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Near Infrared Spectroscopy and Spiroergometry Testing in Crossfit

Petr Schlegel, Jan Hiblbauer, Adrián Agricola

University of Hradec Králové, Faculty of Education, Hradec Králové, Czech Republic

Abstract

PURPOSE: *CrossFit is a young sport discipline which offers varied strength and endurance training through complex exercises. Currently there are relatively few studies focusing on performance analysis in terms of the physiological response of organism. The aim of the research was to verify near infrared spectroscopy (NIRS) in combination with spiroergometry as a functional means for specific load testing in CrossFit and to find out what physiological changes occur in CrossFit.*

METHODS: *Elite crossfitter (male, age 20, body height 185 cm, body weight 87 kg) formed part of this study. Two Moxy sensors (placed on the vastus lateralis muscle and the intercostal muscles) and chest (strap) heart rate (HR) sensor were used for obtaining the data. The Cortex MetaMax 3BR2 system was used for portable spiroergometry. The AMRAP method (as many repetitions as possible) was used for testing. The selected test consisted of (1) 10 Deadlifts, 100 kg, 15 Assault Air Bike Calories; (2) 12 lunges (with two 20 kg Kettlebell), 10 push-ups, 8 ring pull up; (3) 20 SkiErg Calories, 10 50 kg back squat, 10 toes to bar.*

RESULTS: *The testing has confirmed that breathing functions and muscle oxidation can be well observed under load in given exercises and movements. It has been confirmed that CrossFit provides a very varied load to which the organism must respond immediately. The strength load changes, causing deflection in SmO2 and VCO2 which consequently imposes demands on the respiratory component.*

CONCLUSIONS: *This is the first study which monitors the load in the combination of strength and endurance load through crossfit elements. Based on our result, it seems that linking NIRS and spirometry is a suitable combination for a comprehensive analysis of the athlete not only for CrossFit. The information obtained can be applied in practice in the context of optimal training load settings.*

Keywords: *CrossFit, near infrared spectroscopy, spiroergometry, performance*

INTRODUCTION

CrossFit has become a world-wide phenomenon over the last 10 years. Originally intended as training system, it has gradually developed into a full-fledged sport discipline. The goal of CrossFit is to comprehensively develop physical fitness (Glassman, 2007), thus influencing also health. It is a very variable high intensity exercise involving functional movements. The source of exercises and training approaches are three modalities (weightlifting, gymnastics, metabolic conditioning), which are represented to the same extent. The result is so called WOD (workout of the day), which consists of one, two or all three modalities and usually lasts 5–20 minutes. The nature of the exercise can be described as High-Intensity Functional Training (Feito, 2018), which includes multi-joint exercises with the involvement of major muscle groups. At the same time, the exercise takes place at a high heart rate and is usually relatively short. It is a functional tool for the development of metabolic and cardiorespiratory parameters. The purpose of CrossFit, however, is also a targeted effect on strength abilities including work with one's own bodyweight as well as external load. Although there is a concern about the safety of CrossFit (rhabdomyolysis, risk of injury, etc.), it has been confirmed that it meets the requirements stated in the American College of Sports Medicine. Drum (2017) notes that there is no serious risk with properly adjusted load and suitably selected regeneration. There is also a higher oxidative stress during exercise, but it is comparable with running load (Kliszczewicz, 2015). Even in terms of muscle damage indicated through creatine kinase marker, CrossFit does not stand out among other sport disciplines in terms of training load (Heavens, 2014).

High load in CrossFit was confirmed by Fernández, Solana, Moya, Marin, and Ramón (2015), where physical indicators were monitored. After 'Cindy' and 'Fran' WODs, the athletes achieved high levels of heart rate, VO2max and lactate. Also Perciavalle (2016) reaches similar conclusions except that the monitored workout consisted of a rowing machine and a big dumbbell. The mean lactate values measured after exercise were 13.8mmol/L, which mean a high intensity. The Tibana research (2016) was conducted under similar load and achieved similar conclusions. Moreover, it came to the conclusion that, after two demanding training days, the athletes have shown high cytokine values; therefore, the research recommended optimizing intensity in training load.

The physiological response after a CrossFit exercise was examined also by Maté-Muñoz (2018). Here the load consisted of separate gymnastics ('Cindy'), metabolic conditioning (double skip rope jumps), weightlifting (power cleans). Individual modalities differed from each other, for instance they reached lower values of maximum heart rate in power clean. However, in all cases they exceeded the lactate level of 10mmol/L and evaluated the activities with a high RPE. CrossFit performance is determined by many aspects and so far it is not quite clear which of them are key for achieving success, resp. high performances. In terms of physiological determinants, it seems that VO2max and anaerobic peak power are very important (Bellar, 2015; Dexheimer, 2019). Nevertheless, also the level of strength abilities occupies an important position and the exact determination of the effect of specific parameters is not clear (Butcher, 2015). Similarly, as in other sport disciplines, it is important to find a suitable test means to determine performance and functional limitation.

Near infrared spectroscopy (NIRS) is an imaging technique developed in the 1970ies that has expanded during the 1990. Originally focused on brain research, it was later gradually introduced also in other fields of science (Ferrari & Quaresima, 2012). It is a non-invasive imaging of oxidation and hemodynamics in the muscle using infrared radiation. It was used for the first time to monitor haemoglobin resaturation in quadriceps muscles in racing rowers (Chance, 1992). Since then, it has been applied to groups of runners, cyclists, rugby players, swimmers, etc. as well as to various muscle groups (Perry & Ferrarri, 2017). So far, only one study has been aimed at examining the effect of the strength load on lower limbs; the means was isolated knee extension motion (Paradis-Dechênes, 2016). The response to local isometric loading is presented by Freyer (2015) on climbers. Currently, there is no known research which would monitor muscle oxidation through the means of complex training load or combination of strength and endurance loads.

Moxy oxygen monitor is a device which measures, among others, local oxygen saturation (Sm02) and total haemoglobin mass (tHb mass), value of which corresponds to the current muscle blood flow. The validity and reliability of the device has been confirmed on a sample of high performance cyclists (Crum, 2017). It has also proven itself in comparison with a similar PortaMon device. However, the authors add that the comparison of results from various devices may differ (McManus, 2018).

Spiroergometry is a tool for a qualitative and quantitative assessment of cardiovascular, pulmonary and metabolic responses to exercise. Measuring oxygen consumption, carbon dioxide production, minute ventilation and heart rate provides significant diagnostic and prognostic information across a wide range of scientific fields (Wonisch, 2003). The most important variable in spiroergometry is the maximum oxygen consumption (VO2max). It defines the capacity of cardiopulmonary system and provides an objective estimate of physical fitness. Minute ventilation (VE) consists of breathing frequency and tidal volume (Vt). The VE maximum value (VEmax) during exercise is important to achieve a high VO2max value. In addition, the ventilation threshold and 'respiratory compensation point' can be determined as submaximal fitness parameters. The methodology of spiroergometric examination is based on the analysis of the inhaled and exhaled air composition and serves to determine the functional response of the organism to the load (Corrà, 2018). Oxygen consumption and exhaled carbon dioxide levels are monitored during exercise; pulmonary ventilation and heart rate are also monitored. Repeated testing is an important diagnostic parameter in monitoring the adaptation of the organism to training load. Spiroergometry is, in contrast with our research, commonly performed in standardized conditions with precisely defined test parameters.

The physiological reaction of the organism to the load is an important element for optimal adjustment of training intensity, therefore the selection of specific methods, etc. CrossFit uses a very variable load, for which acute physiological responses are not yet clear. The aim of the study was to monitor physiological changes through CrossFit training and to verify whether NIRS in combination with spiroergometry is a suitable means for such testing.

METHODS

Participant

The presented case study is based on the results of the diagnostic process of an elite crossfiter – 4 year experience, result in CrossFit OPEN 2019 in the Czech Republic among top 20, (male; age 20 years; body height 185cm; body weight 87kg). The tested athlete had no special preparation before testing. The athlete was instructed to follow his normal diet and standard daily regimen. He had a rest the previous day before testing.

Material

To obtain the research data, two Moxy sensors were used which were placed on the body of the athlete (on the *vastus laterali*s muscle and the intercostal muscles) and chest (strap) heart rate sensor (HR). The Cortex MetaMax 3BR2 system was used for portable spiroergometry.

Procedure

The selected test consisted of three six-minute sections, between which there were two-minute breaks.

(1) 10 Deadlifts, 100kg, 15 Assault Air Bike Calories[1]

(2) 12 lunges (with two 20 kg Kettlebell), 10 push-ups, 8 ring pull up

(3) 20 SkiErg Calories, 10 50kg back squat, 10 toes to bar

The AMRAP method (as many repetitions as possible) was used, where the athlete tried to do the maximum repetition of given exercises within a set time limit. The breaks or pauses were organized by the athlete himself, as well as exercise speed or pace. The break between the intervals was not organized; the athlete did not have to rest actively. He got time for individual warm-up and preparation before the test.

[1] Calories are the unit of measurement used for cardio machines as Assault Air Bike, SkiErg, rowing machine.

The methodology of the research is based on the evaluation of individual organ energy systems through specific parameters:

(1) Breathing – EV (minute ventilation – L/min) = BF (breathing frequency – 1/min) × VT (tidal volume – L); %BR (breathing reserve percentage) – the amount of remaining breathing capacity
(2) Cardiovascular system – HR (heart rate), VO2 (oxygen consumption/HR (pulse oxygen), tHb (total haemoglobin mass)
(3) Metabolism – indicative value of the level of aerobic/anaerobic metabolism using Respiratory Equivalent Ratio (RER = VCO2/VO2);
(4) carbon dioxide production (VCO2); METS – metabolic equivalents – multiple of resting energy expenditure (VO2=3.5 ml/kg/min)
Muscle tissue – SmO2 (muscle oxygen saturation), tHb

Fig. 1: Assault Air Bike

Fig. 2: A ring pull up

RESULTS

The results showed high heart rate values above the level of anaerobic threshold, while also the rate of their decrease was monitored. Heart pulse rate corresponded to breathing functions. These values were significantly reduced during rest. Figure 3 shows the regeneration process by individual intervals and the speed of return of muscle oxygenation.

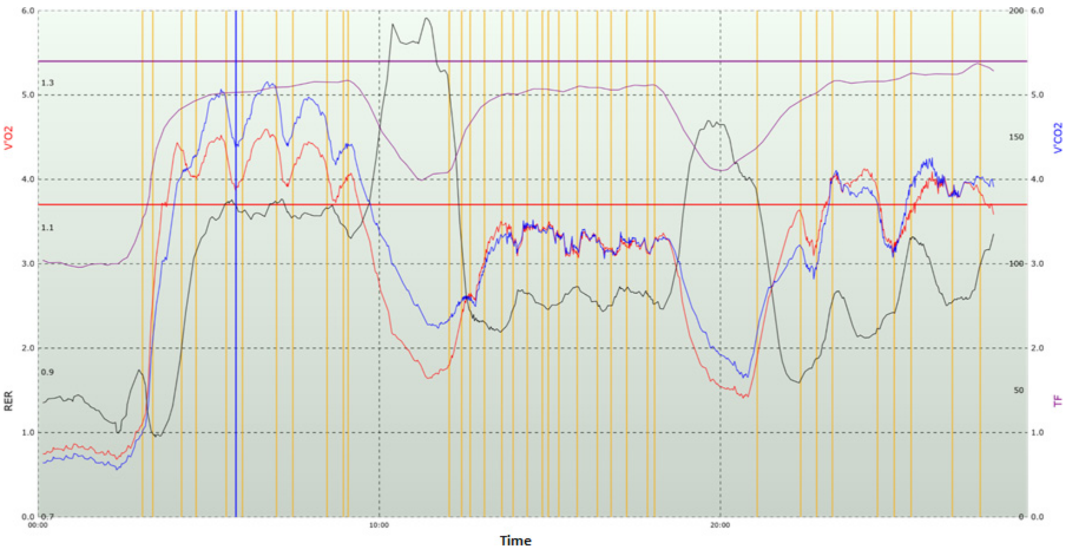

Fig. 3: VO2, RER, VCO2 and HR values

Note: V02 – oxygen consumption; RER – Respiratory Equivalent Ratio; VCO2 – carbon dioxide production; HR – heart rate

The first interval composed of a power exercise aimed at a large muscle group followed by an intense endurance performance led to high absolute levels of O2 compared to the second interval which was composed of exercises with a low external load. During the load, especially *m. vastus lateralis* showed a lower blood supply associated with reduced oxygen delivery to the muscle. In the following phase, however, there was a good recovery (whether on the Assault Air Bike or SkiErg – in both cases, the lower limbs needed to do some work; nevertheless, it was sufficient to improve the oxidative supply).

The changes of VCO2 can be monitored at each interval. The load on the lower limbs was lower in the second part, but there were still significant changes. Compared to the first interval, this part was less metabolically demanding. The connection of isotonic and isometric work of the quadriceps in lunges and push-ups kept the oxidation at lower values. Even though the push-up concentrates on the upper half of the body, it was not an ideal means for the acute full recovery of the lower limb.

The third interval already clearly shows fatigue accumulation from the previous parts. The athlete maintained a high intensity associated again with lower oxygen delivery in both muscles. However, it did not reach such values as in the first part, which dramatically loaded the lower limbs. Good tolerance to anaerobic load and to strength and conditioning load can be observed during testing.

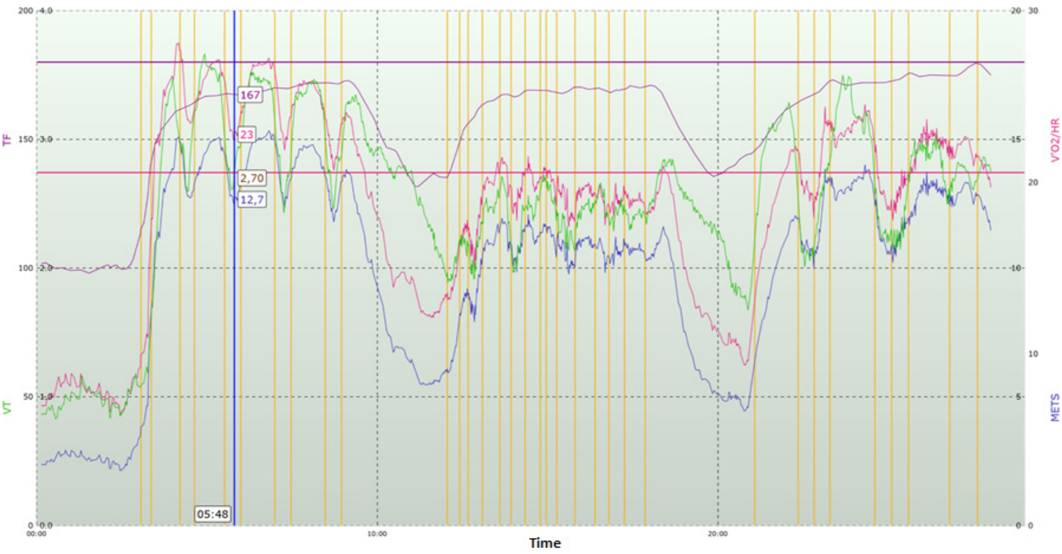

Fig. 4: VT, VO2/HR, METS and HR values

Note: VT – tidal volume; V02/HR –pulse oxygen; METS – metabolic equivalents; HR – heart rate

Figure 4 shows, among others, that HR may not always correspond to the metabolic demand of the exercises. All three intervals take place in comparable HF (160–170/min), but the values of RER, VO2, VCO2 and METS differ significantly, thus determining different metabolic demands. Each interval was different not only in intensity, but also in structure, which can be clearly seen in different graph curves.

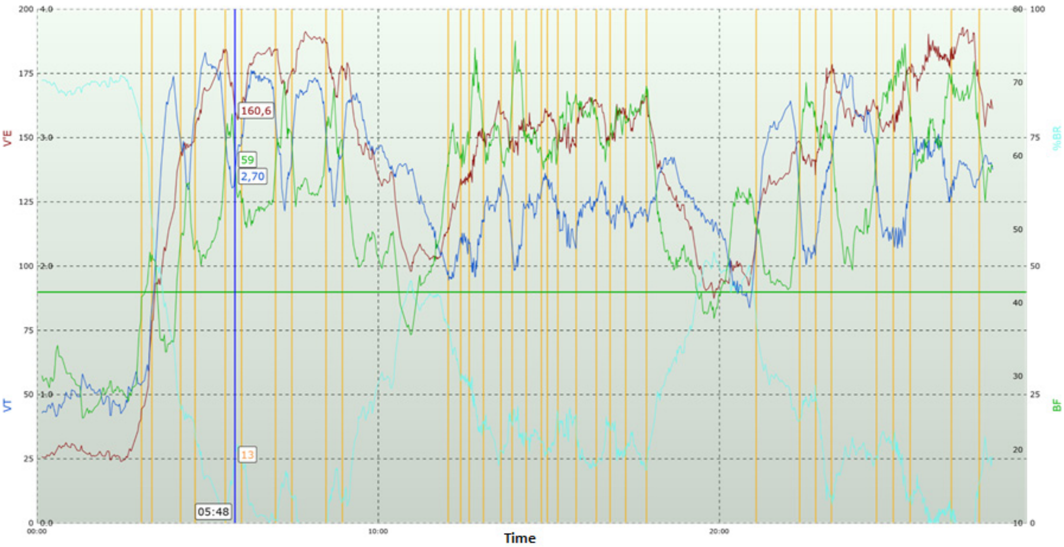

Fig. 5: VT, VE, BF and %BR values

Note: VT – tidal volume; VE – minute ventilation; BF – breathing frequency, %BR – breathing reserve percentage

It can be clearly seen from Figure 5 that, during the first interval after 2.5 minutes, the athlete had already reached the phase in which he used his ventilation capacity almost up to 100%. It is also possible to observe changes in breathing frequency and in inhalation / exhalation quality during the intervals. The specific load for instance in deadlift or exercises on the horizontal bar and rings had led to a change in breathing pattern and partly also to an occasional decrease in respiratory depth.

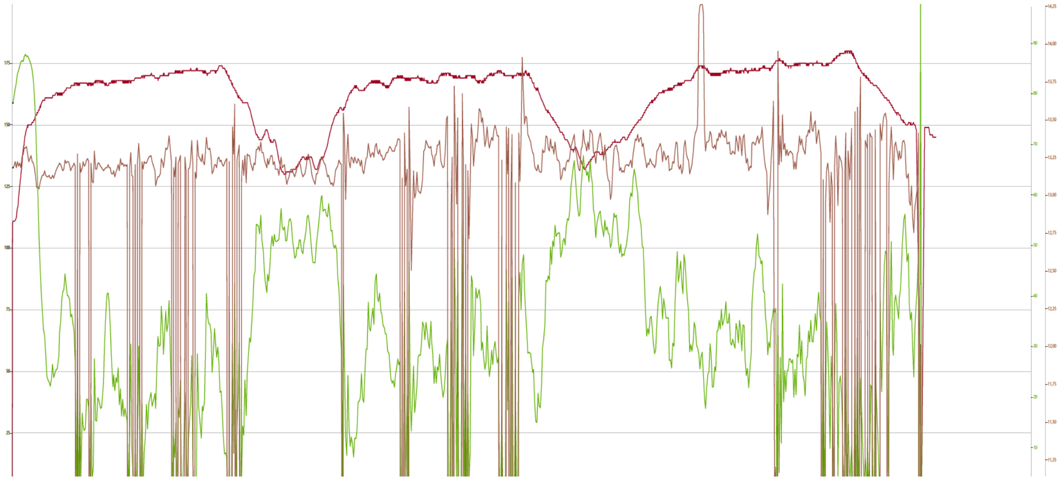

Fig. 6: Moxy record from the intercostal muscle

The record shows the effect of the load on respiratory muscles, which is, among others, related to the detection of the risk of metaboreflex. The green curve shows the course of oxygen utilization in the muscle, the brown one the rate of blood flow, the red curve corresponds to HR.

DISCUSSION

This is the first study which monitors the load in the combination of strength and endurance load through crossfit elements. Isolated muscle work can be seen in Paradis-Dechênes (2016) or Freyer (2015) with a corresponding change of haemodynamics. Nevertheless, it is more important for practical use to apply a load similar to a specific sport performance. The testing has also confirmed that breathing functions and muscle oxidation can be well observed under load in given exercises and movements. Most studies deal with the physiological response in cyclic movements like running, rowing, etc. (Perrey &Ferrari, 2017), from which it is clear that they represent a legitimate tool for monitoring the use of oxygen in the muscle. Here the concept of combined load was applied and, at the same time, specific tools were used. Similarly, however, we note large changes in oxygen saturation during intense load.

It has been confirmed that CrossFit provides a very varied load to which the organism must respond immediately. The strength load changes, causing deflection in SmO2 and VCO2 which consequently imposes demands on the respiratory component. The position of the body is not constant either, which has resulted in a change in spirometric parameters for instance in pull ups or toes to bar. During rest periods, an increase in RER was noted (RER > 1.0 indicates significant anaerobic metabolism) which can be explained by the intensity of activity in the anaerobic zone and by good individual fitness predisposition of the athlete. The athlete used almost his maximum ventilation capacity, which indicates an automatic response to the load at a given intensity, where there is a large consumption of O2 and thus also the production of CO2, of which the body has to automatically dispose (extended spinal cord reflex). Higher breathing capacity is a positive prerequisite for a high intensity of endurance performance. High demands on the work of respiratory muscles can be linked with their fatigue and consequent negative effect on CO2 exhaling, which is main factor determining centrally perceived fatigue (Guynet & Bayliss, 2015). Measurements have shown a significant influence of breathing parameters on performance in CrossFit; therefore, it seems important to monitor the performance of respiratory muscles, which are susceptible to fatigue, but can also be trained like other striated muscles (HajGhanbari, 2013).

HR is a commonly used intensity indicator which, however, has its limitations. There is a delayed response to the load (in tens of seconds) in contrast with NIRS (Morgan & Mora, 2017). The measurements show that there is no direct link between HR and the observed metabolic variables (unlike Maté-Muñoz, 2018). Therefore, HR cannot be perceived as an accurate indicator of body's overall workload during strength-endurance exercises (Born, 2017).

The purpose of testing was to simulate the environment which is identical with the load in CrossFit. The selection of exercises had to be adapted to the conditions. For instance, the measuring devices (see Fig. 1) did not allow the inclusion of Olympic weightlifting or demanding gymnastic exercises which are commonly used in CrossFit. The intervals were put together according to the combination of various modalities to load the athlete in very different ways and to change the strength and endurance demand.

Unlike laboratory tests, where the objective is to expose the body to increasing work intensity, the performance here has moved, from the very beginning, to the area close to the anaerobic threshold. It is therefore not possible to use routine procedures for the evaluation.

It can be stated from the results that the athlete has a tolerance to high load exceeding the anaerobic threshold, in which (in contrast with purely endurance activities) he has to be able to maintain an optimum concentration level for performing movements demanding on coordination.

CONCLUSION

It is possible to analyse very well from the results of the test the overall performance of the athlete and read the physiological response to strength, endurance or combined stimuli in CrossFit. This test gives a good feedback on the response of organism to the load, which may well be used for the subsequent optimization of training. Joining NIRS and spirometry seems to be a good combination for the comprehensive body load analysis: the use of the method could be beneficial also for other sport disciplines. At the same time, it is confirmed that the parameters from both measurements are related and, together with heart rate values, they create the overall picture of the organism's response during testing. Due to the originality of the research, more studies are needed to confirm some conclusions (e.g. magnitude of drop and return smo2 rate, RER values or importance of respiratory rate for CrossFit performance).

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Influence of Long-term Fasting and Intermittent Fasting on the Cognitive Abilities

Marie Crhová, Kateřina Kapounková

Masaryk University, Faculty of Sports Studies

Abstract

OBJECTIVE: *Fasting as skipping or abstaining from eating or drinking for a certain time is known mainly due to religion. In addition to religious reasons, we can also fast for weight loss or detoxication. We have decided to examine the impact of fasting on the human organism more closely, especially on cognitive functions.*

METHODS: *The research underwent and completed 16 participants (M + F; 25.8y ± 2.7; 179.5 cm ± 11.6; 74.6 kg ± 15.1). There were divided into 2 groups (long-term fasting /LTF/ and intermittent fasting /IF/). For measurement cognitive function we used Montreal Cognitive Assessment (MoCA), which has been filled out by all participants in the study before and after the fasting period.*

Results: *The total score of MoCA decreased in both group after the fasting period, more in the IF group (–1.1 points), but not statistically significant. Values for short-term memory evaluation decreased in both groups, also in the IF group more (–0.9 points), there was a large effect size. Word production values decreased in both group and these changes were statistically significant with small effect size.*

Conclusion: *Our results suggest that long-term fasting and intermittent fasting may reduce cognitive abilities. Especially short-term memory can be influenced by intermittent fasting. Both fasting methods decreased the level of word production.*

Keywords: *fasting methods, cognition, Montreal Cognitive Assessment, short-term memory, word production*

INTRODUCTION

Under the term "Fasting" we can imagine voluntary abstinence from food and drink lasting a certain period, from 12 hours to 3 weeks or more (Anton et al. 2018). Fasting is most often contrasted with ad libitum intake, which in modern societies is characterized by three or more meals a day, which, combined with a sedentary lifestyle, may increase the risk of developing the chronic neurological disease (Mattson et al. 2018), insulin resistance or obesity (Mattson, Longo, and Harvie 2017). Recent recommendations mention long-term calorie restriction for the treatment of obesity, but this leads to moderate weight loss, so more and more people are interested in alternative dietary approaches such as intermittent fasting or time-limited food intake (Rynders et al. 2019).

Concerning the effect of fasting on cognitive functions, the results are still ambiguous, and therefore new studies are exploring this issue. We can influence the level of cognition in several ways, such as memory training, exercise and diet (Vance et al. 2011; Vandewoude et al. 2016). Most studies examining the effect of fasting on cognitive functions are still conducted in animals, most commonly mice. Intermittent fasting, as opposed to caloric restriction, increases the tolerance of the hippocampal neuron to excitotoxic stress in mice, which may indicate the neuroprotective effects (Anson et al. 2003) and improves learning and memory in mice (Li, Wang, and Zuo 2013). Lieberman et al. (2017); Solianik et al. (2016, 2018) reached almost the same conclusions: a two-day calorie restriction does not affect cognitive functions, but can negatively affect a person's mood, e.g. increasing aggression and rage. It further increases parasympathetic activity, reduces brain frontal lobe activity and improves cognitive functions associated with the prefrontal cortex, including mental flexibility and decision making. Since it is still a big question in this area of research whether fasting can affect brain function, especially cognitive function, we have decided to extend this knowledge.

METHODS

Research sample

Recruitment of participants for the study took place in the form of leaflets posted at the Faculty of Sports Studies and Social Networks (Facebook, Instagram). Inclusion criteria were: age range 20–35 y; at least secondary education with graduation; good health condition based on their judgment; no medication that could affect response to fasting; no evidence of any acute or chronic bodily or mental disease, eating disorders, and past trauma of the head. Exclusion criteria were: serious health problems that could be affected by fasting; any cognitive diseases. 16 Czech male and female participants took place in the study (25.8 y ± 2.7; 179.5 cm ± 11.6; 74.6 kg ± 15.1). Anthropometric data for each group are listed in Table 1. Written informed consent was obtained from all participants after the explanation of all details of the experimental procedures and after answering all the research questions from the participants.

Tab. 1: Anthropometric data for each group

	LTF group Mean (±SD)	IF group Mean (±SD)
Age	26.8 (±3.5)	24.9 (±1.1)
Weight	79.1 (±16.3)	70.0 (±13.2)
Height	179.1 (±10.7)	179.8 (±13.1)

Study design

The research took place in October 2018 and lasted for one week. Before the research began, the participants got the necessary information about experimental procedures and fasting period, e.g. how to eat before fasting, during fasting and after it, or what happens in the organism during the fasting period. We created two experimental groups: long-term fasting (LTF) and intermittent fasting (IF). The control group was not created. Grouping took place in the form of draws. We have only divided the drawing group by gender, thus achieving the same number of men and women in the group to preserve the homogeneity (5 men, 3 women in each group). LTF group practised a 5-day fast in which they could receive only clean water ad libitum. There were no other restrictions, they behaved according to their habits and feelings – they went to work, to train. IF group practised alternate fasting, so they fasted every other day. On fasting days, the same rules applied to them as to the LTF group. The detailed timeline is below in Figure 1.

The experiment itself consisted of two sessions, each morning at 8 o'clock. Before the session, the participants were instructed to sleep for ≥ 8 h the night before the experiment and to refrain from alcohol, caffeine, and from ≥ 24 h refrain heavy exercise. At the first session (Day 1), the participants arrived at the Faculty of Sports Studies to measure baseline values, witch there were anthropometric data (age, weight, height, previous experience with fasting, level of physical activity, belief in alternative diets such as veganism, vegetarianism, etc. and motivation to enter the study), then the researcher completed the Montreal Cognitive Assessment with each participant separately. The participants rested the rest of the testing day before starting the fasting period (according to the group, detailed are described above) followed by the performance of experimental measurements in the same order as that used in the first sessions (i.e., before fasting).

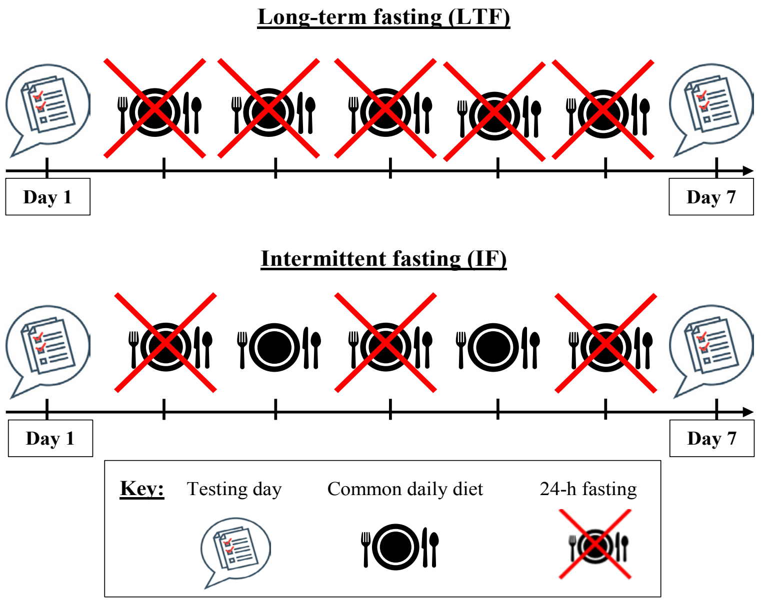

Fig. 1: Research timeline for each group separately

Research methods
We were used to determining the degree of cognitive abilities Czech standardized version of ***Montreal Cognitive Assessment (MoCA).*** This test is validated, with high repeatability, reliability, sensitivity and less time-consuming (Bartoš and Raisová 2015). The test is available free online at the Alzheimer's Centre for Research, Diagnosis and Treatment and has a high-quality Czech equivalent available in 3 variants. We used the MoCA-CZ1 variant for the pre-test and MoCA-CZ3 variant for the post-test, both variants are almost equivalent. One difference is in sequence no. 8, wherein MoCA-CZ1 variant, the participants had to recall as many words as possible to the letter K, invariant MoCA-CZ3 it was the letter N. Detailed description of the test is in Table 2. It takes approximately 10–15 minutes to complete the test. The maximum score is 30 points, "0" means worst performance and "30" means the best performance. The cut-off score is 26 points, for Alzheimer's disease is 23/24 points (Orlíková et al. 2014).

Statistical analysis
Data were collected in the program Statistica 13.2. To evaluate data, we used descriptive (mean, maximum and minimum, standard deviation) and analytical statistics (normality test, non-parametric t-test) and Cohen's d (Effect size). The level of statistical significance was set at $p < 0.05$.

Tab. 2: Content structure and scores of the Montreal Cognitive Assessment (Orlíková et al. 2014)

Sequence	Subtest	What is investigating	Scale	Points
1.	Short path test (from number to letters)	Structural executive function	Executive function	1
2.	Drawing a cube	Drawing a three-dimensional shape	Visual and spatial functions	1
3.	Clock drawing test	Visual and spatial functions		3
		Structural and imaginative executive function		
4.	Naming 3 animals in the picture	Naming	Language	3
5.	Repetition of 5 words	Implantation	Short-term memory	0
		Focus of attention		
6. A	Repeating numbers (front and back)	Working memory	Attention, concentration and working memory	2
6. B	Typing the letter “A”	Wakefulness		1
6. C	Subtraction of number 7	Working memory		3
7.	Repetition of 2 sentences	Repetition	Language	2
8.	Word production per minute	Phonemic word production	Language	1
9.	Abstraction – understanding the similarities between 2 words	Understanding	Executive function	2
10.	Remote recall of 5 words	Spontaneous recall without help	Short-term memory	5
		Recall with help of category		0
		Recognition (choice of 3 options)		0
11.	Time and place orientation	Orientation	Orientation	6
Total score				30

RESULTS

This study sought to determine how fasting has an impact on cognitive function. Research completed 16 participants. They were divided into 2 groups (long-term fasting /LTF/, intermittent fasting /IF/), each with 8 people (3 F, 5 M). Essential anthropometric data are above in Table 1. We used the Montreal Cognitive Assessment to test cognitive abilities, where the maximum possible number of points is 30, the cut-off score is 26 points. First, we examined the differences in the total score (before and after fasting period) for each group separately, then we focused on short-term memory and word production, because they were the most demanding for the participants and at the same time, these sub-tests have undergone the biggest changes. More detailed results for a total score from MoCA are below in Table 3.

Tab. 3: Results for a total score from MoCA

Group	Before fasting Mean ± SD (min–max)	After fasting Mean ± SD (min–max)	p-value	Effect size (Cohen's d)
LTF	27.6 ± 2.3 (23–30)	27.2 ± 1.3 (26–30)	0.50	0.02
IF	28.1 ± 1.6 (25–30)	27.0 ± 2.7 (21–30)	0.23	0.05

Note LTF-long term fasting; IF-intermittent fasting; SD-standard derivation; min-minimum points earned; max-maximum points earned; P value for non-parametric t-test comparing changes in the LTF group and IF group before and after fasting period.

The minimum points in LTF group were 23 points before and 26 points after fasting. In IF group in was 25 points before and 21 points after. These differences were not statistically significant relative to a significance level of $p < 0.05$. According to the effect size, the effect is insignificant. But, the SD changed in every group a different way. In the LTF group, the SD decreased, but in the LF group, SD increased.

One part of MoCA deals with short-term memory. It is tested in two phases. First, the test person tries to instil 5 words. After a while (at least 5 minutes), during which the test person performs other tasks, the test person should recall these 5 words, no matter which order. The maximum possible score is 5 and the minimum is 0. Detailed results for short-term memory are below in Table 4.

Tab. 4: Results of a MoCA sub-test focused on short-term memory

Group	Before fasting Mean ± SD (min–max)	After fasting Mean ± SD (min–max)	p-value	Effect size (Cohen's d)
LTF	4.1 ± 1.4 (2 – 5)	4.0 ± 1.2 (2 – 5)	0,79	0.10
IF	4.8 ± 0.5 (4 – 5)	3.9 ± 1.4 (2 – 5)	0,17	0.86

Note LTF-long term fasting; IF-intermittent fasting; SD-standard derivation; min-minimum points earned; max-maximum points earned; P value for non-parametric t-test comparing changes in the LTF group and IF group before and after fasting period.

The difference in mean values in the LTF group was –0.1, in IF group it was –0,9. Both changes were not statistically significant relative to a significance level of $p < 0.05$. The effect size was less than small in LTF group and large in the LF group. The SD values slightly decreased in LTF group against the LF group, where the value of SD distinctly increased.

Word production is one of the areas tested by MoCA. This task consisted of telling the participants a letter to make up as many words as possible for one minute. The condition was that the words should not be repeated, not even their root and also not allowed proper names. The maximum score is not given. Detailed results for word production are below in Table 5.

Tab. 5: Results of a MoCA sub-test focused on word production

Group	**Before fasting** Mean ± SD (min–max)	**After fasting** Mean ± SD (min–max)	p-value	Effect size (Cohen's d)
LTF	16.8 ± 4.2 (12–24)	12.1 ± 3.3 (7–16)	0,04	0.12
IF	16.1 ± 3.9 (12–24)	11.1 ± 3.2 (7–17)	0,02	0.14

Note LTF-long term fasting; IF-intermittent fasting; SD-standard derivation; min-minimum points earned; max-maximum points earned; P value for non-parametric t-test comparing changes in the LTF group and IF group before and after fasting period.

For LTF participants, the average number of words decreased by 4.7. Statistically, this is a significant difference. The effect size was small. If participants, the average number of words decreased to, but more than in the LTF group, by 5. There is statistical significance and also a small effect size. In both tested groups decreased the values of SD, more in LTF group.

DISCUSSION

The presented study evaluated the influence of two different fasting methods on cognitive abilities. The first testing fasting method was long-term fasting lasting 5 days when participants could receive only clear water *ad libitum*. The second testing fasting method was the type of intermittent fasting, where participants fast every other day, they receive only clean water *ad libitum*. The other days they eat *ad libitum*. The test period lasted one week and we used the Montreal Cognitive Assessment (MoCA) to determine the state of cognitive abilities. During data processing, we realized that it is not appropriate to look only at the total score from the MoCA, but also to focus on the sub-tests. For this reason, we focused on the two areas (short-term memory and word production) that were the most affected by fasting and which were also the most challenging for the research participants.

Based on several studies (Li et al. 2013; Lieberman et al. 2017; Solianik et al. 2016, 2018), we hypothesized that both fasting methods will not adversely affect the level of cognitive abilities. Whereas, our results demonstrated that the total score from the Montreal Cognitive Assessment decreased in both groups, more in the intermittent fasting group. As we mentioned earlier, the most affected areas were short-term memory and word production. However, the changes were not statistically significant with a negligible effect size.

Short-term memory also decreased in both groups, more in the intermittent fasting group. Even these changes did not have statistical significance, however, a large effect size was demonstrated in the intermittent fasting group. Tian et al. (2011) conducted a difference effect of fasting on short-term memory concerning the time of day. While in the afternoon (4 p.m.) the results of short-term memory tests were worse, in the morning (9 a.m.) there was no impairment. Unfortunately, this theory does not support our results. On the other hand, the results of other studies mention that accuracy of recall in verbal short term memory was not impacted by fasting, but subjects needed a little more time to respond (Benton and Parker 1998; Owen et al. 2012; Sünram-Lea et al. 2001). Statistically significant changes with a small effect size were recorded in the Montreal Cognitive Assessment sub-test focused on word production, where participants had to say as many words as possible on a particular letter. This sub-test is useful for examining mainly psychomotor pace, executive functions and semantic and working memory (Bartoš and Raisová 2015).

After evaluating our results, we must agree with the statement by (Tian et al. 2011) that the effect of fasting on cognition is heterogeneous and domain-specific. The individual results of our tested group are really important because they are visible differences, so we should consider the different impact of different fasting methods. On the other hand, individual components, such as short-term memory, word production or attention, show different results than the overall cognitive function test score.

We realize that our results may be influenced by several limiting factors, such as a low number of participants, short experiment time, missing control group, different motivation to participate in research, previous experience with any type of fasting. The level of cognitive abilities could be affected by countless stressful situations for example in the job, in the family, by problems with a partner or friends. Furthermore, the participants' lifestyle and training in between test sessions were not controlled. Other potential confounders include the duration of the previous night's sleep and daytime naps, as well as the time of awakening, which was not regulated in this study. For these reasons, we would like to do more research that could help us better understand the relationship between fasting and cognition in humans.

CONCLUSION

The present study shows, that long-term fasting and intermittent fasting harms the cognitive functions as a whole. On the other side, intermittent fasting can negatively influence short-term memory. And both fasting methods harmed the word production of the participants. We consider the conclusions of our work to be very interesting and beneficial, but some of the changes we are watching are so insignificant that we need further research to confirm our results. For example, it would be interesting to see if fasting can delay ageing and its symptoms, such as degenerative changes in the brain associated with the loss of short-term memory.

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Transfer of Muscle Strength Between Single-Joint and Multi-Joint Exercises for Lower Limbs

Tereza Hammerová[1], Jan Chlápek, Tereza Králová[1], Tomáš Vodička[1], Zuzana Hlavoňová[1], Jan Ondráček[1]

1 Faculty of Sports Studies, Masaryk University

Abstract

Most strength and conditioning coaches deal with the question in the training plan, how to supplement specific exercises, or which non-specific exercises would be the most suitable for achieving the set purpose. This study aims to assess what strength transfer with a focus on the lower limbs is projected from the selected strength intervention program (the right leg exercises only single-joint exercises: leg extension on machine and leg curl; the left leg exercises only multi-joint exercises: deadlift and leg press) to the force of the knee joint flexors and extensors during the eccentric and the concentric contraction. In one training session, the participants repeated every exercise five times in four series. The load intensity was around 90% of 1RM and was increased by 5% after the first and the fifth week. The rest interval was always three minutes long. For the left lower limb, the highest transfer (0.20) was from the leg press to the knee joint extensor at the eccentric contraction and from the deadlift was the highest transfer (0.19) to the knee joint extensor at the eccentric contraction. For the right lower limb, the highest transfer (0.53) was from the leg extension on a machine to the knee joint flexor at the concentric contraction and from the lying leg curl was the highest transfer (0.47) to the knee joint flexor at the concentric contraction.

Keywords: *Multi-Joint Exercises, Single-Joint Exercises, Transfer of Muscle Strength, Extensors and Flexors of Knee Joint*

INTRODUCTION

Due to the ever-increasing sports competition, the trainer must consider what non-specific exercises will complement their fitness training plan. Training transfer decides which exercises are useful for athletic performance and which are useless (Issurin, 2013). The choice of exercises could be influenced by the knowledge of transfers from non-specific exercises to specific exercises. This study will focus on strength abilities.

Strength, or strength ability, is a fitness movement ability of an individual, manifested by overcoming, holding or inhibiting a certain resistance (Dovalil et al, 2005). Strength abilities can be viewed from the perspective of muscle contraction. Muscle contractions are differentiated by muscle length and muscle tension. In isometric contraction, tension increases, but muscle length does not change. In isotonic contraction, muscle length varies, but the tension remains approximately the same (the concentric contraction /CON/ – muscle shortens, the eccentric contraction /ECC/ – muscle extends) (Perič, & Dovalil, 2010).

Exercises used to develop strength can be divided into single-joint exercises and multi-joint exercises. Single-joint (SJ) exercises are considered to be exercises where the movement is performed in only one joint with a focus on one muscle/muscle group (Stoppani, 2016). Multi-joint /MJ/ exercises are those exercises that involve more joints and more muscle/muscle groups in the exercise, which better reflect the daily movement. For example, research Gentil, Fisher, & Steele

(2017) comparing the two groups (MJ, MJ + SJ) concluded that adding a single-joint exercise to multi-joint exercises program does not increase muscle size and muscle strength.

The increase in strength can be achieved in different ways of training. The effect of transfer from one exercise to another, although very similar in performance (for example, from squat to half-squat or leg press), is always significantly lower than from a specific exercise (Zatsiorsky & Kraemer, 2014). The rate of transfer can be determined by the amount of resistance, speed of an exercise, muscle activation, mechanical movement parameters, and energy coverage. To be able to compare the individual performances directly in different exercises, Zatsiorsky & Kraemer (2014, p. 27) introduce a unit of performance increase expressed in standard deviations:

$$\textit{Result gain} = \frac{\text{Gain of performance}}{\textit{Standard deviation of performance}} \ .$$

If the average strength of the group is 60 ± 10 kg (average ± standard deviation) and the athletes improve by 15 kg in performance after the training, the athletes achieve an improvement of 15/10 or 1.5 standard deviations.

For transfer evaluation, we consider the ratio of performance improvement in untrained and trained exercises. We define the transfer coefficient of the training as follows:

$$\textit{Transfer} = \frac{\textit{Result gain in nontrained exercise}}{\textit{Result gain in trained exercise}}$$, Zatsiorsky & Kraemer (2014, p. 27).

Intervention program including both single-joint exercises (leg extension on the machine, lying leg curl) and multi-joint exercises (deadlift, leg press) was applied by Jan Chlápek (2019) in his research. He evaluated the 1RM and isokinetic dynamometer data as follows:

All exercises (leg extension on the machine, lying leg curl, deadlift and leg press) show statistically significant differences ($p < 0.05$) of 1RM values between pretest and posttest measurements based on parametric paired t-test. Strength intervention had a positive effect on the increase of 1RM values in all exercises (Chlápek, 2019).

Chlápek (2019) compares testing on an isokinetic dynamometer considering extensors and flexors of the knee joint and considering the concentric and the eccentric muscular activity. During the concentric muscle activity, the muscle force of the knee joint extensors and flexors was significantly improved as a result of the strength intervention ($p < 0.05$). However, there was no statistically significant difference between the left and right lower limbs before or after the intervention ($p > 0.05$). During the eccentric muscle activity, the muscle force of the knee joint extensors and flexors was significantly improved as a result of the strength intervention ($p < 0.05$). However, there was no statistically significant difference between the left and right lower limbs before or after the intervention ($p > 0.05$) (Chlápek, 2019).

The question remains of how the change in 1RM values is related to the change in the values obtained from the isokinetic dynamometer.

METHODS

All original data were obtained in a research conducted by Tereza Králová and Jan Chlápek to create a thesis (*Effects of isolated and compound exercises on the strength*) by Jan Chlápek and to create this article.

Subjects

The test sample consisted of 10 male students of the Faculty of Sports Studies of Masaryk University. The average age of the group was 24,7 (±0,94) years, average body height was 179,9 (±8,00) cm and average body weight was 78,9 (±9,21) kg (Chlápek, 2019).

Study design

For this study, measurement 1RM (repetition maximum) and measurement on isokinetic dynamometer were essential. Both measurements were performed both before (pretest) and after (posttest) the strength intervention program.

1RM was measured for the following exercises:

- for the right leg, single-joint exercises:
  - leg extension in the knee joint on a machine while sitting (hereafter referred to as leg extension on a machine),
  - leg curl (while lying),
- for the left leg, multi-joint exercises:
  - deadlift
  - and leg press.

1RM was always measured for the specific lower limb and according to the Baechle (2008) protocol.

An isokinetic dynamometer (Humac Norm CSMI (Stoughton, USA)) was used to test lower limb force. Both the pretest and the posttest measurements were carried out in a sitting position, focusing on the knee joint flexors and extensors. First, the right and then the left leg was measured. The range of motion was set to 90 degrees at an angular velocity of $60°\cdot s^{-1}$. The subjects were banded with fixation bands to avoid the involvement of other muscle groups. The force of the selected muscles of the lower limbs was measured in the following order: first, the concentric extension and the concentric flexion, followed by rest and the eccentric extension and the eccentric flexion (Chlápek, 2019, p. 34).

The protocol (Figure 1) gives us the sequence and the most important information of the selected measurements and the intervention strength program.

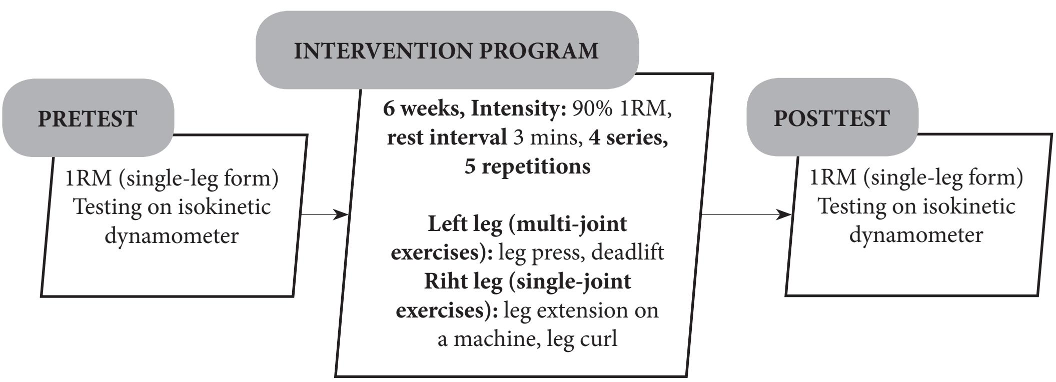

Fig. 1: Diagram of measurements and intervention program

Before all measurements, the subjects were properly warmed up and instructed to avoid possible injury.

The six-week intervention strength program was carried out as well as all tests of research at the Faculty of Sports Studies of Masaryk University. There was a 48-hour rest period between each intervention. To be a progressive load all the time, we increased the load by 5% after the first and the fifth week. The intervention program was focused on the single-leg form exercises. Test subjects loaded the right leg for single-joint exercises all the time and the left leg for multi-joint exercises (2 exercises for each method). The exercise intensity (90% 1RM), rest interval (3 mins), number of series (4 times) and number of repetitions (5 times) were identical in both methods (Chlápek, 2019).

The purpose of the study was to find out the effect size of the transfer of strength abilities from single-joint exercises and multi-joint exercises to the force of the knee joint extensors and flexors during both the concentric and the eccentric work measured on an isokinetic dynamometer.

Statistical analysis

The data were evaluated according to formulas for calculating the transfer from Zatsiorsky & Kraemer (2014) and Microsoft Excel was used afterwards.

Results

Transfer is always calculated from a specific exercise of intervention program (leg press, deadlift, leg extension on a machine, leg curl) to the isokinetic force of the knee joint muscles (flexors, extensors) during various muscular activities (the concentric, the eccentric). We compare the effect of strength progression [1RM] on an isokinetic force of muscle [Nm].

Transfer

First, we will focus on the results of the left lower limb that has been practicing multi-joint exercises during the intervention program. In the leg press exercise, the transfer of strength abilities was following: the highest transfer was for extensor force at the eccentric contraction (0.20), then for flexor force at the concentric contraction (0.19), then for extensor force at the concentric contraction (0.17) and the lowest transfer (0.13) was for flexor force at the eccentric contraction (Table 1). In the deadlift exercise, the transfer of strength abilities was following: the highest transfer was for the extensor force at the eccentric contraction (0.19), then for the flexor force at the concentric contraction (0.18), then for the extensor force at the concentric contraction (0.16) and the lowest transfer (0.12) was for flexor force at the eccentric contraction (Table 1).

Tab. 1: The transfer from leg press and deadlift

LEFT LEG					
TEST	PRETEST	POSTTEST	GAIN OF PERFORMANCE	RESULT GAIN	TRANSFER
LEFT LEG (LEG PRESS SINGLE-LEG, DEADLIFT SINGLE-LEG)					
LEG PRESS Strength [kg]	91.5 ± 19.59	111.5 ± 21.25	20.0 ± Std.Dev.	20.0 : 19.59 = 1.02	
Force [Nm] CON EXTENSORS	217.8 ± 46.78	225 ± 43.07	8.0 ± Std.Dev.	8.0 : 46.78 = 0.17	*0.17 : 1.02 = 0.17*
Force [Nm] CON FLEXORS	126.5 ± 23.17	130.9 ± 28.80	4.4 ± Std.Dev.	4.4 : 23.17 = 0.19	*0.19 : 1.02 = 0.19*
Force [Nm] ECC EXTENSORS	243.7 ± 63.70	256.6 ± 58.10	12.9 ± Std.Dev.	12,9 : 63,7 = 0.20	*0.20 : 1.02 = 0.20*
Force [Nm] ECC FLEXORS	146.2 ± 38.56	151.1 ± 37.03	4.9 ± Std.Dev.	4.9 : 38.56 = 0.13	*0.13 : 1.02 = 0.13*
DEADLIFT Strength [kg]	70.0 ± 12.91	84.0 ± 13.9	14.0 ± Std.Dev.	14.0 : 12.91 = 1.08	
Force [Nm] CON EXTENSORS	217.8 ± 46.78	225 ± 43.07	8.0 ± Std.Dev.	8.0 : 46.78 = 0.17	*0.17 : 1.08 = 0.16*
Force [Nm] CON FLEXORS	126.5 ± 23.17	130.9 ± 28.80	4.4 ± Std.Dev.	4.4 : 23.17 = 0.19	*0.19 : 1.08 = 0.18*
Force [Nm] ECC EXTENSORS	243.7 ± 63.70	256.6 ± 58.10	12.9 ± Std.Dev.	12.9 : 63.7 = 0.20	*0.20 : 1.08 = 0.19*
Force [Nm] ECC FLEXORS	146.2 ± 38.56	151.1 ± 37.03	4.9 ± Std.Dev.	4.9 : 38.56 = 0.13	*0.13 : 1.08 = 0.12*

The values can be interpreted as percentages. It can be argued that the inclusion of the leg press exercise in the intervention program had a 20% transfer to extensor force during the eccentric work, a 19% transfer to flexor force during the concentric work, a 17% transfer to extensor force during the concentric work, and a 13% transfer to flexor force during the eccentric work. We can also say that the inclusion of deadlift exercise in the intervention program had a 19% transfer to the extensor force during the eccentric work, and 18% transfer to the flexor force during the concentric work, a 16% transfer to the extensor force during the concentric work, and a 12% transfer to the flexor force during the eccentric work.

The right lower limb practiced single-joint exercises during the intervention program. In the leg extension on a machine exercise, the transfer of strength abilities was following: the highest transfer (0.53) was for flexor force at the concentric contraction, then for flexor force at the eccentric contraction (0.46), then for extensor force at the eccentric contraction (0.40) and the lowest transfer (0.34) was for extensor force at the concentric contraction (Table 2). In the leg curl exercise, the transfer of force abilities was following: the highest transfer (0.47) was for flexor force at the concentric contraction, then for flexor force at the eccentric contraction (0.40), then for extensor force at the eccentric contraction (0.35) and the lowest transfer (0.30) was for extensors force at the concentric contraction (Table 2).

Tab. 2: The transfer from leg extension on machine and leg curl

RIGHT LEG					
TEST	**PRETEST**	**POSTTEST**	**GAIN OF PERFORMANCE**	**RESULT GAIN**	**TRANSFER**
RIGHT LEG (LEG EXTENSION ON MACHINE SINGLE-LEG, LEG CURL SINGLE-LEG)					
LEG EXTENSION ON A MACHINE Strength [kg]	30.0 ± 5.89	35.95 ± 8.74	5.95 ± Std.Dev.	5.95 : 5.89 = 1.01	
Force [Nm] CON EXTENSORS	226.3 ± 40.07	239.9 ± 38.45	13.6 ± Std.Dev.	13.6 : 40.07 = 0.34	*0.34 : 1.01 = 0.34*
Force [Nm] CON FLEXORS	128 ± 23.80	140.9 ± 27.00	12.9 ± Std.Dev.	12.9 : 23.8 = 0.54	*0.54 : 1.01 = 0.53*
Force [Nm] ECC EXTENSORS	252.2 ± 57.79	275.2 ± 54.05	23 ± Std.Dev.	23.0 : 57.79 = 0.40	*0.40 : 1.01 = 0.40*
Force [Nm] ECC FLEXORS	137.4 ± 38.05	155 ± 40.39	17.6 ± Std.Dev.	17.6 : 38.05 = 0.46	*0.46 : 1.01 = 0.46*
LEG CURL Strength [kg]	25.5 ± 7.15	33.65 ± 10.71	8.15 ± Std.Dev.	8.15 : 7.15 = 1.14	
Force [Nm] CON EXTENSORS	226.3 ± 40.07	239.9 ± 38.45	13.6 ± Std.Dev.	13.6 : 40.07 = 0.34	*0.34 : 1.14 = 0.30*
Force [Nm] CON FLEXORS	128 ± 23.80	140.9 ± 27.00	12.9 ± Std.Dev.	12.9 : 23.8 = 0.54	*0.54 : 1.14 = 0.47*
Force [Nm] ECC EXTENSORS	252.2 ± 57.79	275.2 ± 54.05	23 ± Std.Dev.	23.0 : 57.79 = 0.40	*0.40 : 1.14 = 0.35*
Force [Nm] ECC FLEXORS	137.4 ± 38.05	155 ± 40.39	17.6 ± Std.Dev.	17.6 : 38.05 = 0.46	*0.46 : 1.14 = 0.40*

The inclusion of leg extension on a machine to the intervention program caused 53% transfer to flexor force during the concentric work, 46% transfer to flexor force during the eccentric work, 40% transfer to extensor force during the eccentric work and 34% transfer to extensor force during the concentric work. The inclusion of the leg curl exercise to the intervention program caused 47% transfer to the flexor force during the concentric work, 40% transfer to the flexor force during the eccentric work, 35% transfer to the extensor force during the eccentric work, and 30% transfer to the extensor force during the concentric work.

Overall, it can be argued that the highest transfer of strength (0.53) was manifested in the flexor force of the right lower limb, which was measured during the concentric work. This result was achieved when calculating the transfer from 1 RM of leg extension on a machine to flexor force at the concentric work (isokinetic dynamometer). However, it should be remembered that the right lower limb practiced both leg extension on machine and leg curl throughout the intervention program.

The lowest strength transfer (0.12) was seen in the flexor force of the left lower limb, measured during the eccentric work. This result occurred when calculating the transfer from 1 RM of the deadlift to flexor force during the eccentric work (isokinetic dynamometer). However, the left lower limb practiced both deadlift and leg press throughout the intervention program.

Increase in power expressed as a percentage

An increase in power in percent is reported by Chlápek (2019), rounded to integers without graphical representation. The presented numerical values were recalculated separately for this study.

The influence of training can also be judged by the percentage increase in strength. Looking at changes in 1RM values in individual exercises, we can say that the greatest progression [kg] was achieved in the leg curl (right leg) exercise, where 1RM improved by an average of 31.96%. Then 1RM improved on average by 21.86% for leg press exercise (left leg), by 20% for deadlift (left leg) exercise, and by 19.83% for leg extension on a machine (right leg) exercise (Figure 2).

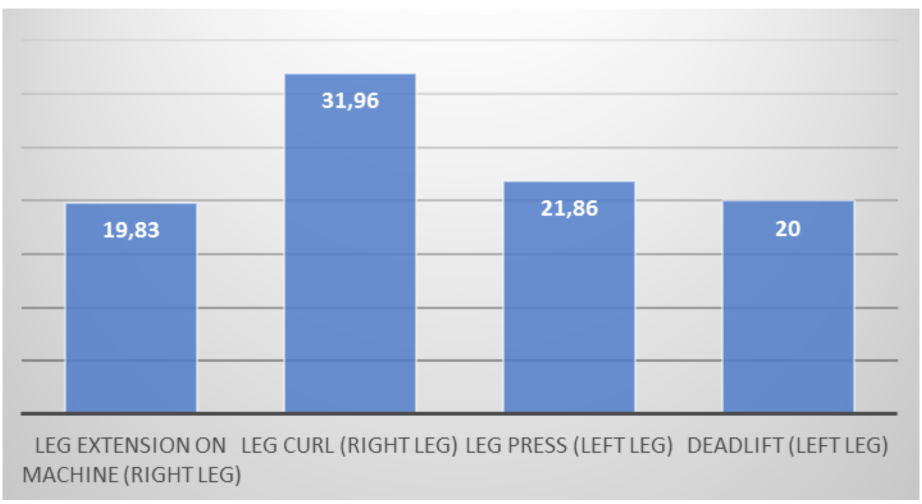

Fig. 2: Gain strength (1RM)

The change in force can also be judged by results from an isokinetic dynamometer. The greatest improvement was achieved by right knee joint flexors during the eccentric contraction, where the force improved by 12.81%. The results for the right leg are following: knee joint flexors during the concentric contraction improved by 10.08%, knee joint extensors during the eccentric contraction by 9.12%, knee joint extensors during the concentric contraction by 6.01%. The results for the left leg are following: knee joint extensors during the eccentric contraction improved by 5.29%, knee joint flexors during the concentric contraction by 3.48%, knee joint flexors during the eccentric contraction by 3.35%, and knee joint extensors during the concentric contraction by 3.31% (Figure 3).

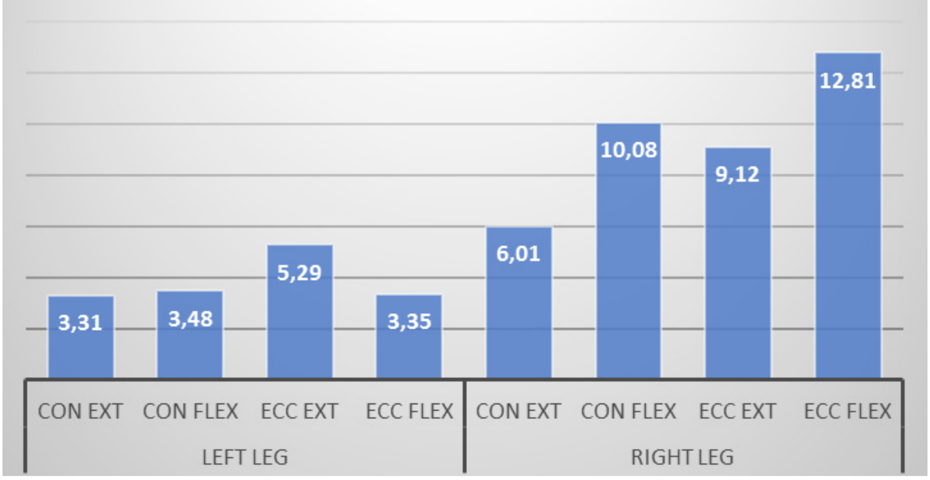

Fig. 3: Gain force (Nm)

DISCUSSION

The intervention program for left leg included deadlift and leg press. In the leg press exercise, the quadriceps, the knee extensor, is the dominant muscle (Evans, 2017; Delavier, 2015). Therefore, the highest transfer is expected for it, primarily during the concentric contraction. The highest transfer was to extensors during the eccentric contraction (0.20).

For the deadlift exercise, we assume the highest transfer to hamstring strength, knee flexor, due to the character of the exercise (Evans, 2017). In this case, the highest transfer was from deadlift to extensor force at the eccentric contraction (0.19). In both cases, we have to remember that we did not have a special experimental group for leg press exercise and a special group for deadlift, but there was only one group that practiced both exercises for the entire duration of the intervention program within the lower left limb. The result of the transfer does not correspond to the presumption probably because the deadlift exercises were also trained with heavy load (90–95% of 1RM) and due to the character of the exercises, quadriceps were more strongly activated.

The intervention program for right leg included leg extension exercises on a machine and lying leg curl. When calculating the transfer from leg extension on a machine to muscle strength, we would assume that the most prominent values will be in the quadriceps during the concentric contraction (knee joint extensor) that is dominant in the exercise (Evans, 2017, Delavier, 2015). However, the highest transfer (0.53) was seen in knee joint flexors (with the concentric contraction). This can be influenced by the fact that the intervention program for the lower right leg always included lying leg curl in addition to leg extension on a machine. Another explanation may be the fact that the participants always exercised with high resistance (90–95% 1RM). Therefore, this exercise also had to produce muscle strength during braking activity. And because the knee joint flexors are not strengthened as often as the extensors, they might have undergone a major adaptation.

For the leg curl exercise, we would assume that the transfer should manifest most into strength of hamstrings, knee joint flexors, during the concentric contraction, because flexors are dominant in this exercise (Evans, 2017, Delavier, 2015). In this case, the transfer results correspond to the assumption. The highest transfer was reflected from leg curl to the knee joint flexors at the concentric contraction (0.47).

The greatest increase in strength (1RM) occurred in the leg curl exercise (right leg), by 31.96% (Figure 2). Corresponding to this, the highest percent increase in knee joint flexor force [Nm] of the right leg (at the eccentric contraction of 12.81%, at the concentric contraction of 10.08%) in Figure 3. Generally, we found higher power transfer from single-joint exercises. This could be due to more demanding technical requirements for multi-joint exercises as well as similarity of single-joint exercises and isokinetic dynamometer testing.

The limit of the study is the inclusion of only two test groups. The transfer would have a higher informative value if only one exercise was applied per group or if there was a separate test group for each exercise.

CONCLUSION

In summary, we have shown that from all selected exercises, there is a force transfer to selected muscles / muscle groups. According to our results, leg extension on a machine should be the most suitable exercise for strengthening knee joint extensors. Leg extension on a machine would also be the most appropriate exercise to strengthen knee joint flexors. Based on the results of this study, athletes should not expect such a large force transfer when training other exercises (leg curl lying, leg press, deadlift). Deadlift seems to be the least effective exercise for force transfer, where the force transfer value for knee joint extensors is only 0.16 and for knee joint flexors 0.12. We would get other results if we focused on gain of force/strength, thus on the improvement of the results for a specific exercise (measured in 1RM) or for a specific limb (measured on an isokinetic dynamometer), instead on the force transfer. While the gain of strength (% of 1RM) showed the highest progress in the exercise leg curl (right leg) and the lowest progress in the exercise leg extension on a machine (right leg), for the gain force we clearly see the highest increase in strength of the flexors of the knee joint on the right leg and the lowest increase in strength of muscles on the left leg, here it is specific with respect to a contraction. We see that the values of gain force correspond to the transfer values. The coach must always consider the purpose for which he is preparing strength training (rehabilitation, improvement of strength performance, preparation for a specific sport, etc.).

From the practical application point of view, this article brings to the strength and conditioning coaches a basic awareness of the suitability of using selected exercises. Trainers should know which exercise (type of contraction, movement speed, number of joints involved, etc.) is best suited for their purpose due to manage and plan the training process. This study provides important information of selected exercises that can help optimize the adaptation process.

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Might Salivary Lysozyme Be an Indicator of Prolonged Intense Training Load in Athletes? A Preliminary Study in Adolescent Male Gymnasts.

Petr Váňa[1], Jana Juříková[1], Martina Bernaciková[1], Radek Ševčík[2], Alena Žákovská[3], Petr Hedbávný[4]

[1] Department of Kinesiology, Faculty of Sports Studies, Masaryk University, Brno
[2] Department of Experimental Biology, Faculty of Science, Masaryk University, Brno
[3] Department of Experimental Biology, Section of Animal Physiology and Immunology, Faculty of Science, Masaryk University, Brno
[4] Department of Gymnastics and Combatives, Division of Gymnastics, Faculty of Sports Studies, Masaryk University, Brno

Abstract

Lysozyme is one of the salivary antimicrobial proteins (AMP) which act as a defence at the mucosal surface. While in adult athletes, a decrease in salivary lysozyme (SLys) levels has been reported after prolonged intense training, to our knowledge, no studies have been conducted to study the relationship between SLys levels and long-term physical activity in children or teenagers.

The aim of this preliminary study was mainly to evaluate in a group of adolescent male gymnasts undergoing prolonged intense training load whether – in accordance with studies in adult athletes – there will also be a decrease in SLys and if so, whether this phenomenon will be so common that we detect it in a small group of study participants.

Twelve adolescent male gymnasts aged from 15.0 ± 1.6 years of national or international performance level were recruited to participate in this study. All participants of the study had their sample of saliva taken: I. Period) after the transitional period (rest), i.e. just before the beginning of the preparatory training period. II. Period) immediately after the end of the preparatory training period that was focused on maximal strength and power development. Preparatory training period lasting 6 weeks consisted of nine 2.5 hour training units (on average) over 6 days in every week. At the same time, three times per week (Mondays, Wednesdays and Fridays) two-a-day training sessions were incorporated. Intensity of the physical exercise was not determined.

We found a significant decrease in SLys levels after the preparatory training period (termed as II. period) compared to its level just before the start of the training (i.e. after the rest, termed as I. period).

The results of this preliminary study suggest that SLys measurements may be an indicator of prolonged training load in adolescent athletes. Although the intensity of the training load has not been determined, the national and international performance level of the gymnasts enrolled in the study allows at least a rough estimate of its level. However, larger studies on male and female adolescent athletes, applying relevant training load with monitoring of variables such as specific sports performance, physical fitness, nutrition, sleep quality, social and psychological factors, are desirable.

Key words: *lysozyme, saliva, athletes, gymnasts, training load, overtraining*

INTRODUCTION

Lysozyme or muramidase (EC 3.2.1.17), a low-weight enzyme with antibacterial activity named according to Greek word "lysis", is one of antimicrobial proteins of innate immune system. This enzyme glycoside hydrolase is able to hydrolyse of 1,4-β-D-glycosidic bonds between structural parts (N-acetylmuramic acid and N-acetyl-D-glucosamine residues) of peptidoglycan (murein), the primary component of Gram-positive bacteria cell wall, resulting in disintegration of the cell wall (lysis of the bacterial cell) and rapid killing of Gram-positive organisms. The enzyme is abundant in secretions and body fluids such as saliva, tears, airway secretions, human milk, urine, blood plasma and can be also found in granules of polymorphonuclear or mononuclear leukocytes (Perera et al., 1998).

Salivary lysozyme cooperates in ensuring of oral tissue health with both, salivary antimicrobial proteins of immunoglobulin (sIgA, IgG, IgM) and nonimmunoglobulin nature (lactoferrin, lactoperoxidases, defensins etc.). Lysozyme and lactoferrin are the two most abundant antimicrobial proteins (AMP) and as parts of airway surface liquid are derived mainly from serous cells of submucosal glands but also from surface epithelium and leukocytes entering the oral cavity through gingival crevices (Dubin et al., 2004; Perera et al., 1998). Both, output and composition of saliva is under control of autonomic nervous system, thus, it means flow rate and composition of saliva are indirect indicators of autonomic nerve's activity (Chicharro et al., 1998). Whilst, increased rate of salivary fluid output occurs in response to parasympathetic stimuli (copious saliva with low levels of organic and inorganic compounds), sympathetic stimuli lead to low volume of saliva rich in proteins and K^+ (rev. by Chicharro et al., 1998).

It is well known that IgA as the most abundant antibody at the mucosal surface plays an important role in protection against infectious objects entering the respiratory tract. In spite of that fact, salivary IgA levels may not parallel incidence of respiratory tract infections (Peters et al., 2010). At least *in vitro,* bactericidal activity of secretory IgA, complement and lysozyme was demonstrated for complex of all mentioned antimicrobial proteins but not for any of them given individually (Hill et Porter, 1974). Therefore, it seems that might be useful to asses also other constituents of mucosal defence system (Gillum et al., 2013). In past, one of them – salivary lysozyme was examined in connections to both, psychological and physical stress conditions and appeared to be inversely correlated to subjectively perceived level of psychological stress (Perera et al., 1997; Perera et al., 1998). On the other hand, acute moderate or high intensity exercise has been shown to increase salivary lysozyme levels (Allgrove et al., 2008; Gillum et al., 2017a; Gillum et al., 2017b) in contrast to prolonged intense training causing its decrease in saliva. For instance, in work published by West and coworkers (West et al., 2010) elite rowers had approximately half the concentration of salivary lysozyme and lactoferrin than non-exercising control subjects over a 5-month training season (West et al., 2010). Cunniffe with colleagues (Cunniffe et al., 2011) reported declines in salivary lysozyme concentrations (paralleled by decrease in salivary IgA) in elite rugby players at certain periods throughout the season in a prospective longitudinal monitoring study during a period of 11 months. Moreover, drops in both markers seemed to occur during/after preceding periods of intense conditioning type work (Cunniffe et al., 2011).

To our knowledge, no studies have been conducted to study the relationship between SLys levels and long-term physical activity in children or teenagers. Therefore, we present this preliminary study comparing the amount of SLys in adolescent male gymnasts of national or international performance level at the end of transitional period (preseason's rest) with the SLys level immediately after finishing preparatory training period characterized by maximal strength and power development. Potential ability of SLys levels to reflect disproportion between high training load and insufficient recovery in children might be beneficial in diagnostics of states of pathological fatigue such as overtraining and overreaching, that may have a negative impact not only on their athletic performance but also on their overall development.

The aim of this study was to evaluate in a group of adolescent male gymnasts whether – in accordance with studies in adult athletes – there will also be a decrease in SLys and if so, whether this phenomenon will be so common that we detect it in a small group of study participants. This could help us to estimate the number of participants in the intended main trial. Moreover, we wanted to assess whether the sensitivity of the lysoplate method used for detection SLys in this work (Tenovuo, 1989) is sufficient enough to reveal anticipated decline in SLys concentrations. Finally, we wished to check, whether the mode of specimen collection and handling is both, acceptable for participants and feasible.

MATERIAL AND METHODOLOGY

Participants

Twelve adolescent male gymnasts (aged from 12 to 17 years, with their other characteristics in Table 1) of national or international performance level were recruited to participate in this study.

Tab. 1: Subject characteristics, n = 12. Measurement of both VO2max (maximal oxygen uptake expressed per kilogram body mass) and Wmax (maximal power output) is described in "The bicycle ergometer test" section.

	Age [years]	Body mass [kg]	Height [cm]	VO_2max (ml/min/kg)	Wmax (W/kg)
Mean ± SD	15.0 ± 1.6	51.6 ± 8.6	160 ± 9.8	53.9 ± 4.0	4.3 ± 0.3

Experimental design

All participants enrolled in the study had their sample of saliva taken:

1) after transitional period (rest), just before the beginning of the preparatory training period *(termed as I. period*).
2) immediately after the end of the preparatory training period lasting 6 weeks that was focused on maximal strength and power development *(termed as II. period*) (table 2).

Characterization of the preparatory training period**:** Mondays, Wednesdays and Fridays were composed of a two-a-day training sessions (2 hours in the morning and 3 hours in the afternoon), whilst Tuesdays, Thursdays and Sundays of a one-a-day training session (lasting 2 hours, and 3 hours on Sunday). Saturdays were training sessions-free.

Tab. 2: *II. period characteristics* (II. period consisted of 9 training units during 6 days in every week lasting 6 weeks. At the same time, three times per week two-a-day training sessions were incorporated)

Training parameters	Volume (hours per: training unit / week)	Frequency (quantity of training units per: week / II. period)	Intensity
Average values	2.5 / 22.5	9 / 54	not determined

The subjects and their parents were provided both, written document describing the study and a verbal explanation. Consequently, all participants (including their guardians) provided written informed consent before volunteering for the study, and anybody who wished to withdraw could do so at any time. This study was approved by the Masaryk university's research ethics committee.

The bicycle ergometer test

To accurately quantify physical fitness exercise testing was used. All gymnasts participated in the bicycle ergometer test (Lode Excalibur Sport, BTL zdravotnická technika, a.s.) to obtain their VO_2max (maximal oxygen uptake expressed per kilogram body mass) and Wmax (maximal power output).

The test was performed at 75 rpm and began at an intensity of 1 W/kg W. The load was increased by adding a 0.5 W/kg weight to the basket every 1 min until exhaustion. In addition, VO_2max was measured during this test using Metalyzer 3B (Cortex). The test was considered as maximal if there was a plateau in VO_2 and/or a respiratory quotient higher than 1.10. The value of VO_2max corresponded to the highest 30 s value.

Saliva sampling and processing

To avoid variation of salivary lysozyme (SLys) levels during the day, whole unstimulated saliva samples were collected between 7 and 8 a.m. on the day of sampling after the subjects (with rinsed their mouth) had not been eating or drinking for 2 hours. Participants were in the seated position, leaning forward with their head tilted and were passively dribbling saliva into Eppendorf microtubes until microtubes became full. Finally, samples of saliva were centrifuged (1500 g for 10 min at room temperature) and supernatant stored at –20 °C until analysed for lysozyme.

SLys concentration was analysed as technical duplicates of the saliva samples (without any pretreatment) using the lysoplate method based on a diffusion of the sample into the agarose gel containing *Micrococcus luteus* (incubation in the wet-chamber at 4 °C). The diameter of the clearance zone measured after 24-hours is proportional to the logarithm of the concentration (Tenovuo, 1989). Lysozyme (Sigma-Aldrich, USA) was used for preparation of calibration solutions.

Statistical analysis

Obtained SLys concentration data (Table 2) were checked for normality using Shapiro-Wilk's test. As a normal distribution of data in both these groups (I. and II. training periods) was excluded, between training period-differences in salivary lysozyme levels were determining using non-parametric Wilcoxon signed-rank test. A 2-tailed level of 0.05 was considered to be statistically significant.

All calculations were done with help of statistical software STATISTICA 12.5.

RESULTS

In table 3 there are average salivary lysozyme concentrations in adolescent male gymnasts just before the beginning of the training period (after the preseason´s rest) after transitional period – "Period I" and immediately after the end of the pre-season training period – "Period II".

Tab. 3: Salivary lysozyme concentrations (SLys) in adolescent male gymnasts enrolled in the study determined after both, pre-season rest and 6-weeks lasting training load (n = 12)

	SLys (μg/ml)		Between period-differences
	Period I (after preseason rest)	Period II (after 6-weeks of training load)	
Mean	222.9	10.4	–212.5
SD	205.3	13.0	205.6

There was a significant difference (decrease, p = 0.0022) between SLys levels measured before (*I. period*) and after (*II. period*) 6-weeks lasting training load (preparatory training period).

DISCUSSION

Based on available data regarding adult athletes (West, 2010; Cunniffe, 2011) the aim of the present preliminary study was to evaluate whether the decreasing effect of prolonged physical training (6 weeks) on salivary lysozyme (SLys) concentrations may also occur in teenagers or, more precisely, if supposed decrease in SLys levels might be both, marked and frequent enough to be detectable in limited number of participants using less sensitive procedure (Tenovuo, 1989). With respect of the aim of the study identifying subject or training characteristics – that might influence the mucosal immune responses, including SLys levels – has not been done as thoroughly as been proposed by Gleeson and colleagues (Gleeson et al., 2004). In the present study, the training load was defined only by the overall duration, volume and frequency of training unit, without measuring the training intensity. The physical fitness of the participants has been desribed using VO_2max and Wmax parameters.

The advantage of the chosen sport branch (gymnastics) was the fact, that compared with other less strenuous branches of sport, gymnasts underwent relatively high training load in the preparatory training period (termed as “II. period” in this article). Thus, we could assume the potential physiologic response, including changes in SLys levels, might be expressed more clearly.

Indeed, we found a significant decrease in SLys levels after the preparatory training period (*II. period*) compared to its level just before the start of the training (*I. period*). This decrease, observed in this study in adolescent gymnasts, is consistent with previous results in adult athletes undergoing longer-term exercise (West et al., 2010; Cunniffe et al., 2011). However, in our study, there was a decline of SLys in the order of magnitude of weeks -and not months- of physical stress, as were in adults. In addition, a significant decrease in SLys concentration was observed after the training period, although no pretreatment of the saliva sample /the pretreatment significantly increasing the amount of detectable lysozyme in saliva (rev. by Tenovuo, 1989)/ was used prior to using the lysoplate method.

Achieved results and mentioned facts indicate that assessment of SLys in adolescent male athletes undertaking prolonged intense exercise might be sensitive sufficiently to detect changes in SLys levels, even if less sensitive procedure without pretreatment of the saliva samples was used. As states of pathological fatigue such as syndrome of overtraining arise mainly due to an imbalance in the training recovery ratio (with preponderance of training or competition activities) (Meussen et al., 2013) SLys might also be useful in diagnosing of these pathologies. Whether SLys determination might be useful even if the pathological fatigue condition is triggered by factors independent of the training patterns (e. g, eating patterns or poor sleep quality) (Cadegiani et Kater, 2018, Cadegiani et Kater 2019; Rietjens et al., 2005) remains – without precise knowledge of pathophysiology of overtraining and similar states – unclear at this time.

In relation to gender, we can speculate that the adolescent female athletes’ SLys levels might differ from male ones as was reported for the acute exercise of adults in the study by Gillum and colleagues (Gillum et al., 2014) Men expressed higher SLys concentration than women in the mentioned study both, at pre-exercise and post-exercise time points.

In addition to gender, there are individual differences in physical capacity, training history and fitness besides others that are able to influence AMP levels, including SLys (West et al., 2006). Therefore, for basic orientation measurements of maximal oxygen uptake (VO_{2MAX}) and Wmax were performed in our study. Obtained values of VO_{2MAX} suggest its moderate level and besides other are comparable with those of professional rugby players (Cunniffe et al., 2011).

CONCLUSION

The results of this preliminary study suggest that SLys measurements may be an indicator of prolonged training load in adolescent athletes, even if the less sensitive lysoplate method is used. (Tenovuo et al., 1989). Although the intensity of the training load has not been determined, the national and international performance level of the gymnasts enrolled in the study allows at least a rough estimate of its level. In addition to this fact, we are aware not only of the general limitations of our study such as the limited number of the subjects, their non-random allocation and participation of male gymnasts only, but also those summarized by Gleeson and co-workers (Gleeson et al., 2004).

Regarding the method of sample collection and handling, it was acceptable to the participants and feasible.

Overall, larger studies on male and female adolescent athletes, applying relevant training load with monitoring of variables such as specific sports performance, physical fitness, nutrition, sleep quality, social and psychological factors, are desirable.

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SOCIAL SCIENCES

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Art Competitions at the Olympic Games 1912–1948 and the Czechoslovak participation

Zdeněk Škoda

Czech Olympic Academy

Methodology

This article is a historical contribution. The historical data was gained mainly from primary sources and relevant literature. I have worked mainly with official reports from the Olympic Games, the estate of the Secretary-General of the Czechoslovak Olympic Committee František Widimský, documents from the archive of the Czech Olympic Committee and published articles by members of International Society of Olympic Historians. The methods that were used were direct and indirect historical approach, biography method and progressive method.

INTRODUCTION

Ten years after Pierre de Coubertin's dream came true and the International Olympic Committee (IOC) was set up, and with it later re-established the Olympic Games, he came up with the bold idea of including sports competitions and art competitions in the Olympic program. The ideal of modern Olympism refers to the ancient Greek idea of kalokagathia, the union of soul and body into one harmonious whole. According to Coubertin, the Olympic Games should be a fusion of sport and art.

In August 1904, the words of Coubertin were published in the Italian newspaper Figaro: "*Time to come to the next step, and to restore the Olympiad to its primal beauty. At the time of Olympia's splendour… the arts and literature in a harmonious combination with sports made the Olympic Games great. The same must hold for the future*." (Coubertin, Müller, 2000, p. 605).

In a circular dated April 4, 1906, Coubertin invited the members of the IOC and asked them to nominate artists from their countries to be invited to the Advisory Conference in Paris: "…*art and literature can participate in the celebration of modern Olympiads...*" was said in the letter (Müller, 1994, p. 70).

At this conference, Coubertin officially proposed that the IOC should organize a competition of artists and works of art in five different disciplines: architecture, music, sculpture, literature and fine arts. A kind of pentathlon muse. All works of art, without exception, are to be inspired by sport and to be original, meaning that it should not have been published on another occasion, and not before the Olympic Games. It was planned that the forthcoming Olympic Games in 1908, which were originally scheduled to take place in Rome, would organize art competitions. However, the Italians had unexpected financial problems in preparing the games (Müller, 2000, p. 623-624). By the way, they were caused, besides other things, by the eruption of Mount Vesuvius in 1906[1]. As a result, preparations for the Games had to stop. London was chosen hastily, and although the British wished for the art competitions to take place in the English capital, due to lack of time of organizing them, the art competitions were eventually withdrawn as part of the Olympic Games.

[1] Vesuvius Threatens Destructions of Towns. (1906, April 6). New York Times. Retrieved in December 14, 2019, from https://timesmachine.nytimes.com/timesmachine/1906/04/07/101838227.pdf

Art competitions at the Olympic Games – from Stockholm 1912 to London 1948

This initial failure did not discourage Coubertin and he strained all his will to Stockholm 1912. But the Organizing Committee for the Games in Stockholm did not receive support from various Swedish art associations and other institutions, including the Royal Swedish Academy, and all ended with the decision that the IOC had to be involved. Coubertin took the matter under his responsibility. And it ended in a fiasco. Only 35 artists entered the competitions. Disappointment. One work, however, impressed the jury. A poem in prose called *Ode to Sport*. It won the first place for literature. The authors of the work were two unknown writers Georges Hohrod and Martin Eschbach. As it turned out later, it was Coubertin's pseudonyms… (Lennartz, 2006).

It wasn't known until the 1990s when Jean Durry, a historian and an Olympic official, discovered that these two names were in fact the names of two villages near Luttenbach near Colmar, where Coubertin's wife was born. (Durry, 2000)

The Games of the VI Olympiad took place in Antwerp. Belgium (the country of fine arts) took the honour of organizing art competitions and took them very prestigiously. The works were of much higher quality than at the Stockholm Games. For the first time, all three medals were awarded, following the example of the awarding of athletes. Still, the competition of artists was only a marginal matter and without much interest.

It finally changed at The Games of the VIII Olympiad in Paris. In Coubertin's homeland, the artistic competitions were equal in importance to sports competitions. Almost 200 artists[2] from 24 countries applied to Paris. The interest in participating in the competitions in any ways was so great that the judges were often more famous than the competitors themselves. Judge for yourself: Paul Valéry[3], Selma Lagerlöf[4], Maurice Ravel[5] or even Igor Stravinsky[6] appeared among the judges. The music jury, by the way, did not give a medal to any musical work or composer and gave only diplomas for an "effort"[7]. Apparently, they were not amazed about the quality of the songs. It is also interesting that three artists from the Soviet Union took part in the competition. Because for the first time the Soviets officially started in Helsinki in 1952.

In 1925, at the IOC meeting in Prague, Pierre de Coubertin resigned from the IOC leadership on his own initiative and was elected a lifelong honorary member.[8]

A year later, the International Olympic Committee decided to set up an International Jury for the art competitions. Artistic quality was no longer decided by art professionals but by functionaries of IOC (Bijkerk, 2006, p. 29).

In Amsterdam 1928 the increase in popularity continued. More than 1,100 works have been exhibited at the City Museum. Architectural works were allowed to be published before the

2 Here we should mention Hungarian Alfréd Hajós (1878-1955), the first Olympic Champion swimmer, winner of Hungary's first Olympic gold medal in Athens 1896, who also won the Art Competition of the Paris 1924 Olympic Games, in the category of Architecture. In the whole long history of modern Olympism, Alfréd Hajós remains to be the only athlete to win an Olympic competition in both sports and art.

3 Paul Valéry (1871–1945) was a French poet, essayist and philosopher. In addition to his poetry and fiction (drama and dialogues), his interests included aphorism on art, history, letters, music, and current events.

4 Selma Lagerlöw (1858–1940) was a Swedish author and teacher, she was the first female writer to win the Nobel Prize in Literature, which she was awarded in 1909.

5 Maurice Ravel (1875–1937) was a French composer, pianist and conductor. His best-known work is Bolero (1928).

6 Igor Stravinsky (1882–1971) was a Russian composer, pianist, and conductor. He is widely considered one of the most important and influential in the 20th century.

7 Art Competitions at the 1924 Paris Summer Games: Mixed Music. Retrieved in November 20, 2019, from https://www.sports-reference.com/olympics/summer/1924/ART/mixed-music.html.

8 More information in Kolář, F. (1999). *Jiří Stanislav Guth Jarkovský* (pp. 73–74). Praha: Olympia. The text is concurrent in English.

Olympic Games. So, for example Jan Wils[9] was able to win a gold medal for the project of the local Olympic Stadium, where the Amsterdam games took place.

Because of the economic crisis and the expensive and long journey to Los Angeles, the 1932 Olympic Games were attended by far fewer athletes than in previous games. Paradoxically, this did not concern works of art. They were mostly sent by the ocean alone without the authors, and the Americans went to help ensure their transportation and insurance. An incredible 384,000 visitors came to the Los Angeles Museum of History, Science and Art in the story of the Games, which was historically the highest attendance ever.

Then came Berlin 1936. The German Art Committee, headed by Joseph Göbless, the German Minister for Folk Education and Propaganda, wanted the competitions in Berlin to be expanded so that the Germans had far more opportunities to show up themselves and succeed in an international competition. They tried to promote the film as another discipline, then they tried it with dance. Coubertin, however, strictly wished to maintain five disciplines. He considered the number 5 as an Olympic symbol (five circles, modern pentathlon…); and the IOC was also behind this. However, the Germans managed to expand the individual categories. So, for example, the music competition had three subcategories: orchestral composition, instrumental music, solo and choral singing. Or sculpture was divided into statues, reliefs, medallions. (Zawadski, 2006, p. 51–54). However, this was not a novelty: already in Amsterdam 1928 in literature the writers competed separately in drama, epic and lyric and also music was split up in three categories (Bijkerk, 2006, p. 30).

After World War II, the Olympic Games returned to London after 40 years. And there were two major changes in the rules: 1) only living artists were allowed to participate and 2) the works had to be first approved by the individual National Olympic Committees of the country from which the artist came from, so that it could no longer appear the work of someone whose country officially did not start at the Olympics, as was the case with the Soviets in Paris in 1924. The art competitions in London 1948 included multiple subcategories for each of the five artistic categories. The complexity of the competition with so many categories lading to devaluation of the Olympic medal (Guillain, 2005). "There was doubt over the quality of the artist, the lack of big names and difficulties with publicity. Whereas many sport fans could identify Zátopek or Blankers-Kern as heroes of '48, few are even aware of the artistic champions". (Barker, 2006, pp. 68–69).

In 1949, the IOC meeting was in Rome and there was an opinion that practically all the artists participating in the Olympics were professionals because they made their living from art. And because only amateurs are supposed to compete in the Olympic Games, art competitions should be cancelled and replaced by an art exhibition without awarding any prizes nor medals (Stanton 2002). This question sparked a heated debate, and it was decided less than a year before Helsinki 1952, that the art competitions would return to the Olympics after all. Like the British in 1908, the Finnish organizers pushed time out of the IOC's sudden decision, so unfortunately the art competitions could not be organized for logistical reasons. There was only an exhibition of works of art. At the 49th session of the IOC in Athens in 1954, the art competitions were finally cancelled.

The Czechoslovak participation and successes

Many Czech and Czechoslovak artists also made their mark in the history of the Olympic Games. They did not participate only in Antwerp 1920 and Amsterdam 1928. From Stockholm 1912 to

[9] Jon Wils (1891–1971). When completed, the Olympic stadium had a capacity of 40,000 (seating for 1,600). The infield was a football field surrounded by an athletics and cycle track. The main stand had a steel roof. In 1987 the stadium was listed as a Dutch national monument. Since 2005, the stadium is home to a sports museum, the Olympic Experience Amsterdam.

London 1948 it was 50 names altogether (Hladík, 2016, p. 15–23). The greatest successes were achieved by Czechoslovaks in the 1930s. Let me introduce them:

At the Olympic Games in Los Angeles 1932, Josef Suk[10] won silver for the "*Into a New Life*" march. Gold and bronze were not awarded at that time and Josef Suk did not earn the title of Olympic champion mainly because the part of this composition was published in 1920 and thus the work did not fully comply with the competition rules. After the death of Josef Suk in 1935, the composition was recognized by the Sokol movement as their official march.[11]

In Los Angeles 1932, sculptor Jakub Obrovský (1882–1949)[12] was awarded the bronze medal for the statue of *Odysseus*. A few years later, Jakub Obrovský was an important figure actively trying to push through the boycott of the 1936 Olympic Games in Berlin. He refused to participate in the "Hitler's Games".

Another success in the USA was noted by architect Aloys Dryák (1872–1932), who was awarded an honourable mention for the project of the Strahov Stadium in Prague, where the Sokol Slets took place.

The composer Jaroslav Křička succeeded in Berlin in 1936. His *Mountain Suite* was awarded a bronze medal. By the way, his brother Petr wrote the lyrics for Suk's march in *Into a New Life*.

In London, 1948, the distinguished Czech architect František Marek (1899–1971) received the honourable mention for the building of the Vinohrady Sokol Hall and musician Jan Kapr (1914–1988) for the composition *Marathon*. Kapr was an enthusiastic Communist after World War II, but in 1968 he fully opposed the occupation of Czechoslovakia by the Warsaw Pact troops and was banned by the Communists from any artistic activity subsequently.

Finally, let me mention the Traveling Prize of Czechoslovak Olympic Committee by Otakar Španiel (1881-1955), which is known today as the *Dr. Jiří Stanislav Guth-Jarkovský*[13] *Award*. It did not receive any awards in Berlin, but it is an important part of the Czech Olympic movement. Since 1934 it has been awarded to athletes or sports teams for extraordinary sport performance in a given calendar year. After the Communist coup d'état of 1948, it was abolished, but it was renewed by the Czech Olympic Committee in 1994. In recent years, the award has been given not by officials or journalists, but by athletes themselves, and so the prize enjoys extraordinary popularity in the Czech Republic.

CONCLUSION

We briefly outlined the history of art competition within the Olympic games. Since the cancellation of art contests, the so-called art festival has appeared at the Olympic Games, where the Olympic Charter has required organizers to include cultural events in the program. Until today,

[10] Josef Suk (1873–1935). An important Czech composer and violinist, student and son-in-law of the world-famous composer Antonín Dvořák (1841-1904).

[11] See Marek Waic & Zdeněk Škoda. (2019). The Story of a Composition: Josef Suk – Olympic Medallist and Sokol Composer. In *The International Journal of the History of Sport*, 35(17–18), 1829–1843. Retrieved from https://doi.org/10.1080/09523367.2019.1632292

[12] He devoted himself to fencing, tennis and boxing.

[13] Jiří Stanislav Guth Jarkovský (1861–1943) was a Czech sports promoter, Secretary General of the International Olympic Committee (1919–1923) and co-author of the Olympic Charter. He was a friend of Pierre de Coubertin since the time they met in 1892 in Paris. In 1900–1929 he was the chairman of the Czech and, after the establishment of the Czechoslovak Olympic Committee, co-founder and first chairman of the Czech Amateur Athletic Union, chairman and editor of the Tourist Club. He is also known as the author of publications on good and decent behavior.

the combination of art and sport has continued without art competitions. But on the other hand, the opening and closing ceremonies are one of the most watched art-cultural events in the world. So even if the works of art themselves do not compete anymore, Olympism continues to relate to art.

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Czech Adaptation of the Brunel Mood States for Adolescent Athletes

Petr Květon[1], Martin Jelínek[1], Iva Burešová[2], Kateřina Bartošová[3]

[1]Institute of Psychology, Czech Academy of Sciences, p. r. i.
[2]Faculty of Arts, Masaryk University
[3]Faculty of Education, Masaryk University

Abstract

The Brunel Mood States is a 24-items long questionnaire (formerly referred to as the Profile of Mood States for Adolescents POMS-A) used to capture emotional profile of an individual. It has been used in various settings including sport psychology, where it is considered a valid indicator for overtraining syndrome. The aim of this study was to develop the Czech adaptation of BRUMS and verify its psychometric properties in adolescent athletes. The data were collected from a sample of 246 participant (50.8% females; age range 14–19 years). Confirmatory factor analysis was used to evaluate original six-dimensional structure (with factors of Depression, Tension, Confusion, Anger, Fatigue, and Vigor). Even though this model showed acceptable fit to the data, Depression and Tension factors were empirically indistinguishable. Therefore, we proposed and verified alternative five-factor model with these two factors collapsed. Measurement invariance across gender was assessed using the Multiple Indicators Multiple Causes (MIMIC) model. Although three items showed signs of differential item functioning, the Czech adaptation of the instrument can in general be considered a measurement invariant.

Keywords: *emotions assessment, overtraining, gender, BRUMS*

INTRODUCTION

Emotions are an ever-present part of human activities. Researchers in various disciplines put considerable efforts into understanding the role emotions play in our performance, health, and wellbeing. Sport psychologists consider emotions to be a critical factor in either enhancing or impairing individual or team performance (Hanin, 2000). Changes in mood states have also been studied in connection to overtraining syndrome (OTS) and were repeatedly found to be its valid indicator (Goss, 1994; Hollander et al., 1995). OTS can be defined as an abnormal extension of the training process resulting in chronic fatigue, underperformance, and/or an increased vulnerability to infection leading to recurrent infections (Budgett, 1998). OTS is usually accompanied by six emotions: anger-hostility, anxiety, confusion, depression, sadness, and lack of vigor (Henschen, 2000)[1]. It is thus not surprising that in the field of sport psychology the Profile of Mood States (POMS) was established as the most prominent instrument, as it captures all above mentioned emotions. There are various versions of POMS but all of them share the same internal structure with six distinct but interrelated factors: (1) depression-dejection reflects experiences of mood states characterized by feelings of sadness and feelings associated with negative self-schema; (2) tension-anxiety reflects somatic tension (either observable or non-observable) and anxious states; (3) confusion-bewilderment is characterized by mental confusion and cognitive ineffectiveness connected to inability to control attention; (4) anger-hostility captures states of anger and antipathy toward others; (5) fatigue-inertia combines symptoms of tiredness and weariness; (6) vigor-activity reflects states of high energy and vitality.

[1] Henschen in his text prefers medical term *maladaptive fatigue syndrome* but notes that it describes the same phenomenon as OTS.

The first version of POMS (McNair et al., 1971) was developed via factor analytic procedures. It is used mainly for monitoring effect of psychotherapy, medication, sleep deprivation and other experimental interventions in research settings. In the revised version of the instrument's manual McNair, Lorr, and Droppleman (1992) declared that it is valid to use the POMS in sport and exercise environments. The POMS is an adjective checklist which consists of 65 items unevenly distributed into 6 dimensions, which are described in the previous paragraph and one additional dimension called friendliness. The latter dimension is conceptually different from others and thus is not typically used in research practice. The instrument's manual admits two variants of instructions which focus either on actual emotion states ("How you feel RIGHT NOW?") or on temporary mood states ("How have you been feeling over the PAST WEEK, INCLUDING TODAY?"). Individual dimensions can be scored separately or added together (with vigor scored negatively) to determine the total mood disturbance score.

Even though the completion of the POMS questionnaire is in normal and healthy population relatively fast (usually between 3 and 7 minutes), Shacham (1983) argued that the administration can be overly demanding in specific populations like patients with severe pain. Therefore she developed a shortened form of the POMS with 37 items (POMS-SF). Scores for shortened and original versions of POMS shared substantial portion of variance (more than 90% for individual dimensions and 98% for total mood disturbance). Given the fact that shortening of POMS did not resulted in significant loss of information on the level of individual dimensions, the POMS-SF can be considered a good alternative for situations where there are time limits (e.g. research purposes) or respondent limitations (clinical practice). The psychometric qualities of the shortened form were confirmed in various settings and national contexts (Aroian et al., 2007; Baker et al., 2002; Curran et al., 1995).

POMS-SF has been previously translated into Czech language and its psychometric properties have been evaluated (Stuchlíková et al., 2005). On a sample of 162 university students Stuchlíková et al. confirmed that the Czech version of POMS-SF respects original six-factor structure, however, to achieve good fit to the data, secondary factor loadings in case of five items needed to be added. Moreover, the authors estimated multiple indicators, multiple causes model (MIMIC) to examine effect of gender and age on measurement parameters. In either case no signs of severe measurement invariance were detected.

In 1999, Terry, Lane, Lane, and Keohane published a new version of POMS designed specifically for use in adolescent population. The authors suspected that adjectives in original POMS might be in some cases inappropriate for adolescents and therefore they added additional 18 items to an initial item pool. In the pilot stage, face validity of the items was evaluated on small samples of teachers and children. Based on their ratings, preliminary 42-item inventory was assembled with seven items per each dimension. Confirmatory factor analysis on a larger sample revealed poor fit of the six-factor model and thus the authors decided to remove the weakest three items from each dimension. The revised 24-item version was then administered to extensive samples of young athletes and school children for final evaluation of its psychometric properties. In general, Terry et al. concluded that their instrument showed strong evidence of factorial validity and can be used with school children and young athletes. In a follow-up study, Terry, Lane, and Fogarty (2003) further examined construct validity of POMS-A for use with adult athletes. They presented evidence supporting the psychometric integrity of the POMS-A when extended from adolescent to adult populations. The POMS-A scale was subsequently renamed to the Brunel Mood Scale (BRUMS; Terry & Lane, 2003).

The present study
The general aim of the study was to create and verify Czech adaptation of the Brunel Mood States questionnaire in adolescent athletes' population. More specifically, our goal was to confirm factor structure postulated by Terry et al. (1999), and, due to the differences in emotionality between males and females, also to test measurement invariance across gender subgroups.

METHODS

Participants
A total of 251 adolescent athletes recruited from a sport-focused high school in Brno, Czech Republic participated in our study. Five cases were removed due to a substantial number of missing answers (more than five missed items from 24 items long instrument). The final research sample consisted of 246 participants aged from 14 to 19 years (M = 16.40, SD = 1.31). Participating athletes were engaged in various sports (mostly volleyball, swimming, football, athletics, basketball, or tennis). Most of the athletes competed at national (49.6%) or international (31.3%) level, 14.2% at regional level and only 4.9% participants on recreational level.

Tab. 1: Sample characteristics

Gender	males	49.2%
	females	50.8%
Age	14 y.	5.3%
	15 y.	24.4%
	16 y.	22.0%
	17 y.	28.0%
	18 y.	14.2%
	19 y.	6.1%
Type of sport	individual	58.5%
	team	41.5%
Achievement level	recreational	4.9%
	regional	14.2%
	national	49.6%
	international	31.3%

Procedure
Students were contacted through class teachers and coaches. Prior to the actual data collection, informed consent for students to participate in the research was obtained from parents or legal representatives. Participation in the study was voluntary and no incentives were given in exchange for participation. The data were obtained using a paper/pencil questionnaire battery. It contained

numerous instruments focused on demographic, social, psychological, and sport-related characteristics. The whole questionnaire battery including Brunel Mood States and other research instruments was administered in school settings in autumn 2018 and the administration took two one and a half hour. Data collection was provided by trained administrators, acquainted with the purpose of the project and research methods.

Instruments

Brunel Mood States (BRUMS, earlier also referred to as POMS-A; Terry, Lane, Lane, & Keohane, 1999). This instrument is used to assess transient, distinct mood states. It contains 24 items evenly distributed into 6 dimensions – confusion, depression, fatigue, tension, vigor, anger. The instruction we used was:"Please describe how have you been feeling over the past week, including today?". Individual items are in the form of single adjectives (e.g. "angry"). The response format is a 5-point rating scale (0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, 4 = extremely). The Czech translation of the instrument is available in the Appendix and original item wording in Terry et at. (1999). Because BRUMS shares 14 items with POMS-37 (Shacham, 1983), in our translation procedure we utilized existing and verified Czech translation of POMS-37 items (Stuchlíková et al., 2005). Unique BRUMS items were translated using a sequential process generally considered a standard for cross-cultural questionnaire adaptations in the field of social sciences (e.g. Guillemin et al., 1993): a) forward translation by a professional familiar with psychological terminology, b) back translation by an independent translator, c) resolving inconsistencies in a team of study authors and the two translators, and d) pre-testing on a sample of 10 adolescent athletes focused on clarity and unambiguity of items.

Data analysis

Prior to main analyses, we used the expectation-maximization method to impute missing values (there were no more than 1.0% of missing values in any of the items). The instrument structure was evaluated using confirmatory factor analysis (lavaan package in R; Rosseel, 2012). Measurement invariance regarding gender was assessed using the MIMIC procedure (Brown, 2006). The MIMIC model was used to examine effects of gender on measurement parameters, because it is more suitable to detect differential item functioning in relatively small sample sizes than Multiple Group Confirmatory Factor Analysis (Brown, 2006). In the first step of this procedure, the latent factors of BRUMS were regressed on the exogenous predictor gender (0 = males, 1 = females). Next, direct path between predictor and item indicator with highest potential to improve the model fit was identified using modification indices. Then, the model was re-specified with free estimation of the identified path. A significant (1% level) direct effect of gender on the item was considered as an indication of differential item functioning (DIF). This process was repeated until all DIF items were identified. In all the analyses, we assumed multivariate nonnormality of the data (Henze-Zirkler's coefficient = 1.01, $p < 0.01$) and therefore we used maximum likelihood estimation with robust standard errors and Satorra-Bentler scaled test statistic, and robust CFI, NNFI, and RMSEA fit indices. According to Little (2013), we used the following ranges for interpreting model fit: mediocre fit (RMSEA: 0.10–0.08, CFI and NNFI: 0.85–0.90) and acceptable fit (RMSEA: 0.08–0.05, CFI and NNFI: 0.90–0.99). Internal consistencies of the scales were assessed using McDonald's omega coefficient.

RESULTS

Confirmatory factor analysis of BRUMS

In concordance with originally proposed structure of the instrument the six-factor model with correlated factors was initially evaluated. This model showed acceptable fit to the data (S-B $\chi^2 = 471.27$, df = 237, $p < 0.01$; CFI = 0.92; NNFI = 0.90; RMSEA = 0.07, 90%CI[0.06, 0.08]). As can be seen in Table 2, all factor loadings are sufficiently high (higher than 0.05). Correlations between latent factors with their 95% confidence intervals are presented in Table 3. In general, all factors are closely related, which is especially evident for the depression and tension factors. In this case, corresponding confidence interval includes the value of 1, indicating that these factors are almost indistinguishable in our sample. Therefore, we proposed modified model in which depression and tension factor were collapsed into a single dimension. This new model showed a similar fit to the data as the original one (S-B $\chi^2 = 495.00$, df = 242, $p < 0.01$; CFI = 0.91; NNFI = 0.90; RMSEA = 0.07, 90%CI[0.06, 0.08]). All factor loadings were higher than 0.05 (see Table 2). Factor correlations in the five-factor model do not suggest the existence of indistinguishable factors (see Table 3). Internal consistencies of individual dimensions in both models were acceptable (McDonald's omega higher than 0.70).

Tab. 2: BRUMS item factor loadings with 95% confidence intervals

	Six-factor model	Five-factor model
Depression		
depressed	0.82[0.76;0.87]	0.80[0.74;0.86]
downhearted	0.86[0.82;0.90]	0.84[0.80;0.88]
unhappy	0.82[0.77;0.87]	0.83[0.78;0.87]
miserable	0.81[0.76;0.87]	0.81[0.75;0.86]
Tension		
Panicky	0.60[0.49;0.71]	0.56[0.45;0.67]
anxious	0.81[0.76;0.86]	0.81[0.75;0.87]
worried	0.65[0.58;0.73]	0.65[0.57;0.73]
nervous	0.60[0.52;0.68]	0.58[0.49;0.66]
Confusion		
confused	0.75[0.68;0.82]	0.75[0.68;0.82]
mixed-up	0.70[0.61;0.78]	0.70[0.61;0.78]
muddled	0.82[0.76;0.89]	0.84[0.77;0.90]
uncertain	0.72[0.63;0.80]	0.70[0.61;0.79]
Anger		
annoyed	0.76[0.68;0.83]	0.76[0.68;0.83]
bitter	0.79[0.72;0.87]	0.79[0.72;0.87]
Angry	0.70[0.62;0.78]	0.70[0.62;0.78]
bad-tempered	0.81[0.76;0.87]	0.81[0.76;0.87]

	Six-factor model	Five-factor model
Fatigue		
worn-out	0.67[0.59;0.76]	0.67[0.59;0.76]
exhausted	0.84[0.78;0.89]	0.84[0.78;0.89]
Sleepy	0.77[0.70;0.83]	0.77[0.70;0.83]
Tired	0.85[0.80;0.90]	0.85[0.81;0.90]
Vigor		
Lively	0.76[0.69;0.84]	0.76[0.69;0.84]
energetic	0.51[0.40;0.61]	0.50[0.40;0.61]
Active	0.76[0.67;0.84]	0.76[0.67;0.84]
alert	0.71[0.62;0.81]	0.71[0.61;0.81]

Note. Standardized parameter estimates are stated.

Tab. 3: Internal consistencies and correlations between BRUMS latent factors

Six-factor model	ω	(2)	(3)	(4)	(5)	(6)
Depression (1)	0.90 [0.87; 0.92]	0.95 [0.89; 1.01]	0.78 [0.70; 0.86]	0.70 [0.60; 0.79]	0.61 [0.51; 0.70]	−0.64 [−0.73; −0.55]
Tension (2)	0.76 [0.72; 0.81]		0.90 [0.83; 0.97]	0.72 [0.62; 0.82]	0.54 [0.42; 0.66]	−0.52 [−0.64; −0.40]
Confusion (3)	0.83 [0.80; 0.87]			0.61 [0.48; 0.73]	0.53 [0.42; 0.64]	−0.35 [−0.49; −0.22]
Anger (4)	0.85 [0.82; 0.88]				0.50 [0.38; 0.63]	−0.37 [−0.49; −0.24]
Fatigue (5)	0.86 [0.83; 0.89]					−0.64 [−0.74; −0.54]
Vigor (6)	0.79 [0.75; 0.83]					
Five-factor model			(3)	(4)	(5)	(6)
Depression/ Tension (1)	0.91 [0.89; 0.93]		0.82 [0.75; 0.89]	0.71 [0.63; 0.79]	0.59 [0.49; 0.69]	−0.62 [−0.71; −0.52]
Confusion (3)				0.60 [0.47; 0.73]	0.53 [0.42; 0.64]	−0.35 [−0.49; −0.22]
Anger (4)					0.50 [0.38; 0.63]	−0.37 [−0.49; −0.24]
Fatigue (5)						−0.64 [−0.74; −0.54]

Note: ω = McDonald's Omega. 95% CI intervals for correlations between factors are stated in square brackets.

MIMIC analysis of differential item functioning

The MIMIC analysis started with model based on the five-factor solution (with depression and tension factors collapsed) with gender added as exogenous predictor of all latent variables and direct paths from gender to all items set to zero. Even though this model showed acceptable fit to the data (S-B χ^2 = 546.45, df = 261, $p < 0.01$; CFI = 0.90; NNFI = 0.89; RMSEA = 0.07, 90%CI[0.06, 0.08]), we attempted to identify items showing signs of DIF. Using the iterative step-wise procedure (see the Data analysis section for more details) suggested by Brown (2006), we found three items that were significantly influenced by gender. These were items *angry* (from the Anger factor), *worn-out* (from the Fatigue factor), and *active* (from the Vigor factor). When controlling for the appropriate latent factor, males scored higher than females in *angry* and *worn-out* items, and conversely females scored higher than males in *active* item. Gender significantly predicted all but one (Anger) latent factors. Values of semi-standardized regression coefficients in Table 4 (which can be interpreted akin to Cohen's d) show that males scored higher than females in Vigor, whereas females scored higher than males in Depression/Tension, Confusion, and Fatigue. However, we can conclude, that freeing the three gender-item parameters did not lead to substantial increase in model fit (S-B $\chi 2$ = 508.20, df = 258, $p < 0.01$; CFI = 0.92; NNFI = 0.90; RMSEA = 0.07, 90%CI[0.06, 0.08]).

Tab. 4: MIMIC model results – regression coefficients for the effects of gender on items and latent factors

Items/factors	unstandardized / semi-standardized coefficients	95%CI
DIF items		
Angry	0.56	[0.36; 0.76]
Worn-out	0.38	[0.15; 0.62]
Active	–0.36	[–0.60; –0.11]
Latent factors		
Depression/Tension	–0.45	[–0.69; –0.20]
Confusion	–0.42	[–0.69; –0.15]
Anger	–0.06	[–0.34; 0.21]
Fatigue	–0.48	[–0.74; –0.23]
Vigor	0.75	[0.49; 1.02]

Note: In case of the items, unstandardized coefficients are stated. In case of factors, semi-standardized coefficients are stated.

DISCUSSION

The BRUMS represents the shortest standardized questionnaire from the family of POMS instruments. Authors of the method convincingly proved that it is suitable to capture emotional states of an individual during the whole (adolescent and adult) athletic career (Terry et al., 1999; Terry, Lane, et al., 2003). Reliable qualities of the BRUMS were verified in many cultural contexts (Hashim et al., 2010; Quartiroli et al., 2017; Terry, Potgieter, et al., 2003; Zhang et al., 2014). The aim of this study was to develop Czech adaptation of BRUMS, verify its factorial structure on a sample of adolescent athletes, and concurrently evaluate measurement equivalence across gender.

Results indicated good empirical support for originally postulated six-factor model of BRUMS. All item factor loadings were sufficiently high and individual dimensions showed reasonable levels of internal consistency. Latent factors in our sample were highly correlated in general, but especially high intercorrelations were found in case of depression-tension and tension-confusion. These findings contradicted original Terry et al.'s (1999) study and several other studies (Terry, Lane, et al., 2003; Terry, Potgieter, et al., 2003; Zhang et al., 2014). Nevertheless, low discriminant validity of negative emotions subscales were found by others. Hashim et al. (2010) mentioned correlations above 0.9 in case of depression-confusion and depression-anger. Aroian et al. (2007) reported even more extreme results with intercorrelations between depression, tension, anger, and confusion ranging from 0.89 to 0.98. Based on our results we decided to propose a modified model, where depression and tension were collapsed, because in this case the factors seemed to be empirically indistinguishable. Despite the high correlation of tension-confusion, we decided to preserve both dimensions, because confidence interval did not suggest lack of differentiation. Modified model with five dimensions did not show signs of substantial misspecification.

Besides examining factorial structure, we also focused on measurement invariance. Previous studies examined this psychometric quality across various grouping variables, such as developmental stages or sport-nonsport involvement (Zhang et al., 2014), languages (Terry, Potgieter, et al., 2003), and gender (Quartiroli et al., 2017; Stuchlíková et al., 2005). We contributed to this discussion by testing measurement invariance across gender. Due to the relatively small sample size we decided to use the MIMIC procedure instead of multigroup CFA approach. We detected sings of differential item functioning in case of three items. Despite this finding we suggest that assumption of measurement invariance across gender was not substantially violated because (a) overall model fit was not substantially deteriorated by omitting appropriate parameters and (b) each item originated from different dimension. Moreover, our conclusion about gender-related measurement invariance is partially supported by study of Quartiroli et al. (2017), who used multigroup analysis and confirmed factorial invariance across adult male and female athletes. Also, in Czech cultural context, Stuchlíková et al. (2005) did not find measurement invariance across gender in a related POMS-SF questionnaire.

CONCLUSION

Our study demonstrated factorial validity of the Czech adaptation of the 24-item BRUMS questionnaire in adolescent athletes. Confirmatory factor procedures revealed that questionnaire items represent high-quality indicators of mood states dimensions, but also suggested problems with differentiation of negative mood factors, especially depression and tension. Measurement invariance analysis did not reveal serious manifestations of differential item functioning regarding gender.

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APPENDIX

The Czech version of BRUMS

Níže je seznam slov, která popisují lidské pocity. Každé slovo si pozorně přečti, a potom zakroužkuj odpověď, která nejlépe vystihuje, jak ses cítil/a v průběhu minulého týdne včetně dneška. *V průběhu minulého týdne jsem se cítil/a:*	vůbec ne	trochu	středně	docela	extrémně
1. vyděšeně	0	1	2	3	4
2. plný/á života	0	1	2	3	4
3. zmateně	0	1	2	3	4
4. opotřebovaně	0	1	2	3	4
5. depresivně	0	1	2	3	4
6. sklesle	0	1	2	3	4
7. rozzlobeně	0	1	2	3	4
8. vyčerpaně	0	1	2	3	4
9. chaoticky	0	1	2	3	4
10. ospale	0	1	2	3	4
11. rozhořčeně	0	1	2	3	4
12. nešťastně	0	1	2	3	4
13. úzkostně	0	1	2	3	4
14. ustaraně	0	1	2	3	4
15. energicky	0	1	2	3	4
16. mizerně	0	1	2	3	4
17. popleteně	0	1	2	3	4
18. nervózně	0	1	2	3	4
19. vztekle	0	1	2	3	4
20. aktivně	0	1	2	3	4
21. unaveně	0	1	2	3	4
22. podrážděně	0	1	2	3	4
23. nabuzeně	0	1	2	3	4
24. nejistě	0	1	2	3	4

Note. Original English instruction: "Below is a list of words that describe feelings that people have. Please read each one carefully. Then circle the answer which best describes, how have you been feeling over the past week, including today?" English wording of the items (in the same item ordering) can be found in Terry et al. (1999, p. 872). BRUMS subscales: Depression – 5, 6, 12, 16; Tension – 1, 13, 14, 18; Confusion – 3, 9, 17, 24; Anger – 7, 11, 19, 22; Vigor – 2, 15, 20, 23; Fatigue – 4, 8, 10, 21.

Does Personality Matter When We Are Approaching the Subjective Perception of Overtraining Among Adolescents?

Radek Šíp, Iva Burešová

Masaryk University

Abstract

This article deals with the issue of overtraining among elite adolescent athletes. The aim of our study was to examine the relationship between certain personality traits, as perfectionism, extraversion, neuroticism and other Big 5 traits and subjective perception of training load (which is one of the best indicators of overtraining syndrome). We also focused on the relationship between a perceived training difficulty and perceived training load to find out, if there is some kind of integral relationship. To collect data we used a questionnaire, which was given to adolescent elite athletes playing team sports in a mid-season period. The results show significant relationship between perceived training load and overall perfectionism ($r=0.189$, $p<0.001$), extraversion ($r = -0.241$, $p < 0.001$), neuroticism ($r = 0.343$, $p < 0.001$) and consciousness ($r= -0.287$, $p < 0.001$). After the closer examination we found an interesting relation between single dimension of perfectionism and perceived training load, suggesting the contribution of maladaptive perfectionism on development of overtraining syndrome. Besides that, we differentiated athletes into two groups, according to the level of perceived training difficulty. Those, who perceived training as difficult to exhausting ($M = 2,19$, $SD = 0.50$) were significantly higher than low to medium group ($M = 1.99$, $SD = 0.47$) in the perceived training load $t(178) = -0.894$, $p = 0.007$. Those results extend our knowledge of overtraining topic and can be used in coaching practice to help identify athletes with higher risk of overtraining, or even prevent these states among young athletes before they occur. Hereby results suggest the importance of psychological aspects in sport preparation.

Key words: *Adolescence, personality, perfectionism, overtraining, sport*

INTRODUCTION

An elite adolescent sport is becoming more advanced every year. Sport channels started broadcasting finals of elite juvenile competitions, more coaches are taking part of single training unit, parents tend to provide their child with skills coaches, nutritionist and even sport psychologist. An overall demand on young athletes increasing in form of higher training loads, more frequent training units and general stress on professionalism. Results matters. In a such competitive, achievement-centred environment one may find himself without means or time to cope the increasing demands and recover. That may lead to the development of maladaptive overload or even the overtraining syndrome. (Meeusen et al., 2006).

As mentioned above, young athletes tend to train several training units per week up to the point, where total number of units is higher than number of days in one week (that is due to working-out twice a day some days).

There are three main goals of training procedure. The first is known as Motor skill learning – a process in which an individual acquires new movements, gradually automates them and in the end is able to use them creatively. (Blahutková, & Sližik, 2014). Second one is Tactical adoption – which is aiming on a such skills as one's understanding and usage of game tactic or decision making. The third one is Physiological adaptation – A constant process of intentional overload one's muscle capacity in order to disturb his or her homeostasis, which results in acute fatigue leading to an improvement in performance (Meeusen, Duclos, Foster, et al., 2013). Fundamentally, this improvement in performance is natural coping mechanism against physical load, caused by adaptive changes in three domains (Bernacikova, 2013): Adaption as increase of metabolic supplies (increase of ATP and glycogen level, etc.), Adaption as increase of body functional capacity (increase in both, aerobic and anaerobic capacity) and Morphological adaptation (muscle hypertrophy, ligaments strengthening, etc.).

However not every time are these adaptions enough to cope. When they become insufficient and cannot longer provide organism with means to withstand the training load, that is where pathological fatigue and overtraining begin. While suffering from these states, adaptions become maladaptive. Máček, Máčková, & Radvanský (2003) points out that general base of overtraining and maladaptive overload is inequality between length, intensity, frequency of training loads and necessary recovery. Almost universally decrease in performance occurs.

Having said that, such a maladaptive state does not happen overnight. That is why most of the authors (Meeusen, 2013, Armstrong,& Vanheest, 2002), see overtraining as a spectrum, starting with acute (non maladaptive) fatigue reaching up to the overtraining syndrome. The differences between single states are length of time necessary to recover and a way in which performance is affected. Table 1. illustrate this well.

Tab. 1: Overtraining spectrum (Meeusen, Duclos, Foster, et al., 2013)

Process	Training (overload)	Intensified Training		
Outcome	Acute Fatigue	Functional Overreaching (short-term OR)	Non-Functional OR (extreme OR)	Overtraining syndrome (OTS)
Recovery	Day(s)	Days – weeks	Weeks – months	Monhts – …
Performance	Increase	Temporary decrement	Stagnation – Decrease	Decrease

Nevertheless, there are other factors, which contribute on developing these conditions besides having little or no time at all to regenerate. An increasing number of studies identified several of them: low self-esteem, parental or coach pressure, high level of anxiety (Kanmani, & Kalpana, 2016), early sport specialization (Jayanthi, Pinkham, Dugas, Patrick, & LaBella, 2013), perfectional concerns (Madigan, Stoeber & Passfield, 2016) or parent-initiated motivational climate (Brenner, 2007). The last one is especially relevant among youth athletes. Although some of the factors contributing on the development of the overtraining syndrome may be specific for adolescents, manifesting symptoms are the same as for the adults. They can be sort out according on the affected area.

The symptoms in the first group are psychological as sleep disturbances (Roy, 2015), loss of self-confidence, apathy, irritability, depression, anxiety, and confusion (Johnson, & Thiese, 1992) also poor concentration (Pearce, 2002) and decline in competitive drive and sexual libido may occur (Budgett, 1994), as well as muscular soreness often mentioned by athletes (Urhausen, & Kindermann, 2002). The symptoms in second group are physiological. One of the most frequent physiological symptom of overtraining is higher resting heart rate (Máček, Máčková & Radvanský, 2003), followed by changes in normal blood pressure, elevated body temperature, impeded respiration (Johnson & Thiese, 1992), weight loss (Budgett, 1990) and even amenorrhea among girls (Roy, 2015). In third group immunological symptoms are. While suffering from overtraining, one exhibit considerable immune-suppression and increased stress (Wyatt, Donaldson & Brown, 2013). Also, upper respiration symptoms may occur, but surprisingly without affecting performance itself (Ferrari, Gobatto, & Manchado-Gobatto, 2013). The symptoms in fourth group are hormonal, as increase in cortisol level (Johnson & Thiese, 1992) or decrease in the level of testosterone (Roberts et al., 1993).

Hoverer the most significant and mentioned symptom is performance decrease, which cannot be explain by any other reason than overtraining.

Tab. 2: Symptoms of the overtraining with diagnostic suitability (Urhausen, & Kindermann,2002, p.100).

Tool		Changes in OTS	Suitability
Sports-specific performance	(Sub)maximal exercise	↓	Gold standard; regular testing problematic (in most sports)
Ergometric performance	Anaerobic threshold	(↑)	Does not diagnose OTS, but targets other training errors
	Maximal exercise	↓ or ↔	Incremental graded tests less sensitive than tests-to-exhaustion (or time-trials)
Neuromuscular excitability	At rest	↓	Difficult method; needs more data
Mood profile	At rest	↓	Very sensitive; may be manipulated
Subjective complaints	At rest, submaximal exercise	↑	'Heavy legs': very common; sleep disorders: less common; may be manipulated
Borg-scale	Submaximal exercise	(↑)	Small changes
Heart rate	At rest	↔	↑ may indicate other problems (infection)
	Variability	?	Insufficient data
	Maximal exercise	(↓)	Rather small changes
Respiratory exchange ratio	(Sub)maximal exercise	↓	Limited data
Lactate	Submaximal exercise	(↓)	Does not diagnose OTS, but excludes other training errors
	Maximal exercise	↓	Typical change, but probably not in every sport
CK, urea	At rest	↔	↑ may indicate muscular overuse or prolonged carbohydrate depletion

Testosterone	At rest	↔	↓ may indicate high physiological strain?
Cortisol	At rest	↔	↑ may indicate high physiological strain
	Maximal exercise	(↓)	Differentiation between intensive training and OTS may be questionable
ACTH	Maximal exercise	↓	Very sensitive, differentiation between intensive training and OTS may be questionable
Catecholamines	Excretion (urine)	↓	Marked ↓ as late indicator of OTS
	Maximal exercise (plasma)	↓ or ↔	Parallels changes of lactate

ACTH = adrenocorticotropic hormone; CK = creatine kinase; ↓ = decreased; (↓) = slightly decreased; ↔ = unchanged; ↑ = increased; (↑) = slightly increased; ? = not established.

When accessing overtraining syndrome, several measure tolls can be used. That is due to various number of different symptoms. There are two main diagnostic approaches: measuring athletes while they trains or measuring them while they are calm (rest day). Both approaches measure heartbeat, level of lactate in a blood, level of performance and other physio-humoral symptoms. Additionally, impaired mood and subjective complaints can be measured during calm measurement. (Urhausen, & Kindermann, 2002). These indicators seem to be one of the earliest symptom of overtraining syndrome (Urhausen, Gabriel, Brückner, & Kindermann, 1998, Foster, 1998).

To diagnose impaired mood several questioners were developed. The most used are: Profile of Mood states (POMS, McNair, Lorr, & Droppleman, 1992), The Recovery-Stress Questionnaire for Athletes (RESTQ Sport, Kellmann, 2010) or The Borg's Rating of Perceived Exertion (RPE, Borg, 1998).

Unfortunately, there is no unified treatment for athletes suffering from overtraining syndrome, due to various symptoms. The best thing afflicted athlete can do to improve his state is prolong rest time. Hoverer that may cause additional stress, especially if the afflicted athlete is competitive. In a such case, more active resting forms are recommended (Armstrong & Vanheest, 2002). Taking into consideration severity of overtraining syndrome and difficulty of curing it, the best solution to this issue may be early prevention.

The aim of this study was to explore the relationship between perfectionism, perceived training difficulty and perceived training load to further extend our knowledge of overtraining topic, to be able preventing these states among young athletes.

METODOLOGY

Participants

We gathered data from 180 young elite athletes, playing team sport (72 hockey players, 108 football players) on national or international level. Participants had a mean age of 16.1 years (SD = 1.4), varying from 14 to 19 years. In average, they trained 6 time a weak (SD = 1.1). Data were collected in a mid-season period.

Materials and procedure

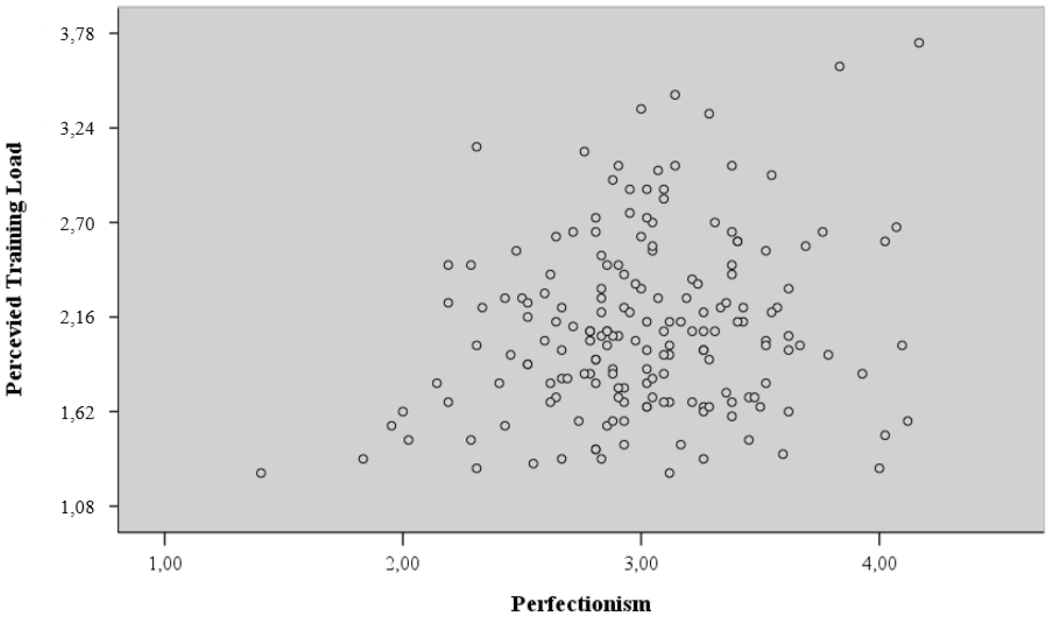
Participant were accessed all around Czech Republic and measurement usually take place in a school class. They were asked to complete questionnaire packet containing four section. The first section was focused on demographic items like type of sport, age, number of training per week etc. It also contained question to measure perceived training difficulty by 5-point Likert scale (effortless, low, medium, difficult, exhausting). The second section contained a czech version of Sport Multidimensional Perfectionism Scale – 2 (SMPS-2; Gotwals & Dunn, 2009). This questionnaire was invited directly to measure perfectionism among athletes. Respondents rate to which degree they agree with 42 items on a 5-point Likert scale. Questionnaire measures six dimensions: Personal Standards (PS), Concern Over Mistakes (COM), Perceived Parental Pressure (PPP), Perceived Coach Pressure (PCP), Doubts About Actions (DAA), Organization (ORG). The third section contained czech version of Profile of Mood States (POMS; Stuchlíková, Man & Hagtvet, 2005). It is scale used to asses transient, distinct mood states. It is often used by sport and experimental psychologists. Respondents rate if and how much they felt each of 37 items (mood states) in past week on a 5-point Likert scale. Questionnaire measures six dimensions: Tension, Anger, Fatigue, Depression, Confusion and Vigor. The fourth section contained Czech version of Big Five Inventory (BFI-44; (Hřebíčková, Jelínek, Blatný et al., 2016). That is one of the most frequently used questionnaires to measure personality traits in nowadays psychology. Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism were measured through 5-point Likert scale on 44 items.

RESULTS

For each questionnaire and single scale an index of internal consistency was counted with generally satisfying results (POMS overall Cronbach's alpha was 0.90, BFI-44 Cronbach's alphas vary from 0.44 for Agreeableness to 0.73 for Neuroticism, SMPS-2 all Cronbach's alphas were above 0.70).

The hypothesis about the relationship between perceived load level and personality traits was confirmed. We found correlation between perceived load level (POMS results) and Extraversion (–0.241, $p < 0.001$), Conscientiousness ($r = -0.287$, $p < 0.001$) and Neuroticism ($r = 0.343$, $p < 0.001$).

Also, the hypothesis about the relationship between perceived load level and perfectionism was confirmed with weak but significant relationship ($r = 0.189$, $p < 0.001$) – see Graph 1.



Graph 1: Correlation between perceived training load level (POMS) and overal perfectionism (SMPS-2)

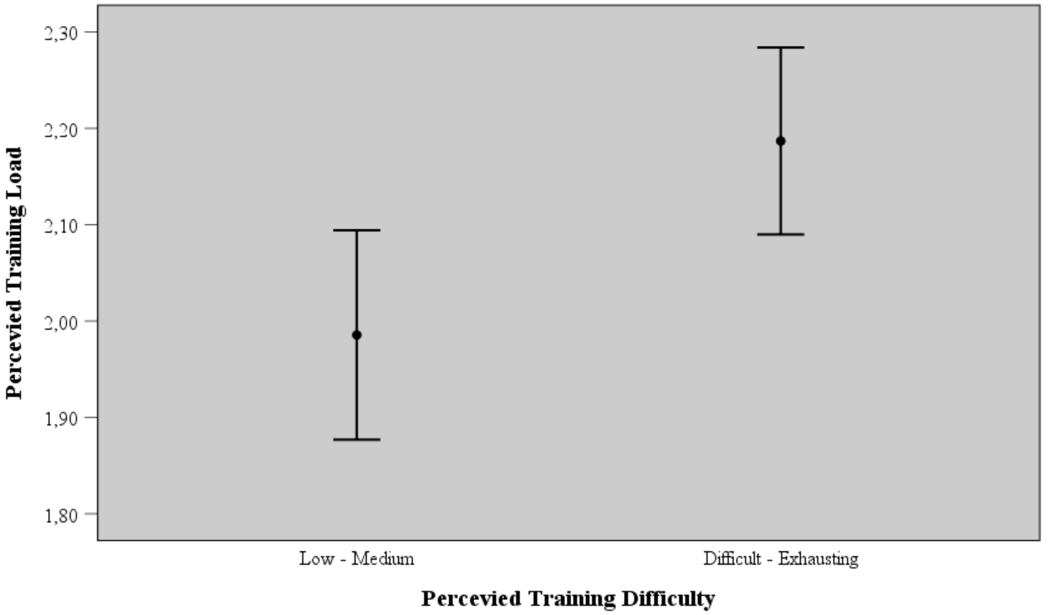
Besides, when we analysed a single scales of perfectionism questionnaire, distinguish between adaptive and maladaptive perfectionism started to be noticeable. We found significant correlations between perceived load level and scale Concern over mistake, Doubts About Actions and Perceived coach pressure. All relationships between single dimensions of perfectionism and perceived load level are summarized in Table 3.

Tab. 3: Correlation between perceived training load level and dimensions of perfectionism.

Dimension of SMPS-2	POMS
Personal Standarts	–.094
Concern Over Mistakes	.242*
Doubts About Actions	.351*
Perceived Parental Preassure	.136
Perceived Coach Preassure	.181*
Organization	–.146

*Statistically significant correlations ($p < 0.05$).
Note I. Dimensions associated with maladaptive perfectionism are cursived.

Also, we hypothesised that subjective perceived training difficulty matters. Significant difference between groups in perceived training load according to perceived training difficulty was found. Those, who perceived training as difficult to exhausting (M = 2.19, SD = 0.50) were significantly higher than low to medium group (M = 1.99, SD = 0.47) in the perceived training load $t(178) = -0.894$, $p = 0.007$. – see Graph 2.



Graph 2: Group differences between perceived training load level according to perceived training difficulty.

No significant difference was found between athletes playing different sports. Furthermore, there was not found any significant difference between these two groups in a POMS, BFI-44 or SMPS-2 measurement. That is the reason why we used these two group as one.

DISCUSSION

In development of overtraining syndrome, several factors may serve as protective or risk factors. Our study confirms certain role of personality traits. Negative correlation between extraversion and level of overtraining may be explain by the fact, that extraverts tends to have wider social network, which was found as protective factor (DeFreese, & Smith, 2013). Furthermore, extraversion is personality trait characterised by positive emotions (Hřebíčková, Jelínek, Blatný et al., 2016) while POMS is based mainly around negative emotions. Conscientiousness itself may leads to better diet or higher compliance in a matter of regeneration etc. On the other hand, neuroticism may serve as risk factor of overtraining, due to smaller amount of positive emotions and higher irritability. Research showed negative correlation between neuroticism and sport performance (Kajtna, Tušak, Barić, & Burnik, 2004). That may lead, especially among perfectionist and highly goal-oriented athletes to lower self-esteem or even mood disturbance.

Mentioning perfectionism, athletes with its maladaptive form are in higher risk of injury (Madigan, Stoeber, Forsdyke, Dayson, & Passfield, 2017). They also tend to have lower self-esteem (Flett & Hewitt, 2005) and higher anxiety (Kawamura, Hunt, Frost & DiBartolo, 2001).

Longitudinal study has shown higher tendency of suffering from training distress among athletes with perfectionistic concerns (Madigan, Stoeber, & Passfield, 2016).

Our results are in line with these previous finding. Concern over mistakes and doubts about actions showed the strongest relationships with perceived training load. However, relationship with overall perfectionism was really weak. Therefore, we hypothesize that form of perfectionism may be the key factor. Since most of the scientist believes, that personality traits are biologically based (with some contribution of environment), it is the perfectionism what we can affect. Richardson, Rice, Sauer, & Roberts (2019) showed the effect of psychotherapy on perfectionism, declined perfectionistic concerns, leaving person with just non-maladaptive striving. Taking this study into consideration with our results, the importance of psychological aspects in sport preparation stands out.

Finally, we confirmed the importance of monitoring athlete's perception of training difficulty. That was already know before this study (Urhausen, Gabriel, Brückner, & Kindermann, W, 1998; Foster, 1998), but we proved that really simple question may provide valid answer. Therefore, we would like to encourage coaches to pay attention to athlete's feelings.

Limitation

Our work has clearly some limitations. As a main one we consider narrow approach of gathering information about overtraining syndrome. Thought, mood disturbance is one of the earliest and almost universal indicator of overtraining, physio-humoral analysis could have provide us with more overall and deeper data. Also, testing methods itself has several limitations. We think that not all POMS items in Czech version are easily understandable. Furthermore, in first section of questionnaire packet, the item asking the number of training per week, was not clearly understand with every participant equally. Thought, most of the participants answered in a same range, there were few who vary too much. Another limitation was Cronbach's alpha for Agreeableness in BFI-44 – just 0.44.

CONCLUSION

Adolescent sport does not seem to reduce stress on professionalism, neither sport clubs does not seem to decrease amount of single training units (or the volume) of young athletes. With this trend, parents, coaches, teachers and other persons, with direct supervision on young athletes has to extend their knowledge of overtraining issue, in order to be able to prevent these states, or at least be able to help young athletes cope them.

Since there is not an unified treatment for overtraining syndrome, wider knowledge, skills and creativity are necessities of paediatricians and even school and sport psychologist to be able to cure this condition.

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STUDENT SECTION

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Structure and Performance-Related Changes in Puberty in a Group of Ice Hockey Players

Jakub Krajňák

Masaryk University

Abstract

The article deals with structure and performance-related changes occurring in the beginning of puberty in relation to ice-hockey players of the older pupil category. 20 male players born in 2005 and in 2006 of corresponding biological age underwent measuring of their somatic parameters, balance and specific performance on ice. To evaluate the maturity age, the Roche-Wainer-Thissen method was used; moreover, the Star excursion balance test (SEBT) was used to assess the balance and the Illinois agility test (IAT) without a puck was used to assess the performance on ice.

The results show that players born in 2005 show bigger structural changes in comparison with those born in 2006; nevertheless, no differences in somatotypology were found. As far as performance is concerned, the players born in 2005 were faster in the IAT while those born in 2006 displayed bigger reaches in SEBT – specifically in the anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL), anterolateral (AL) direction and the composite score (COMP). These findings strongly indicate that IAT depends on the production of strength which was bigger due to the structural changes. The SEBT results of the players born in 2005 may have been influenced by the puberty spurt during which adolescents' coordination stagnates due to a worsened postural control. The growth of body proportionality may have led to lever changes and to ineffective motor control while dealing with a new motor task as well. Another reason for the above-mentioned may also be muscle shortening.

Keywords*: puberty, maturity age, ice hockey, Star excursion balance test, Illinois agility test*

INTRODUCTION

Puberty begins in the older school age during which functional and structural changes occur. The state of having reached puberty cannot be deduced from the chronological age; e.g. two boys of the same chronological age and different maturity age can reach puberty even two years apart from each other (Dimock, 1935). Structural changes tend to correlate with maturity age rather than with chronological age as puberty can be gone through in a large span of chronological ages (Sugden & Wade, 2013). Puberty causes the increased production of growth hormones supporting the production of thyroxine and sex hormones in the hypophysis which leads to the bodily growth accompanied by changes in bones, tissues and metabolism (Tanner, 1990). It leads to the peak height velocity which occurs in the 14th year of age of boys (Jones, 1946). Dimock (1935) tested motor ability tests by Brace test among boys ages 12–16. The overall results of the test indicate worsening of progress in the 14th and 15th year of age. He explains this by saying that swiftly-growing adolescents are characterised by partial clumsiness due to the growth of bones and the body which has grown out of their muscle control. Espenschade et al. (1953) confirm the decrease of dynamic balance in the beam walking test manifesting itself by a considerable "adolescent lag".

Balance is a component of physical condition which is essential for the performance and the prevention of injuries. It is an ability to maintain the body in a balanced condition even during tense situations and in changeable environment (Lehnert et al., 2014). A notion closely related to balance is the level of proprioception in connection with orientation skills (Perič & Dovalil, 2010). Besides the everyday life, balance (both static and dynamic) is made use of especially in combat sports, artistic and rhythmic gymnastics, figure skating, skiing, and team sports. To assess the level of dynamic balance, the Star Excursion Balance Test (SEBT) was selected. Its simplicity, low cost and applicability both in a laboratory as well as on a sports ground were the crucial attributes which led to the selection of this test.

Agility movements can be defined as rapid whole-body movements that require single or multiple changes in velocity or direction in response to an external stimulus (Sands, Wurth, & Hewitt, 2012). Agility training includes multiple modalities including strength and power, sprint, specific agility, balance and coordination as well as flexibility training. It can be enhanced by many agility drills (Ratamess, 2012). To assess the agility level the Illinois agility test was selected.

METHODS

The tests were conducted on male ice hockey youth of HC Kometa Brno born in years 2005 and 2006 (n = 35). During a season, they usually train on-ice for 4–5 hours per week and 2–3 hours per week off-ice. In most cases, they have 1–2 matches per week. The tests were applied during the off-season from June 2019 to September 2019.

The subject had a warm-up for 10–15 minutes consisting of running and dynamic stretching. After the warm-up, the subject underwent a SEBT test (figure 1). The subjects were instructed about the technique as well as to undergo the test in usual off-ice sport clothes (shorts, shoes) and with a hockey stick. Each subject could take the test once. The standing limb had to stay in the middle of a cross with no move to a side and no raising the heel. The hockey stick could be held either in one hand or in both hands but its contact with the ground was considered a failed attempt. If the subject made a mistake, he was asked to repeat the same direction with correction.

After completing the SEBT test, he went on to prepare for an on-ice training. Before the on-ice training, he underwent the agility test. For the purpose of on-ice testing, the Illinois agility test without a puck was chosen (figure 2). This modification is more typical for ice hockey players. It is used by the Czech Ice Hockey Association to test young Czech ice hockey players (Český hokej, 2017). After a sound signal, the subjects were asked to skate as fast as possible on the track. An extra attempt was allowed in case of a mistake.

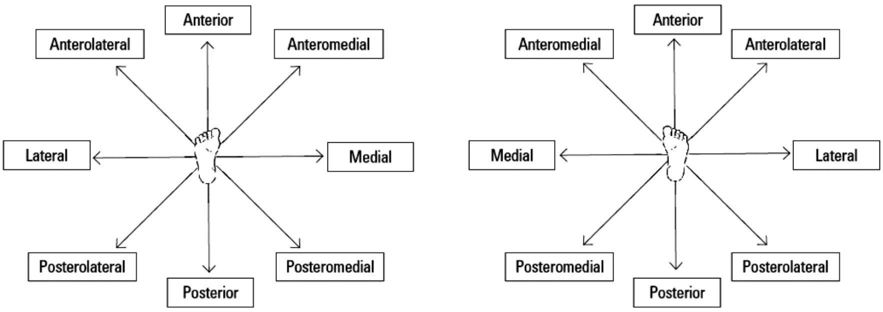

Figure 1 Star excursion balance test

Figure 2 Illinois agility test on-ice

Finally, after the training the anthropometric data were measured and the subject was questioned about his personal information (table 1). The obtained data were used to determine the somatotype with the use of the Heath-Carter protocol (Carter, 2002). Maturity age was calculated using the Roche-Wainer-Thissen method (RWT) which predicts the body height of an adult at the age of 18 (Roche & Davila, 1972). It can be determined from the mid-parent stature (MPS), skeletal age (SA), present weight (W) and recumbent length (RL). If the recumbent length value is unknown, it can be calculated from the present stature + 1.25 cm. Due to the limited possibilities of determining the SA the modification of the RWT method for adult stature was used where SA is replaced by chronological age (CA). The constants used to determine the adult stature prediction are given in Table XXVII (Roche, Wainer, & Thissen, 1975).

The Roche-Wainer-Thissen method of the adult stature prediction:

$$Predicted\ adult\ stature = RL \times ß\,RL - W \times ß\,W + MPS \times ß\,MPS - CA \times ß\,SA + ß\,0$$

The results are subsequently converted to the relative statures estimated without the SA:

$$(Present\ stature \div predicted\ adult\ stature) \times 100$$

Relative statures were compared to the FELS Longitudinal study which measured child growth and development since 1927 (Khamis & Roche, 1994). Using FELS, the maturity age (MA) was determined by half-years. Maturity age higher than 14 was labelled as 14+.

Tab. 1: Data for predicting maturity age

Number	Year of birth	Position	RL (cm)	Weight (kg)	Age		MPS (cm)	RWT (cm)	RWT (%)	MA
					year	month				
1	2006	D	168.25	58	12	10	168.5	185.3	90.8	14.0
2	2005	D	178.25	72	13	9	170	186.8	95.4	14+
3	2006	F	165.25	54	12	8	179	188.5	87.7	13.0
4	2005	F	164.25	46	14	4	177.5	180.4	91.0	14.0
5	2005	F	168.25	51	14	1	178.5	184.4	91.2	14.0
6	2005	D	168.25	58	14	2	169	178.8	94.1	14.0
7	2006	D	155.25	42	13	1	172.5	178.1	87.2	13.0
8	2006	F	166.25	49	12	10	180	189.6	87.7	13.0
9	2006	F	167.25	59	13	4	170.5	182.5	91.6	14.0
10	2006	D	167.25	63	13	4	166	180.0	92.9	14.0
11	2006	F	156.25	41	12	8	169	179.2	87.2	13.0
12	2006	F	158.25	44	13	5	178.5	181.1	87.4	13.0
13	2006	D	150.25	37	12	10	171.5	175.2	85.7	12.0
14	2006	D	148.25	43	12	9	166	170.2	87.1	13.0
15	2005	G	178.25	63	13	11	180	191.4	93.1	14.0
16	2005	F	159.25	57	14	1	173.5	175.0	91.0	14.0
17	2006	F	170.25	50	13	3	178	189.5	89.9	13.0
18	2006	F	165.25	48	13	3	176	185.1	89.3	14.0
19	2005	D	172.25	54	13	11	182	189.1	91.1	13.0
20	2006	G	169.25	49	12	10	172	188.7	89.7	13.0
21	2005	F	183.25	65	14	4	181	192.7	95.1	14+
22	2005	F	177.25	57	13	9	179.5	191.8	92.4	14.0
23	2005	F	163.25	50	13	10	173.5	179.9	90.7	14.0
24	2006	F	157.25	46	12	11	174	180.2	87.3	13.0
25	2005	F	167.25	52	14	2	174.5	181.0	92.4	14.0
26	2006	F	156.25	46	12	10	175	180.0	86.8	12.5
27	2006	F	156.25	52	12	7	171	178.3	87.6	13.0
28	2006	D	160.25	50	12	11	169	180.4	88.8	13.0
29	2005	G	159.25	46	13	7	173	178.6	89.1	13.0
30	2005	D	174.25	85	13	8	179	184.9	94.3	14.0
31	2005	D	172.25	62	13	10	172	183.8	93.7	14.0
32	2005	F	169.25	63	13	11	176	183.5	92.2	14.0
33	2006	D	154.25	42	12	8	174.5	179.7	85.8	12.0
34	2006	F	173.25	66	13	4	173.5	187.0	92.7	14.0
35	2006	D	168.25	62	13	4	172.5	183.4	91.8	14.0

RESULTS

The result of all the participants (n = 35) show that the biological age of 20 of them corresponds with their year of birth (n = 10 both groups). Goalkeepers were eliminated from the measuring in order to increase the homogeneity of the sample. The obtained anthropometric data along with the values obtained from the exercise tests are given in table 2.

Tab. 2: The mean values and SD of general data about groups, anthropometric measuring, somatotype and performance tests (IAT and W170) with Cohen's d

	2006 (n = 10)		2005 (n = 10)		Cohen's d
	Mean	SD	Mean	SD	
Age	12.87	0.24	13.95	0.18	5.09*
Height (cm)	158.10	6.06	167.10	5.07	1.61*
Weight (kg)	47.10	4.28	58.10	10.32	1.39*
Length of limb (cm)	82.65	3.55	86.35	3.15	1.10*
Body fat (%)	13.06	3.92	11.65	5.13	0.31
W170 (W/kg)	2.76	0.27	3.10	0.18	1.48*
Illinois (s)	17.62	0.92	16.72	0.55	1.19*
Anthropometry					
Suprailiacal skin fold (mm)	5.10	0.94	5.90	2.12	0.49
Subscapular skin fold (mm)	5.50	0.81	6.50	1.32	0.91*
Skin fold of thigh (mm)	10.50	1.86	9.40	1.44	0.66
Skin fold of calf (mm)	11.95	2.13	10.65	1.68	0.68
Skin fold of triceps (mm)	8.80	1.54	7.80	1.60	0.64
Skin fold of biceps (mm)	4.20	0.60	4.50	0.81	0.42
Circuit of thigh (cm)	44.60	2.58	47.10	5.26	0.60
Circuit of calf (cm)	32.20	1.60	33.70	3.00	0.62
Circuit of arm (cm)	25.35	1.14	27.70	1.75	1.59*
Humerus width (mm)	64.40	1.80	67.10	3.62	0.94*
Femur width (mm)	90.50	4.70	95.80	5.40	1.05*
Somatotype					
Endomorphy	2.00	0.45	1.95	0.65	0.09
Mesomorphy	4.45	1.00	4.40	0.88	0.05
Ectomorphy	3.55	0.99	3.20	1.35	0.30

* Values with large effect size

Table 3 contains the values from SEBT which were normalized by the length of the lower limbs and composite score was calculated as a sum of the distances in all the directions divided by the number of directions.

Tab. 3: The mean values and SD of 2006 and 2005 groups with SEBT score and Cohen's d

SEBT directions	Standing limb	2006 (n = 10)		2005 (n = 10)		Cohen's *d*
		Mean	SD	Mean	SD	
Anterior	left	91.23	6.15	86.87	5.27	0.76
	right	90.12	6.44	85.64	4.73	0.79
Anteromedial	left	98.40	5.43	92.98	4.40	1.10*
	right	101.41	7.65	94.07	6.35	1.04*
Medial	left	102.44	9.39	96.18	7.83	0.72
	right	105.33	6.86	95.57	9.36	1.19*
Posteromedial	left	108.06	7.72	99.59	10.52	0.92*
	right	109.88	6.77	102.47	7.78	1.02*
Posterior	left	112.10	6.89	103.15	8.30	1.17*
	right	110.62	8.28	106.97	5.23	0.53
Posterolateral	left	103.09	7.30	97.50	5.41	0.87*
	right	101.57	6.50	97.47	6.32	0.64
Lateral	left	86.72	7.61	89.07	9.37	0.28
	right	90.09	8.43	85.87	8.32	0.50
Anterolateral	left	80.04	5.73	73.85	5.63	1.09*
	right	80.37	5.66	73.50	6.03	1.17*
Composite score	left	97.76	4.51	92.40	4.84	1.15*
	right	98.67	4.89	92.69	5.02	1.21*

* Values with large effect size

DISCUSSION

The obtained results show that as far as somatotypes are concerned, the players born in 2005 are better-built than the players born in 2006; this may be caused by the puberty spurt. Even though somatotypology in accordance with the Heath-Carter protocol did not show any somatotype-related differences between the groups of players, the variables necessary to determine a somatotype are of great substantive significance (subscapular skin fold: Cohen's *d* = 0.91, large; circuit of arm: Cohen's *d* = 1.59, large; humerus width: Cohen's d = 0.94, large; femur width: Cohen's d = 1.05, large).

The players born in 2005 also achieved better results in the IAT from the point of view of performance. The same result was achieved also in the W170 test in which the players born in 2005 achieved better relative values than the players born in 2006 (3.10 W/kg vs. 2.76; Cohen's d = 1.48, large). As Jones (1946) noted, the growth of strength tends to begin approximately at the skeletal age of 14 years, which corresponds with the result.

The players born in 2006 were more successful concerning dynamic balance; they achieved substantive significance with large effect in AM, M, PM, AL a COMP in relation to both lower limbs and only in relation to the standing left lower limb in the P and PL directions. It can be caused by the adolescent lag during which the linearity of the progress is disrupted which manifests itself in sudden changes of postural control; coordination subsequently stabilizes in a later stage of puberty (Dimock, 1935). Moreover, it can be caused by the puberty spurt during which the musculoskeletal system develops and manifests itself by the imbalance between strength and flexibility (Shanmugam & Maffulli, 2008) which leads to a worse performance in SEBT (Gribble, Hertel, & Plisky, 2012).

IAT is considered to be a versatile test influenced by several skills: agility, speed, strength and coordination. The players born in 2005 not having reached better results in dynamic balance than the players born in 2006 could be caused by the fact that ice skating is an acquired skill while SEBT is a new motor task. It could also be caused by the fact that undergoing IAT depends mainly on strength skills rather than on coordination skills.

CONCLUSION

The aim of the study was to discover structural and performance-related differences in relation to older pupils during the puberty spurt. As the period during which the puberty spurt can begin is too broad, the chronological age is insufficient to determine the maturity. On the other hand, the maturity age is determined by somatic parameters which indicate the stage of development of a young sportsman more precisely. The research focused on the differences between prepubescent and pubescent players, which is why biologically delayed as well as accelerated players were eliminated from the research.

From the total number of players (n = 35) only forwards and defensemen of the above-mentioned maturity age corresponding with the chronological were selected. The players were divided into two groups: the players born in 2005 (n = 10) and the players born in 2006 (n = 10). The subjects underwent SEBT and IAT as well as an anthropometric measuring which was used to calculate the maturity age and the somatotype. The results were averaged with the standard deviation and compared in accordance with Cohen's *d* to determine the substantive significance.

The results show that while the players born in 2005 are more physically fit, they lag behind the players born in 2006 as far as dynamic balance is concerned. This may be caused by the "adolescent lag" which causes many changes in the body due to the puberty spurt – these changes can be structural or functional such as e.g. the control of lower neural units by higher brain centres, lower centres operating independently, a decrease in the heart rate, and an increase in the amount of the oxygen transported.

It is only a matter of time before the adolescent adapts to the changes in their body and the performance grows linearly again. Coaches training adolescents during their pubertal development need to bear in mind that it is necessary to respect the changes occurring to their charges and to adapt their training loads to them.

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Address:
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