis of players who effectively participated in the matches. *Motriz: Revista de Educação Física*, 21(4), 403–406. doi:10.1590/S1980-65742015000400009.

Barnsley, R., Thompson, A., & Barnsley, P. (1985). Hockey success and birthdate: the relative age effect. *Cahper Journal, 51*(8), 23–28.

Coutts, A., Kempton, T. & Vaeyens, R. (2014) Relative age effects in Australian Football League National Draftees, *Journal of Sports Sciences, 32*(7), 623–628, doi: 10.1080/02640414.2013.847277.

Bedřich, V. (2006). *Fotbal rituální hra moderní doby*. Brno: MU. 195 s.

Bozděch, M., Nykodým, J., Agricola, A., & Zháněl, J. (2017). The relative age effect in the world junior tennis finals 2012–2016 (male). In M. Zvonař (Ed.), "*11th International Conference on Kinanthropology. Sport and quality of life.*" (p. 45). [Book of abstrats]. Brno: Masarykova univerzita.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Deprez, D., Vaeyens, R., Coutts, A. J., Lenoir, M., & Philippaerts, R. (2012). Relative age effect and Yo-Yo IR1 in youth soccer. *International Journal of Sports Medicine*, *33*(12), 987–993. doi:10.1055/s-0032-1311654.

Filipcic, A. (2001). Birth date and success in tennis, *Coaching & sport science review, 23*, 9–11.

Green, D. R., & Simmons, S. V. (1962). Chronological age and school entrance. *The Elementary School Journal, 63*(1), 41–47.

Loffing, F., Schorer, J., & Cobley, S. P. (2010). Relative Age Effects are a developmental problem in tennis: but not necessarily when you're left-handed!. *High Ability Studies, 21*(1), 19–25.

Málek V. (1989). *Sportovní střelba*. Praha: ÚV Svazarmu. 139 s. ISBN 80-7062-109-5.

Pacharoni, R., Aoki, M. S., Costa, E. C., Moreira, A., & Massa, M. (2014). Efeito da idade relativa no Tênis. The relative age effect in Tennis. *Revista Brasileira De Ciência E Movimento, 22*(3), 111–117.
Paulík, K. (2006). *Psychologie sportu*. Ostrava: FF. 154 s.
Ulbricht, A., Fernandez-Fernandez, J., Mendez-Villanueva, A., & Ferrauti, A. (2015). The Relative Age Effect and Physical Fitness Characteristics in German Male Tennis Players.*Journal of Sports Science & Medicine, 14*(3), 634–642.

Fear of Falls in Wheelchair Users

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Abstract

The article deals with the issue of fear of falls in wheelchair users and the change in fall concerns after completing a self-defense course. The aim of this study was to assess the impact of a self-defense course for wheelchair users on their fear of falls. To collect data we used a questionnaire and participant observation in the lessons of self-defense for wheelchair users. The participants filled in the questionnaires at the beginning and at the end of the course.

The results show that the course of self-defense has an effect on wheelchair users' fear of falls. This effect differs depending on the type of disability of the participant and on the level of self-confidence. We can claim that the participants with a low level of fear at the beginning of the course this attitude has shifted slightly and they became more aware of potential threats. On the contrary, the participants whose level of fear was high, those fears were reduced and their attitude towards a potential fall is slightly more relaxed.

Key words: *wheelchair, falls, self-defense*

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INTRODUCTION

The instincts to preserve one's life, interests and values are deeply ingrained in every individual (Pavelka & Stich, 2015). It is therefore natural that these instincts take over in life-threatening, stressful, self-defense situations. A self-defense conflict, even though it may only take a few seconds in most cases, has a certain cycle and can be divided into seven stages: education, initiation, escalation, confrontation, stabilization, normalization, evaluation (Wagner, 2006).

In this paper we deal with self-defense in people with disabilities where it is necessary to primarily focus on the pre-conflict stage. It is the phase of education, getting information about where the participant can gain an advantage over the assailant thanks to the knowledge of tactics and strategy. The stage of initiation is typically triggered by the assailant, however it is important to make sure the defender does not become an initiator e.g. by making an inappropriate comment or movement or by bumping into the assailant. The last of the pre-conflict stages is escalation. This stage directly precedes the confrontation itself and can occur repeatedly during a conflict. To prepare for it the participants learn assertiveness and ways to control the assailant effectively.

The theory of self-defense takes into account the fact that some people are disadvantaged in self-defense situations – particularly women, children, the elderly and people with disabilities (Reguli, 2005). It is therefore necessary to adjust self-defense courses to individual needs

of these individuals by selecting appropriate strategies and methods of teaching. Studies show (Čihounková, Skotáková & Kohoutková, 2016) that people with physical disabilities are victims of assaults more often than people without disabilities. This fact can lead to greater fear of an assault and lower self-confidence in people with disabilities.

It has been found that in certain countries (Kane, 2008) people with disabilities are three times more likely to be a victim of a crime and that crime is also these people's main concern. They fear an assault and they do not feel safe in the streets, nor in their own homes. This fear is most widely spread among people with limited mobility or visual impairment. One of the consequences of this fear is obviously a higher risk of social isolation as these people fear going out unaccompanied. The higher risk of victimization in these people has been pointed out also by Čírtková (2014). Due to these facts it is necessary to also aim to improve the mental condition of the participants. Self-defense exercise per se is highly emotionally and mentally demanding, which makes it an ideal tool for building one's confidence and improving their mental wellbeing since the growing level of skills correlates with the level of confidence as demonstrated e.g. by Wong (1991).

Previous research in the area of self-defense (Čihounková et al., 2016, Skotáková, Čihounková, & Sklenaříková, 2017) implies that wheelchair users greatly fear falling off the wheelchair. Other studies (Kirby, Ackroyd-Stolarz, Brown, Kirkland & Macleod, 1994; Gavin-Dreschnack, Nelson, Harrow & Ahmed, 2005; Gaal & Rebholtz, 1997; Berg, Hines & Allen, 2002; Chen, Wang, Hunang, Chang, Mao & Wang, 2011) confirm that falls are a frequent phenomenon encountered by wheelchair users, where 40–60% of them will have experienced a fall. Furthermore, the authors of the above studies state that although the injuries resulting from the falls are not lethal in most cases, 60–80% of total injuries of wheelchair users are caused by a fall.

Therefore, our course of self-defense for wheelchair users focuses namely on the issue of falls both in terms of methodology (an integral part of the course was teaching the techniques of falls applied in model situations) and also in terms of research whose results are presented in this paper. We bear in mind that every physical activity as such is beneficial to wheelchair users (cf. Shephard, 1991).

The aim of this study is to assess the impact of a self-defense course for wheelchair users on their fear of falls.

Design of the research

This study's design is quasi-experimental (Privitera & Ahlgrim-Delzell, 2018), it was supplemented with case studies due to the small number of respondents. These studies incorporate quantitative data and contribute to explanation of the results of our intervention. Case studies combine data obtained from personal questionnaires, observation and non-structural dialogues. Personal questionnaire included questions concerning the fear of the potential fall during daily activities. Respondents were answering it two times, at the beginning and at the end of intervention. The dialogues concerned the topics of respondents' private lives and experience with self-defence and falls. They were done in the course of respective educational units. Respondents were observed by Jakub Tomeček and Alena Skotáková, what was observed was primarily the behaviour in crisis situations, reactions to unexpected impulses and personal traits of respondents.

The research sample

The research sample consisted of wheelchair users. The experimental group was composed of the participants of the self-defense course, which in this case represented an intervention programme. The experimental group composed of 6 women and 1 man aged 23 to 60 with a varying degree of education (vocational or secondary with school-leaving exams), see table 1.

Tab. 1: Basic Characteristics of the Experimental Group.

participant	age	gender	occupation	education	degree of disability/ specification	wheelchair experience
1	23	female	student	secondary with school-leaving exams	mobility of lower limbs	16 years
2	27	female	interpreter	secondary vocational	paraplegia	22 years
3	48	female	self-employed	secondary vocational	paresis of lower limbs	4,5 years
4	60	female	–	secondary with school-leaving exams	3rd degree quadri-plegia	5 years
5	27	female	–	secondary with school-leaving exams	mental problem	5 let
6	35	male	IT-specialist	secondary with school-leaving exams	paraplegia	15 years

Intervention programme "Self-defence course for wheelchair users"

The experimental group had in total 10 practical double session. The course took place at the Faculty of Sports Studies Masaryk University in Brno. The course gradually dealt with all the phases of conflict (with an emphasis on pre-conflict) and the participants learned how to behave in these situations.

The course also included teaching of strategic solution of self-defense situations and verbal self-defense, the development of technical skills needed for self-defense per se (e.g. blocks, punches, etc.), training of fall techniques including combat in a disadvantaged position on the ground and the final stabilisation of a conflict situation (getting assistance, moving away to safe distance, etc.). The final part of a teaching session was always devoted to conditioning compensation exercise and relaxation to cool down. At the end of each session there was a direct feedback slot from the participants with the aim to gradually improve the dynamics of the course. Some of the comments given above are included in the case study. At the end of the course, all the techniques and skills were applied in model situations.

Research methodology

To gain data we used a questionnaire "The Spinal Cord Injury – Falls Concern Scale" (SCI–FCS) by Boswell-Ruyse (2010). The SCI-FCS includes a test of internal reliability and validity with an excellent score. Yardly (2005) states that this questionnaire is partly based on FES-I questionnaire. The Czech version of the questionnaire was done by a back-translation according to Boswell-Ruyse (2010). The questionnaire includes 16 closed questions, the respondent marks the most suitable answer with a cross. The questions deal with everyday activities.

The following four options of answers are provided: not at all concerned; somewhat concerned; fairly concerned; very concerned. Each of the options has an assigned value 1–4, thanks to which the result of each questionnaire can be interpreted as a score (s). If the respondent does not perform the activity they are asked to answer as IF they had to do it. Having answered all the questions the points are added up and classified into one of the categories: 16–19 points low level of fear; 20–27 slight fear; 28–64 high level of fear see table 2. Subsequently the data are sorted into a table of frequencies and processed into a graph. Further data were obtained by observations at the sessions of the intervention course.

Tab. 2: The Questionnaire.

	Not at all concerned 1	Somewhat concerned 2	Fairly concerned 3	Very concerned 4
1. Getting dressed or undressed	1	2	3	4
2. Moving around the bed (including sitting up)	1	2	3	4
3. Inserting enema or toileting	1	2	3	4
4. Washing or showering self	1	2	3	4
5. Transferring on/off a commode or toilet	1	2	3	4
6. Transferring in/out of bed	1	2	3	4
7. Transferring in/out of a car	1	2	3	4
8. Reaching for high objects (e.g. pressing button on a lift, reaching to a high shelf)	1	2	3	4
9. Picking objects up from the floor (e.g. clothes, pet bowl, pen)	1	2	3	4
10. Cooking or food preparation (e.g. making a sandwich, stirring food on the stove)	1	2	3	4
11. Pushing wheelchair on flat ground	1	2	3	4
12. Pushing wheelchair on an uneven surface (e.g. rocky ground, irregular pavement)	1	2	3	4
13. Pushing wheelchair up/down gutters or curbs	1	2	3	4
14. Pushing wheelchair up/down a slope	1	2	3	4
15. Shopping	1	2	3	4
16. Lifting heavy objects across body (e.g. shopping bags, wheelchair into the car)	1	2	3	4

The course of measurements

The questionnaire was distributed twice among the respondents (at the beginning and at the end of the intervention programme). Each member of the experimental group is described individually as a case study.

RESULTS AND DISCUSSION

We present the results of a survey concerning fear of falls and additional case studies.

The average score (s) of the experimental group was identical at the beginning and at the end of the intervention programme, i.e. s = 28, while the individual results of participants differed. Considering that value 1 in the questionnaire signifies no fear and value 4 great fear of a participant, we can assume that the lower average score indicates a higher level of self-confidence in people who (despite their disability) decided to attend a relatively challenging self-defense course. For the individual values achieved by the participants, see Table 3.

Table 3: The Score Achieved by Individual Participants of the Experimental Group at the Beginning and at the end of the Course.

	Experimental group	
participant	**Beginning of course**	**End of course**
1	32	29
2	23	28
3	26	27
4	40	31
5	20	20
6	27	33
average	**28**	**28**

The answers of individual participants are given in graph 1 in percentages, which makes apparent the positive, neutral or negative change between the first and second investigation. Displays the frequencies of positive and negative changes in answers in the experimental group. Neutral answers constitute the empty field between the positive and negative value. Specifically, e.g. in question 16 one of the participants noticed a positive change, one a negative change and 4 gave the same answer meaning there was no change.

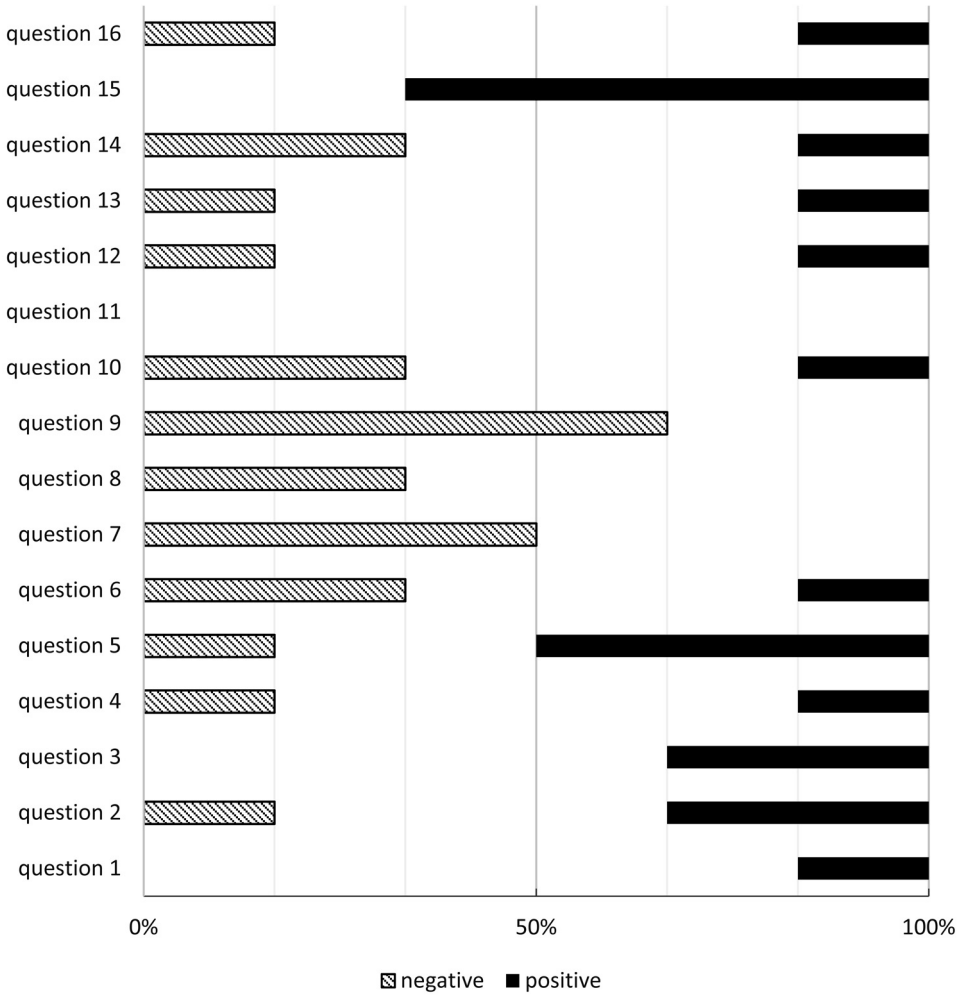

Fig. 1: Displays the frequencies of positive and negative answers in the experimental group. Neutral answers constitute the empty field between the positive and negative value.

Case studies

In the case study analysis below we discuss the results from the questionnaire in greater detail and we also include our observations during the self-defense course.

Participant 1:

Woman aged 23, completed secondary education with school-leaving exams, paraplegic, wheelchair experience of 20 years. She has a congenital disorder and has been using a wheelchair since early childhood. She is quite confident on the wheelchair while performing everyday activities but is also aware of potential risks. Thanks to the techniques taught in the course this participant's self-confidence has increased and so has her confidence in performing everyday tasks. Her starting score was 32, while at the end her score was 29, i.e. she has moved from great fear category into slight fear. Participant 1 is still aware of potential risks but she proclaimed several times in the feedback after the session that thanks to higher self-confidence her quality of life has improved as confirmed by her questionnaire score. Changes were noted specifically in questions concerning getting dressed and undressed, moving on the bed, using the toilet, as well as lifting objects from

the ground and preparing food. In these cases there was a lower fear of fall while being engaged in the above activities. These changes can be attributed to an improvement in motor skills and coordination of movements on the wheelchair, which were trained e.g. during self-defense against multiple assailants. During this activity it is essential to observe the surroundings and move the wheelchair quickly and precisely. On the other hand, there was a slight increase in the fear of getting over grooves and curbs and while going uphill and downhill. These activities involve tilting the wheelchair and the participant is more aware of potential risks of this as a result of being trained the assisted fall.

Participant 2:
Woman aged 27, interpreter, completed secondary vocational education, paraplegic, wheelchair experience of 22 years. The participant is a positive young woman, her disability is congenital and she has been using a wheelchair since early childhood. The functional mobility of her lower limbs has been partly preserved, thanks to which she is able to move around across short distances, e.g. to load the wheelchair into a car and then get into the car. The participant has an assistance dog which affects her perception of potential risks. The participant chose her assistance dog as a form of passive or active self-defense aid. As a result of the course the participant has become aware of the potential risks and injuries associated with a wheelchair fall. The effect the intervention course had on this participant was the opposite to Participant 1. At the beginning of the programme her score was 23 and at the end it was 28, which means that in both cases she fell into the category of slight fear. This might be interpreted in such a way that at the end of the course the participant is now aware of potential risks and due to that she improved in the area of fall prevention, or injuries associated with a fall. There were noted specific changes concerning moving around, such as in going to the toilet, getting onto a bed or into a car. These activities require certain exertion. We can assume that thanks to taking the course under supervision of a trainer she could test her actual physical limits and she has therefore changed her perception of these activities and the fear of performing them. In the course the participants trained several times the transfer from the ground onto the wheelchair as well as manipulation with the wheelchair. Also in this instance the training led to higher self-confidence in performing the task. On the contrary, there was an increased level of fear of riding on uneven terrain. Similarly to other participants, participant 2 also practised a fall off the wheelchair with the trainer's assistance so she has experienced feelings associated with such a fall and is aware of the risks of riding on uneven terrain.

Participant 3:
Woman aged 48, self-employed, completed secondary education with school-leaving exams, paresis of lower limbs, wheelchair experience of 4.5 years. Participant 3 is an active woman with many hobbies. Although she is not able to move her legs, she is capable of rotation of the trunk on the wheelchair and the general mobility of her upper body is very good. She decided to enrol on the course to gain new experience. This participant was not fully aware of potential threats and the training sessions were mainly fun for her. Having completed the whole intervention and model situations her perception of the risks has changed and now she also knows how to respond to them. The score achieved at the beginning of the course was 26 and 27 at the end, which means slight fear. The difference between the two scores is not great, however, there are significant changes in the individual answers to the questionnaire.

The fear of fall while performing everyday activities has been reduced, while alertness when performing other everyday activities has grown. Specifically there have been changes in washing and taking a shower, lifting objects off the floor and cooking and preparing food where the fear has grown slightly. These activities require relatively strenuous moves which increase the risk of falls. The changes are minor, which means that the opportunity to practise the fall off the wheelchair

has changed the participant's view of the risk and she is now aware of potential threats. On the contrary, the fear of going to the toilet has been reduced, perhaps as a result of enhanced physical condition thanks to the training of challenging self-defense techniques.

Participant 4:
Woman aged 60 years, unemployed, completed secondary education with school-leaving exams, quadriplegia of the 3rd degree, wheelchair experience of 5 years. This participant is an elderly lady who is fully aware of her limits but attempts to lead a fulfilled life nevertheless. As the only one in the group she is using an electric wheelchair but is also able to operate a non-electric one if necessary and uses the services of an assistant. In case of a fall off the wheelchair she is completely reliant on the help of others due to the extent of her disability. The participant has got personal experience of an assault and it was also her main motive for enrolling on the self-defense course. Her initial score was 40, i.e. relatively high, which indicates that the participant rather fears a fall while performing all everyday activities. In the course of the intervention programme, however, the participant was engaged and enthusiastic, which led to an increase in her self-confidence. By the end of the course her score was reduced to 31, classified as the great fear group. Participant 4 is still aware of her limits and potential threats but in her own words in the feedback has improved the quality of her life thanks to aligning her fears with reality rather than exaggeration. There were changes in almost two thirds of the questionnaire, to be more precise in 10 out of 16. The changes were mostly positive, i.e. the fears were reduced. The participant had a chance to try out where her limits are. According to her description there was a shift in her perception of performance of individual activities and her attitude. The participant stated in the interview that thanks to completing individual parts of the course, such as assisted fall off the wheelchair, verbal and nonverbal communication but also self-defense techniques as such, she built her muscles and improved her motor skills on the wheelchair, which led to an increased self-confidence in her everyday life.

Participant 5:
Woman aged 27, unemployed, completed secondary education with school-leaving exams, mental incapacity to walk, wheelchair experience of 5 years. The participant is an energetic woman with an unusual disability – she claims that when she is alone and in familiar environment, she is capable of walking but whenever there is another person watching her (acting as a stressor) she has to rely on the wheelchair. Her mobility on the wheelchair is relatively good, and also in case of a fall she is able to get up using her lower limbs. Her final score reflects that as it was 20 both at the beginning and the end of the programme. The results of this participant are specific with regard to the type of her disability, her results fall into the category of slight fear and as the only one of the group her results are close to the low fear category. Individual answers varied in the course of the programme. Comparing the results before and after the intervention, there was an increase in the fear of riding on uneven terrain, which could be associated with the participant's mental problem. Falling off a wheelchair was also in this case trained with the assistance of professional trainers. There was a decline in the fear while doing shopping, which can be attributed to the fact that the participant's self-confidence is higher and she does not have to fear everyday activities away from home anymore thanks to her improved mobility. The participant has changed her perception of potential threats – at the end of the course she is aware of the fact that a fall off the wheelchair might occur. Although her functional mobility is adequate and her problem is only mental, there are risks of injuries of the same extent as in the case of persons suffering from functional impairment of the skeletal-muscular system.

Participant 6:
Male, aged 35 years, IT specialist, secondary with school-leaving exams, paraplegia, wheelchair experience of 15 years. His ability to defend himself against potential threats is significantly reduced due to the inability to reference the muscles below the waist. The participant seemed composed and confident both at the beginning and at the end of the course. He exercised with enthusiasm and interest. His initial score was 27 and final 33. These values point to a shift from the great to slight fear group at the end of the intervention programme. The score suggests that considering the relatively long experience of wheelchair use, the participant manages everyday activities without major problems and fears. The course, however, raised his awareness of potential risks and threats.

The higher final score indicates that the participant started to recognise potential risks associated with falls. The fear was higher specifically regarding various transfers or overcoming obstacles which were trained in the course with the assistance of a trainer. Thanks to the experience the participant's view may have changed. On the other hand, the participant's fears were reduced while moving on a bed and while doing shopping, which can be attributed to improved coordination and mobility on the wheelchair as a result of self-defense practice.

CONCLUSION

Although some authors (Best, Heller & Bigge, 2005; Vítková, 2006) claim that the living conditions of people with disabilities are improving worldwide, our course of self-defense for wheelchair users was unique for our respondents who had not encountered a similar learning opportunity before. Although the self-defense course for wheelchair users was taken by only 6 participants, we obtained quality data which gave us an insight into the issue of falls in wheelchair users while performing everyday activities. Our primary interest was whether completing the course has an effect on the fear of falls and what kind of effect it is. Based on the results it can be said that the effect is apparent on two levels depending on the level of self-confidence of the participants and their wheelchair experience.

In case of self-confidence, there was an increase and thus a decrease in the final score, which corresponds with a decrease in real fears of falling off a wheelchair. In the case of wheelchair experience occurring mainly in those who had been using the wheelchair for relatively long period of time or had retained functional mobility of lower limbs, there was a shift in thinking. Having completed the course, the participants are more aware of their own limits and of potential risks. The issue of mental state and injury prevention in wheelchair users is extensive and further research is needed to address these areas. There are two dimensions of the course, one of them the self-defence training and the other training as such as the participants improve their physical condition, motor skills on the wheelchair as well as coordination. It is therefore not only the training of techniques suitable for self-defence but also a type of exercise that can improve quality of life.

References

Berg, K., Hines, M., Allen, S. (2002) Wheelchair users at home: few home modi- fications and many injurious falls. *Am J. Public Health*. 92(1), 48.

Best, S. J., K. W. Heller, J. L. Bigge (2005). *Teaching individuals with physical or multiple disabilities*. Upper Saddle River, N. J.: Pearson/Merrill Prentice Hall, 568 p.

Boswell-Ruys, C. L., Harvey, L. A., Delbaere, K., Lord, S. R. (2010). A Falls Concern Scale for people with spinal cord injury (SCI-FCS). *Spinal Cord*. 48(9), 704–709. doi: 10.1038/sc.2010.1.

Chen, W.-Y., Jang, Y.,Wang, J.-D., Hunang, W.-N., Chang, C.-C., Mao, H.-F., Wang, Y. H. (2011). Wheelchair-related accidents: relationship with wheelchair-using behavior in active community wheelchair users. *Archives of Physical Medicine and Rehabilitation*, 92 (6), 892 – 898. doi: 10.1016/j.apmr.2011.01.008.

Čihounková, J., Skotáková, A., Kohoutková, J. (2016) Security concerns of people using wheelchair. *Revista de Artes Marciales.* 11(2s), 136 doi:10.18002/rama.v11i2s.4208.

Čírtková, L. (2014). *Viktimologie pro forenzní praxi*. Praha: Portál.

Gaal, Ronald P., Rebholtz, Nancy (1997). Wheelchair rider injuries: Causes and consequences for wheelchair design and selection. *Journal of Rehabilitation Research and Development,* 34(1), 58.

Gavin-Dreschnack, D., Nelson, A., Harrow, J., Ahmed, S. (2005). Wheelchair related falls: current evidence and directions for improved quality care. *Journals of Nursing Care Quality*, 20 (2), 119–127.

Kane, J. (2008). *Violence and disability.* Luxembourg: EUR-OP. Retrieved from http://www.kaneinternational.com.au/assets/daphne6_violence-and-disabiity_english_1.pdf.

Kirby, R. L., Ackroyd-Stolarz, S. A., Brown, M. G., Kirkland, S. A., Macleod, D. A. (1994). Wheelchair-related accidents caused by tips and falls among noninstitutionalized users of manually propelled wheelchairs in Nova Scotia. *American Journal Of Physical Medicine.* 73(5), 319–330.

Pavelka, R., Stich, R. (2015) *Sebeobrana: nebuďte snadnou obětí!.* Praha: Ikar.

Privitera, G., & Ahlgrim-Delzell (2018). Chapter 13: *Quasi-Experimental and Single-Case Experimental Designs. In Research Methods for Education* (s. 333–370). Sage Publications Inc.

Reguli, Z. (2005*)* Úpolové *sporty*. [learning text]. Brně: MU FSpS.

Shephard, R. (1991). Benefits of sport and physical activity for the disabled: Implications for the individual and for society. *Scandinavian journal of rehabilitation medicine.* 23 (2) 51–59.

Skotáková, A., Čihounková, J. Sklenaříková, J. Evaluace kurzů «Sebeobrana pro vozíčkáře». In *Conference "Adapted Physical Activity through the lifespan" Prague*.

Vítková, M. (2006). *Somatopedické aspekty.* Brno: Paido.

Wagner, J. (2006). *Defensive tactics for professionals and civilians: reality-based personal protection system.* Madrid: Budo International.

Wong, H. (1991). *More Power to the Disabled: Self-Defense Project Gives Handicapped a Fighting Chance.* Los Angeles Times. Retrieved from http://articles.latimes.com/1991-08- 30/news/vw-1444_1_fighting-chance.

Yardley, L., Beyer, N., Hauer, K., Kempen, G., Piot-Ziegler, C., Todd, C. (2005). Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age And Ageing*. 34(6), 614–619.

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