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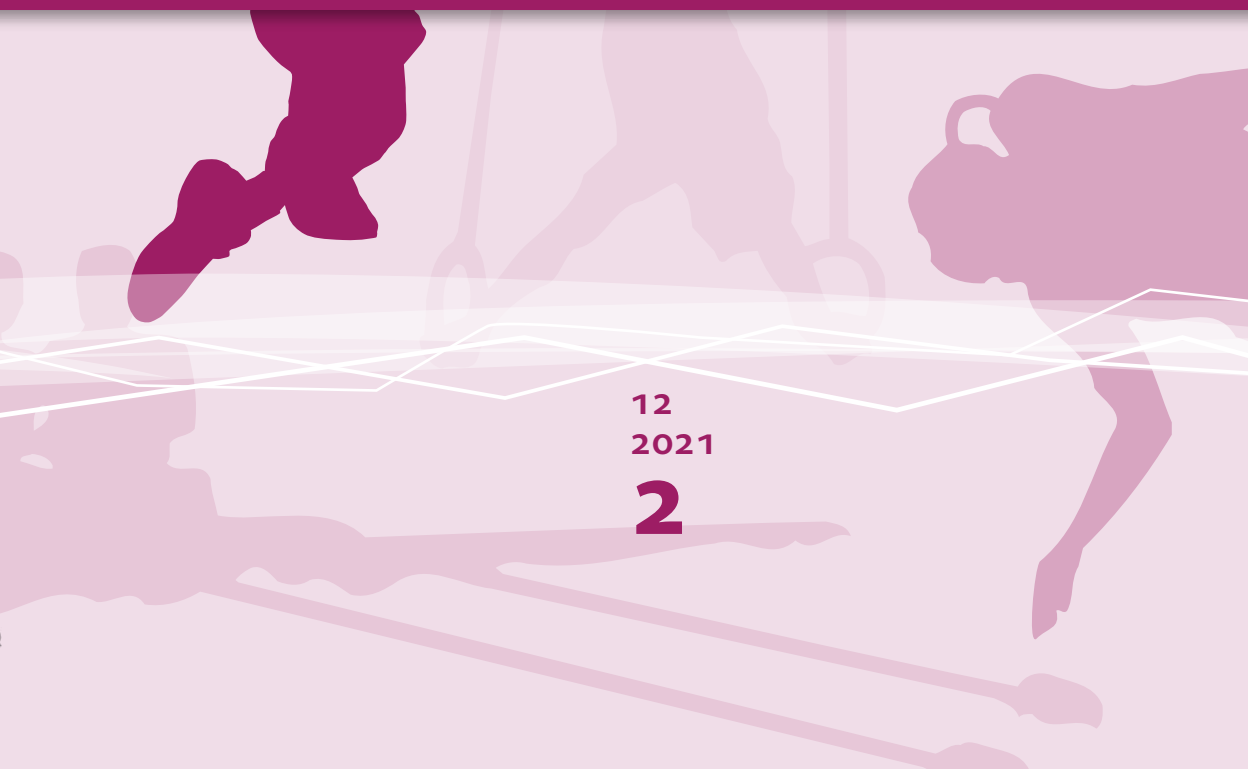

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EDITORIAL

This issue is again marked by the impact of the COVID-19 pandemic and the related restrictive measures, which is why the authors examine the possibility of curative exercise with aids that can ease the effort of exercise, especially for lung patients. Unfortunately, research often does not provide immediate answers and it takes time, new measurement protocols, new subjects, etc. to translate scientific findings into practice. It is this new, unexpected experience with the coronavirus disease that continues to raise new questions in all fields. Due to its preventive, rehabilitative and curative aspects, kinesiology is one of the applied sciences, alongside medicine, that needs to find answers as quickly as possible.

Competitive sport is also no exception. The knowledge that certain physiological parameters of the athlete can be influenced by non-invasive procedures, personalised training and specific dietary regimes is very useful for coaches and athletes. In this journal, the authors discuss how body mass manipulation and a specific high-intensity training routine in wrestling can influence grip strength, and how certain anthropometric and motor parameters are related to the competitive performance of young alpine skiers. As an aid to training routines and general monitoring of an athlete's development, applied knowledge once again demonstrates that it can significantly contribute to peak performance, in addition to talent and external factors.

That knowledge becomes latent in one's own behaviour and that habits of an active and healthy lifestyle remain lifelong companions if they are introduced early enough in the form of regular and organised physical/sporting activity in childhood is the finding of a longitudinal study that concludes the scientific contributions of this issue.

We are also pleased to present some of the activities of the Institute for Kinesiology Research of the Science and Research Centre Koper. The live workshop on sports injuries in young athletes and the international scientific and specialist conference Child in Motion, which both saw a high attendance, confirm their relevance in the professional and scientific arena.

In conclusion, we pledge to continue our efforts in future editions to pursue the journal's mission and to present answers to current issues. Clearly, the impact of the pandemic will continue to accompany and fuel research momentum, and the need to raise awareness of the syndemic effects of the COVID-19 pandemic among the professional community is already becoming apparent. The effects of the pandemic will continue to be present in all aspects of our lives for quite some time, and kinesiologists and experts in related disciplines will continue to be forced to play an important role in the "battle" to stay healthy.

Saša Pišot, PhD,
Editor

UVODNIK

Tudi tokratno številko zaznamujejo izkušnje omejitvenih ukrepov in posledic pandemije covida-19, zato se avtorji sprašujejo o mogoči kurativni vadbi s pripomočki, ki bi predvsem pljučnim bolnikom olajšali napor pri vadbi. Raziskave žal velikokrat ne prinašajo takojšnih odgovorov in potreben je dodaten čas, nov merski protokol, novi subjekti ipd., da se znanstveni izsledki lahko prenesejo v prakso. Prav ta nova, nepričakovana izkušnja s koronavirusno boleznijo še vedno odpira nova vprašanja na vseh področjih. Kineziologija je zaradi svojega zdravstvenega preventivnega, rehabilitacijskega in kurativnega vidika poleg medicine med tistimi uporabnimi vedami, ki morajo kar najhitreje poiskati odgovore.

Tudi vrhunski šport ni izjema. Zavedanje, da je na določene fiziološke parametre športnika mogoče vplivati z neinvazivnimi posegi, prilagojeno vadbo in določenimi prehranskimi režimi, je dobrodošla podpora trenerjem in športnikom. Kako lahko manipulacija telesne mase in poseben visoko intenziven vadbeni režim pri rokoborcih vplivata na moč stiska ter kako so določeni antropometrični in motorični parametri povezani s tekmovalno uspešnostjo mlajših alpskih smučarjev, odkrivajo avtorji v reviji, ki je pred vami. Uporabno znanje kot pripomoček pri vadbenih režimih in splošnem spremljanju športnikovega razvoja ponovno kaže, da lahko poleg talenta in zunanjih dejavnikov pomembno prispeva k vrhunskemu rezultatu.

Da postane znanje latentno v lastnem vedênju, da navade aktivnega in zdravega življenjskega sloga ostanejo vseživljenjske spremljevalke, če so »sprožene« dovolj zgodaj v obliki redne in organizirane gibalne/športne aktivnosti v otroštvu, je ugotovljeno v longitudinalni raziskavi, ki končuje znanstvene prispevke te številke.

Veseli nas, da lahko predstavimo tudi nekaj dejavnosti Inštituta za kineziološke raziskave ZRS Koper. V živo izpeljani delavnici o športnih poškodbah mladih športnikov ter mednarodni znanstveni in strokovni konferenci Otrok v gibanju, obe z zavidljivim odzivom, potrjujeta svojo pomembnost v strokovnem in znanstvenem prostoru.

Ob koncu še zaveza, da si bomo tudi v prihodnjih letnikih prizadevali slediti ciljem poslanstva revije in predstavljali odgovore na aktualne probleme. Očitno bodo izkušnje in posledice pandemije še naprej spremljevalke in vzvod za dodaten raziskovalni zagon, ob tem pa se že kaže nuja po ozaveščanju strokovne javnosti o t. i. sindemičnih učinkih pandemije covida-19. Ti bodo še lep čas prisotni na vseh področjih našega življenja, strokovnjaki kineziologije in sorodnih ved pa bodo še naprej prisiljeni imeti pomembno vlogo v »boju« za ohranjanje zdravja.

Dr. Saša Pišot,
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THE EFFECT OF PHONATED BREATHING ON OXYGEN UPTAKE DURING AND AFTER SUBMAXIMAL CYCLING

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ABSTRACT

Purpose: *Positive expiratory pressure (PEP) exhalation during exercise is reported to improve body adaptation to exercise and enhance the exercise tolerance in patients with chronic obstructive pulmonary disease. Wearing mouthguards results in lower oxygen consumption and increased performance by increasing PEP in athletes. Airway resistance during expiration can be manipulated by phonation. Thus, the aim of our study was to examine the effects of phonated breathing on cardiopulmonary adaptation to moderate exercise and subsequent recovery.*

Methods: *26 young healthy participants conducted the same moderate steady cycling protocol using three different breathing patterns: spontaneous breathing (BrP1), phonated breathing pronouncing the sound "h" (BrP2) and phonated breathing pronouncing the sound "sh" (BrP3). Heart rate, oxygen consumption, CO_2 production, respiratory rate, tidal volume, respiratory exchange ratio and ventilatory equivalents were measured (Cosmed, Italy) before, during and 20 minutes after cycling. Data were analyzed using SPSS, with significance level $p<0.05$.*

Results: *The analysis revealed no significant differences related to the breathing economy; respiratory rate was increased, and tidal volume decreased with spontaneous breathing compared to both phonated breathing patterns during exercise; no effect of BrPs on cardiopulmonary parameters was found in recovery.*

Conclusion: *Our results do not confirm the assumption that PEP breathing improves exercise economy probably because of the low exercise intensity applied. Further studies should be conducted at higher exercise loads or in patients with pulmonary dysfunction.*

Keywords: *phonated exhalation, breathing pattern, positive expiratory pressure, metabolic efficiency, moderate exercise*

VPLIV DIHALNEGA VZORCA NA VENTILACIJO IN PRIVZEM KISIKA MED IN PO SUBMAKSIMALNI VADBI NA SOBNEM KOLESU

IZVLEČEK

Cilj: *Izdih s pozitivnim tlakom (PEP) izboljša zmožnost fiziološke prilagoditve na napor ter vadbeno toleranco pri bolnikih s kronično obstruktivno pljučno boleznijo. Nošenje ustnih varoval, ki prav tako povečale upor v dihalnih poteh, zmanjša porabo kisika in poveča zmogljivost športnikov. Upor v dihalnih poteh lahko spreminjamo s fonacijo. Tako je namen naše raziskave ugotoviti, ali fonacija med zmerno telesno vadbo vpliva na spremembe srčnih in dihalnih parametrov med in po taki vadbi*

Metode: *26 mladih prostovoljcev je trikrat izvedlo enako zmerno kolesarjenje, vsakič ob uporabili drugačnega dihalnega vzorca (DV): spontano dihanje (DV1) in izdih ob izgovarjanju glasu H (DV2) oziroma Š (DV3). Pred, med in 20 minut po vadbi smo merili srčno frekvenco, porabo kisika, izločanje ogljikovega dioksida, frekvenco in volumen dihanja, pljučno ventilacijo, respiratorni količnik in ventilacijske ekvivalente z metabometrom Cosmed. Podatke smo obdelali s programom SPSS in postavili mejo signifikantnosti pri $p<0,05$.*

Rezultati: *Analiza rezultatov ni pokazala nobenih statistično značilnih sprememb metabolnih parametrov, kakor tudi ne srčne frekvence z ozirom na uporabljen DV. Značilno povečana je bila le frekvenca dihanja in zmanjšan dihalni volumen pri spontanem dihanju glede na oba s fonacijo povezana DV med naporom. V okrevanju po naporu ni bilo nobenih razlik v merjenih parametrih.*

Zaključek: *Rezultati naše študije niso potrdili domneve, da dihanje s PEP, ki ga povzročimo s fonacijo, poveča učinkovitost telesne vadbe, zmanjša porabo kisika in izboljša telesno zmogljivost vendar ocenjujemo, da je bila intenziteta vadbe v naši študiji premajhna, da bi se tovrstne razlike izkazale. Zato bi bilo treba opraviti še nadaljnje raziskave in sicer z večjo obremenitvijo pri zdravih preiskovancih ali pa na bolnikih z respiratorno motnjo.*

Ključne besede: *fonacija, dihalni vzorec, pozitivni tlak v dihalnih poteh med izdihom, metabolna učinkovitost, zmerna vadba*

INTRODUCTION

Breathing patterns (BrP) differ according to breathing frequency, breathing depth, inhalation/exhalation time relationship, and maneuvers applied during expiration (Dallam & Kies, 2020). Expiratory maneuvers are particularly important since changing the resistance of the airways upon expiration can help maintain a positive pressure until the end of exhalation, thus keeping the alveoli and airways open (Francis & Brasher, 1991) longer during the exhalation period. Phonation requires sustained/controlled exhalation. During speech and singing, breath duration and flow rates are controlled to support sound generation by the larynx (Lewis et al., 2021). Regulation of the glottic aperture by laryngeal muscle activity also helps to control ventilation (Lewis et al., 2021). Therefore, the larynx could be considered a key modulator of expiratory flow upon phonation. Pronunciation of different voices can be used to change the resistance in the airways during exhalation (Hoffmann, Torregrosa, & Bardy, 2012). Grunting has been shown to improve force production during exercise (O'Connell et al., 2016).

In elite sports, there is a continuous search for strategies to improve performance (Harbour, Stöggl, Schwameder, & Finkenzeller, 2022). On the other hand, in patients with compromised breathing, strategies to minimize breathing effort during exercise would be appreciated to allow these patients to minimize the exercise associated discomfort (Fagevik Olsén, Lannefors, & Westerdahl, 2015). The way we breathe strongly affects not only the respiratory system itself but also other systems in our body: cardiovascular, nervous, endocrine, lymphatic, immune, digestive (Saoji, Raghavendra, Madle, & Manjunath, 2018).

To manipulate exhalation, pursed lip breathing (Tiep, Burns, Kao, Madison, & Herrera, 1986), specially designed mouthguards (Lässing et al., 2021) or simply phonation of some particular voices could be applied during exercise to increase the airways resistance during exhalation. By breathing out against increased resistance, positive expiratory pressure (PEP) is achieved and it is commonly believed that PEP improves ventilation, at least in patients with pulmonary diseases (Fagevik Olsén & Westerdahl, 2009; Fagevik Olsén , Lannefors, & Westerdahl, 2015), and potentially during exercise (Phimphasak, Ubolsakka-Jones, & Jones, 2018).

There are only a few studies about the effects of BrP on the physiological response to exercise (Green, Benson, & Martin, 2018; Lässing et al., 2021). Our recent study (Klanjšček, 2018) found that BrPs with increased expiratory resistance had a significant favorable effect on the economy of short-lasting trunk stabilization exercise. Expiratory resistance was manipulated by pronouncing different sounds during exercise (Klanjšček, 2018) – sound “sh” (as in push to increase resistance, and “h” (as in host) to decrease it – and compared to spontaneous breathing. Oxygen consumption and carbon dioxide production decreased during short-lasting trunk stabilization exercise in the “sh” breathing pattern compared to the “h” breathing pattern and spontaneous breathing. Additionally, the respiratory quotient, ventilation, and heart rate during exercise decreased while ventilatory equivalents increased in the “sh” pattern compared to the “h” pattern and spontaneous breathing. The participants

perceived the "sh" pattern to be significantly easier compared to the other two BrPs (Klanjšček, 2018).

Thus, we aimed to test whether the BrP where exhalation is manipulated by pronouncing different sounds during exercise affects the physiological response to aerobic exercise. To this purpose, the heart rate, oxygen consumption, CO2 production, and ventilation were measured before, during and after moderate cycling at constant load using the three different BrPs: the pronunciation of "sh" or "h" during exhalation, and spontaneous breathing. Crossover design was used to avoid differences between participants.

METHODS

The study was performed in the Exercise Physiology Laboratory of the Institute of Physiology, Medical Faculty, University of Ljubljana. Ethical approval of the study was obtained from the National Ethics Committee (No. 0102-326 / 2018/5).

Subjects

26 healthy participants with comparable levels of physical activity were recruited by public invitation to participate voluntarily in this crossover study. Their physical examination and histories revealed no autonomic dysfunction, chronic diseases, medication usage or smoking. Their ECG and arterial blood pressure values were normal. Written informed consent was obtained before participation. The trial included 18 women and 8 men, 20.85 ± 0.2 years old, with body mass index (BMI) 22.97 ± 0.59 kg/m^2.

Experimental procedure

The study was carried out in a climate controlled laboratory room between 9 and 12 am. The participants refrained from physical exertion for at least 1 day before the first exercise test and were asked not to perform additional physical activities during the experiment period. They were not allowed to consume any alcohol, caffeine or tobacco for at least 2 hours before the beginning of each exercise test and were asked to eat a light meal 1 hour before coming to the laboratory. Each participant visited the laboratory 3 times in February and March with at least one relaxing day between the two consecutive visits. During the three visits, participants performed the same submaximal aerobic cycling with different BrPs during exercise. The BrP applied during a particular visit was chosen randomly and marked BrP1 for spontaneous breathing and BrP2/BrP3 for exhaling upon pronouncing "h"/"sh", respectively.

Each session started with blood pressure measurement at sitting rest and an explanation of the breathing technique for the selected BrP. A silicone breathing mask was

placed upon the mouth and nose (Quark, Cosmed, Italy) to measure oxygen consumption, CO_2 production, and ventilation; ECG electrodes and a finger cuff for continuous blood pressure tracing were attached (Finapres 2300, Ohmeda, USA). The measurement consisted of 5 minutes sitting at rest on a cycloergometer Ergoselect 100 (Ergoline, Germany) (baseline), 5 minutes of cycling at 100 W (women) and 140 W (men), respectively, at a cadence of 60 rpm and followed by 10 minutes of passive recovery. During cycling, a randomly selected BrP was applied.

Data acquisition and statistical analysis

Signals were captured simultaneously breath by breath using Quark CPET hardware and software (Cosmed, Italy); arterial blood pressure and ECG were recorded by DATAQ system (DATAQ instruments Inc., DI-720 series, Ohio, USA). For analysis, three separate intervals were determined: the last three minutes of sitting rest (baseline), the last three minutes of cycling (exercise), and the last three minutes of recovery (recovery). Oxygen consumption per body mass (VO_2/kg), CO_2 production per kg (VCO_2/kg), respiratory exchange ratio (RER), ventilator equivalents (Veq for O_2 and CO_2), respiratory rate (RR), tidal volume (VT), and heart rate (HR) were determined. The data are presented on graphs as mean values ± standard deviation (SD). Additionally, enhanced post-exercise oxygen consumption (O_2 debt) and oxygen deficit (O_2 deficit) at the onset of exercise were determined using Quark CPET analyzing software (Cosmed, Italy) based on the work of Hughson and Morrissey (Hughson and Morrissey 1983).

Statistical analysis was completed using IBM SPSS Statistics, version 27 (IBM, New York, USA). Data were tested for normality and a $p<0.05$ level of confidence was selected. We compared mean differences in measured parameters over time (before and during exercise + recovery) for all three BrPs with a one-way repeated measures ANOVA (rANOVA). The assumption of sphericity was checked using Mauchly's test; Greenhouse-Geisser or Huynh-Feldt corrections were applied when sphericity assumption was violated as published elsewhere (Hopkins, Marshall, Batterham, & Hanin, 2009). When detecting a significant time effect, corresponding contrast tests were used to identify differences between means according to BrP and time interval. For post hoc comparisons a least significant difference test was applied and the Bonferroni correction was used to eliminate type I error in multiple comparisons (Hopkins et al. 2009). In case of significant differences, Cohen's d was determined to represent the effect size (ES) (Hopkins et al., 2009).

RESULTS

RR increased during exercise in all three BrPs (Figure 1, Table 1), most in BrP1, where the mean value was 22.56 ± 1.1 min^{-1}. RR in BrP1 was significantly higher than in BrP2 ($p < 0.001$) and BrP3 ($p = 0.007$). There were no statistical differences between BrP2 and BrP3 ($p = 0.103$). After exercise, RR dropped as expected, but in the last 3 minutes of recovery it was still higher than the baseline values in all BrPs, but significantly higher only in BrP1 ($p = 0.001$) (Table 1).

Table 1: Effect sizes presented as Cohen's d values for all significant differences.

	RR	VT	VE	RER	VO_2/kg	VCO_2/kg	Veq for O_2	Veq for CO_2
BrP1base/ex	1.59	3.53	6.46	1.34	6.94	6.48	1.50	4.03
BrP1base/rec	0.67	-	1.26	0.80	-	-	0.99	0.60
BrP1ex/rec	1.227	3.42	6.27	0.81	6.71	6.58	2,19	3.23
BrP2base/ex	0.41	3.46	4.00	1.18	6.54	6.59	1.81	2.38
BrP2base/rec	-	-	0.68	-	-	-	0.82	6.82
BrP2ex/rec	0.22	3.54	5.01	1.43	6.69	6.89	2.44	6.89
BrP3base/ex	0.41	3.24	4.42	1.50	7.49	6.76	1.41	2.40
BrP3base/rec	-	0.46	1.10	0.76	-	0.63	1.14	0.63
BrP3ex/rec	0.47	3.23	4.36	0.88	6.55	6.07	1.96	6.37
BrP1ex/BrP2ex	0.72	1.05	-	-	-	-	-	-
BrP1ex/BrP3ex	0.14	0.35	-	-	-	-	-	-
BrP2ex/BrP3ex	-	0.72	-	-	-	-	-	-

BrP1 – breathing pattern 1, BrP2 - breathing pattern 2, BrP3 – breathing pattern 3, base – baseline, ex – exercise, rec – recovery, RR – respiratory rate, VT – tidal volume, VE – ventilation, RER – respiratory exchange ratio, VO_2/kg – oxygen consumption per body mass, VCO_2/kg – carbon dioxide production per body mass, Veq for O_2 – ventilatory equivalent for oxygen, Veq for CO_2 - ventilatory equivalent for carbon dioxide.

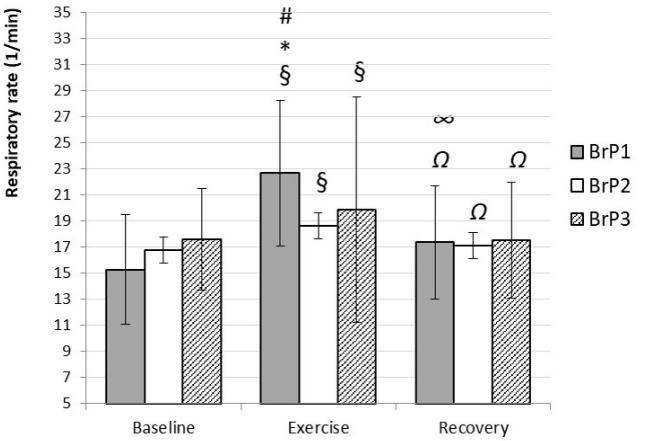

*Figure 1: Changes in RR during rest, exercise and recovery in different BrPs. Values are presented as the mean ± SD. * - significant difference between BrP1 and BrP2, # - significant difference between BrP1 and BrP3, § - significant difference in all BrPs between rest and exercise, Ω - significant difference in all BrPs between exercise and recovery, ∞ - significant difference in all BrPs between rest and recovery.*

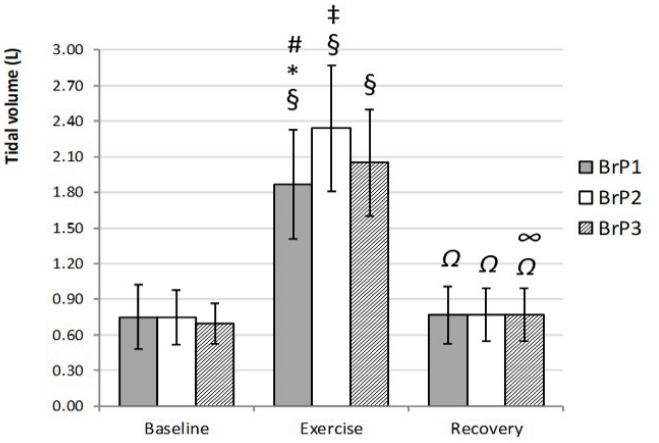

*Figure 2: Changes in tidal volume during rest, exercise and recovery in different BrPs. Values are presented as the mean ± SD. * - significant difference between BrP1 and BrP2, # - significant difference between BrP1 and BrP3, ‡ significant difference between BrP2 and BrP3, § - significant difference in all BrPs between rest and exercise, Ω - significant difference in all BrPs between exercise and recovery, ∞ - significant difference in all BrPs between rest and recovery.*

Figure 2 shows the changes in VT, related effect sizes are presented in Table 1. The value increased the most in the group with BrP2, which had the lowest RR during exercise. We found significant differences between all three BrP; the statistical difference between BrP1 and BrP2 was $p < 0.001$, between BrP1 and BrP3 $p = 0.016$ and between BrP2 and BrP3 $p = 0.002$. As can be seen from Figure 2, the values returned to baseline values at recovery; only in BrP3 did we find a significant difference between baseline and recovery ($p = 0.008$).

During exercise ventilation increased (Figure 3, Table 1), but no significant differences were found between the groups. During the recovery, the values dropped but not to baseline values. Ventilation in recovery was significantly higher compared to baseline ($p < 0.001$ for BrP1 and BrP3, and $p = 0.003$ for BrP2, respectively).

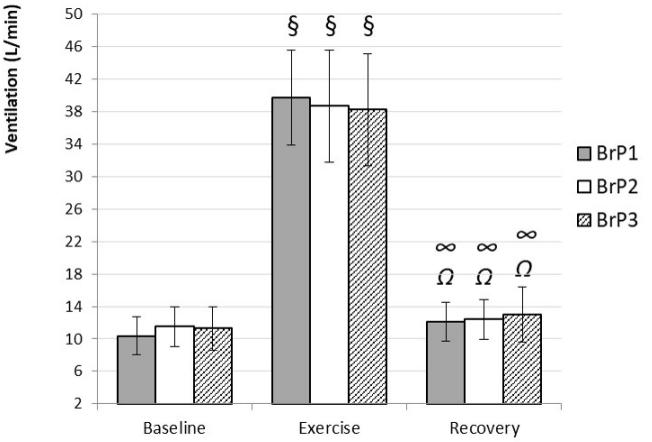

Figure 3: Changes in ventilation during rest, exercise and recovery in different BrPs. Values are presented as the mean ± SD. § - significant difference in all BrPs between rest and exercise, Ω - significant difference in all BrPs between exercise and recovery, ∞ - significant difference in all BrPs between rest and recovery.

Figure 4 shows the changes in RER. No significant differences were found between BrPs; related effect sizes are reported in Table 1. In recovery, the RER remained elevated above the resting value. It was significantly higher in the groups with BrP1 ($p < 0.001$) and BrP3 ($p = 0.001$); in the group with BrP2 we did not find a difference ($p = 0.333$).

As expected, VO_2/kg increased during exercise and remained increased at the end of the measurement (Fig. 5, Table 1). As can be seen from Figure 5, no significant differences were observed with regard to BrPs, neither at rest nor during exercise or recovery.

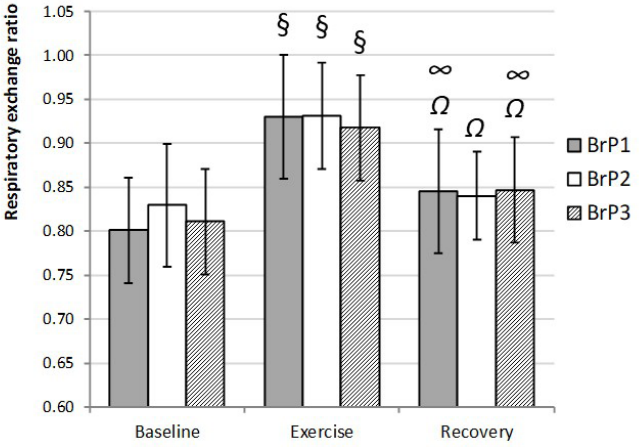

Figure 4: Changes in respiratory exchange ratio during rest, exercise and recovery in different BrPs. Values are presented as the mean ±SD. § - significant difference in all BrPs between rest and exercise, Ω - significant difference in all BrPs between exercise and recovery, ∞ - significant difference in all BrPs between rest and recovery.

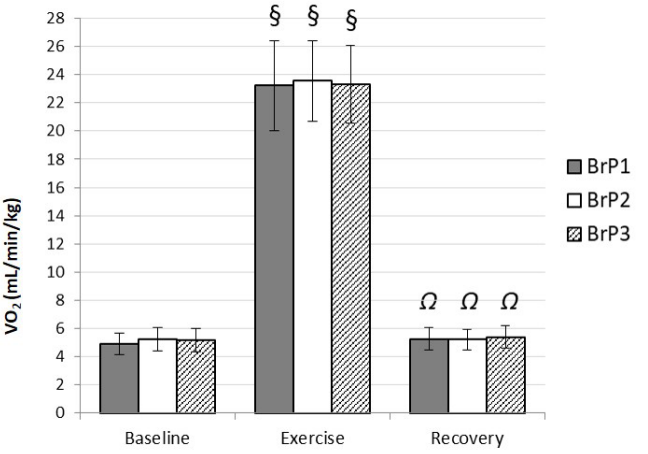

Figure 5: Changes in oxygen consumption during rest, exercise and recovery in different BrPs. Values are presented as the mean ±SD. § - significant difference in all BrPs between rest and exercise, Ω - significant difference in all BrPs between exercise and recovery.

Regarding VCO_2/kg, there were no significant differences between groups during rest and exercise, we did, however, find a significant difference between baseline and recovery in BrP3 ($P < 0.001$) (Fig. 6, Table 1).

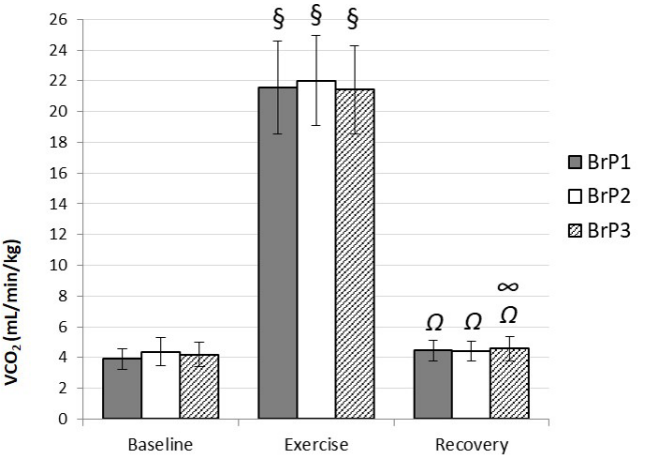

Figure 6: Changes in production of carbon dioxide during rest, exercise and recovery in different BrPs. Values are presented as the mean ± SD. § - significant difference in all BrPs between rest and exercise, Ω - significant difference in all BrPs between exercise and recovery, ∞ - significant difference in a particular BrP between rest and recovery.

Figure 7 presents the change in VEq for O_2. No statistical differences were found between the groups in any of the phases, but a higher value was observed in the BrP2 and BrP3 groups at rest and lower during exercise compared to BrP1. We found a statistical difference between baseline and exercise as well as between rest and exercise with respect to recovery, which was $p < 0.001$ in all BrPs (Table 1).

No significant differences between groups were observed during exercise and recovery in Veq for VCO_2 (Figure 8). Statistical differences were observed between baseline and recovery. In the group with BrP1 the difference was $p = 0.009$; in the group with BrP2 $p = 0.007$; and in the group with BrP3 $p = 0.002$. Veq for CO_2 was significantly increased during exercise compared to rest or recovery ($p < 0.001$) (Table 1).

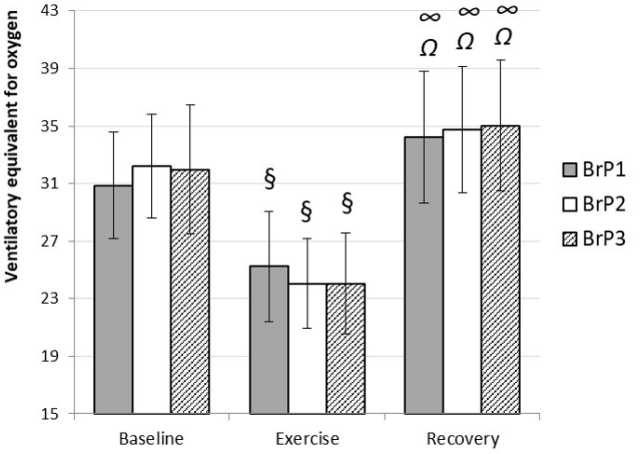

Figure 7: Changes in ventilatory equivalent of oxygen during rest, exercise and recovery in different BrPs. Values are presented as the mean ± SD. § - significant difference in all BrPs between rest and exercise, Ω - significant difference in all BrPs between exercise and recovery, ∞ - significant difference in all BrPs between rest and recovery.

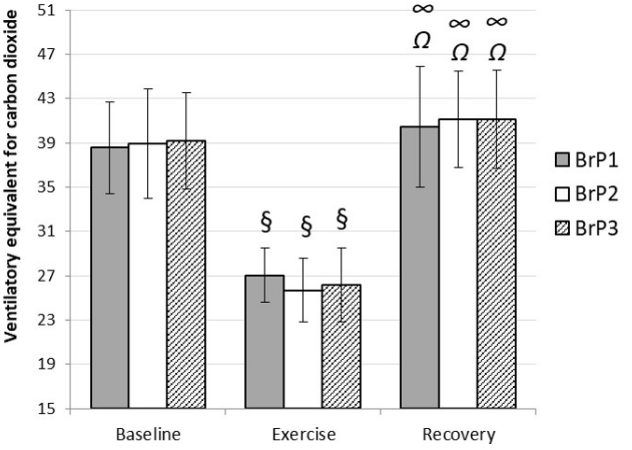

Figure 8: Changes in ventilatory equivalent of carbon dioxide during rest, exercise and recovery in different BrPs. Values are presented as the mean ± SD. § - significant difference in all BrPs between rest and exercise, Ω - significant difference in all BrPs between exercise and recovery, ∞ - significant difference in all BrPs between rest and recovery.

Figure 9 shows O_2 deficit and O_2 debt throughout the three BrPs. O_2 deficit (but not O_2 debt) in spontaneous breathing was significantly higher compared to other BrPs (ES = 0.42 for BrP1 compared to BrP2 and 0.36 for BrP1 compared to BrP3, respectively). O_2 debt was significantly lower compared to O_2 deficit in all BrPs (ES = 0.87 for BrP1, 0.20 for BrP2 and 0.15 for BrP3, respectively).

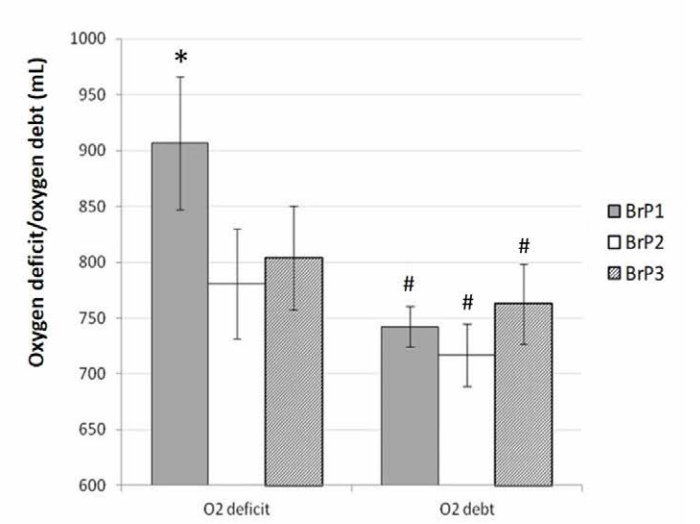

*Figure 9: Changes in oxygen deficit (O2 deficit) and oxygen debt (O2 debt) throughout all breathing patterns: spontaneous breathing (BrP1), pronouncing "h" (BrP2) and pronouncing "sh" (BrP3), respectively. * - significant with respect to BrPs. # - deficit versus debt.*

DISCUSSION

Our first main finding was that phonation during moderate exercise has a minimal effect on the respiratory response to exercise and recovery in young, healthy participants.

Our second main finding was that phonated breathing during moderate exercise provoked an increased rate of perceived exertion compared to spontaneous breathing. And our third main finding was that oxygen deficit at the onset of moderate exercise is significantly higher in spontaneous compared to phonated breathing. On the other hand, EPOC was not affected by BrP, indicating that in a steady state during moderate exercise excessive oxygen deficit was successfully eliminated by aerobic metabolism.

Although not significantly different, evidently lower RER during steady state exercise in BrP3 compared to other BrPs suggested that restricted air flow during expiration may cause CO_2 retention. This assumption was supported by the increased CO_2 exhalation in the recovery phase after exercise (Fig.6) in BrP3. Additionally, during steady state exercise, RR in BrP3 was higher compared to that in BrP2, presumably because of the stimulation of the inspiratory center by increased arterial CO_2 partial pressure. RR during spontaneous breathing was significantly increased compared to those in both BrP2 and BrP3 because of phonation excluding prolonged exhalation. Breathing against increased airway expiratory resistance (pronunciation of "sh") versus open airway expiration (pronunciation of "h") does not appear to alter airway diameter sufficiently to augment the minute ventilation response during moderate exercise. Even upon spontaneous breathing, minute ventilation was not changed compared to phonated breathing patterns.

The similar minute ventilation across all BrPs at steady state moderate exercise corresponding to an oxygen uptake of 23.5 mL/kg/min suggests that all BrPs applied can accommodate a moderate level of exercise intensity in young healthy participants (Plowman and Smith n.d.).

In our study, VO_2 did not differ during moderate physical activity at different BrPs. This finding is not in compliance with our previous study, where the reduced VO_2 in the low-intensity trunk stabilization exercise with hand-oscillation was confirmed upon phonated exhalation while pronouncing "sh" (Klanjšček, 2018). One possible explanation for this could be that the participants breathed in respiratory coupling with locomotion in the previous study. The entrainment could be responsible for better breathing economy (Sporer, Foster, Sheel, & McKenzie, 2007). Further, VO_2 was measured at the onset of trunk stabilization exercise in our previous study and not during the steady state, and thus was accompanied by anaerobic metabolism. When substituting anaerobic metabolism with aerobic in the continuation of trunk stabilization exercise, the differences in VO_2 between different BrPs decreased. This could imply that as the exercise is aerobic, the beneficial effects of PEP exhalation are decreased.

The association between anaerobic metabolism and breathing economy in connection to the use of a mouthguard was established (Schulze, Kwast, & Busse, 2019). The results of the studies examining the effect of different mouthguards on athletes' performance concluded that the economy of breathing is improved by wearing mouthguards at high but not moderate exercise intensities (Lässing et al., 2021; Schulze et al., 2019). The mechanism proposed is altered exhalation, potentially against higher resistance produced by mouthguards (Schulze et al., 2019). The impact of breathing using mouthguards is being researched in connection with sports that due to their nature need this type of protection (such as rugby and hockey) (Phimphasak et al., 2018; Schulze et al., 2019). Studies including young healthy athletes have found that altered exhalation due to wearing this equipment reduces the proportion of anaerobic metabolism at high-intensity exertion, compared to unmodified exhalation when not wearing it (Lässing et al., 2021). Francis and colleagues (Francis & Brasher, 1991) described reduced VO_2 and VEq for O_2 upon mouthguard usage at high-intensity exercise

but not at low-intensity exercise. Since we did not confirm the beneficial effect of BrP3 in our study, we may speculate again that the beneficial effect of phonated expiration is limited to predominantly anaerobic or high-intensity load. Additional investigations should be conducted to test this assumption.

Phonated exhalation can be compared to breathing with pursed lips. There are some articles about the effects of pursed lip breathing on the breathing load, but only researched in patients with impaired pulmonary function (Sakhaei, Sadagheyani, Zinalpoor, Markani, & Motaarefi, 2018). Sakhaei and colleagues (Sakhaei et al., 2018) found that in patients with COPD, oxygenation and CO_2 excretion improve – as respiratory work is reduced - upon PEP provoked by pursed lips, while De Araujo (Pereira De Araujo, Karloh, Martins Dos Reis, Palú, & Fleig Mayer, 2015) and colleagues found that this type of breathing reduces dynamic hyperinflation, improving tolerance for exercise and O_2 saturation in the blood during exercise in COPB. Breslin (Breslin, 1992) found that spontaneous rhythmic breathing through pursed lips can affect the coordination of respiratory muscle recruitment and provides patients with a sense of control over ventilation, which results in less anxiety, panic, and consequently reduces dyspnea. Exercise in healthy participants can be seen as a model of impaired pulmonary function, as it increases the load on the respiratory system due to increased need for O_2 and produces more CO_2. Based on our results we can conclude that the intensity of moderate exercise applied in our study was not high enough to reveal the advantages of PEP breathing during exercise in young healthy adults. The physiological effects of phonated breathing in COPB patients should be examined to determine the potential benefits of phonated exhalation (decrease exercise respiratory load and perceived exertion) during exercise in such patients.

We found a significantly increased O_2 deficiency at the onset of moderate exercise upon spontaneous breathing compared to both phonated breathing patterns, indicating that spontaneous respiration was the least economical at the onset of exertion. On the contrary, the EPOC did not differ with regard to BrP. This finding supports our speculation that beneficial effects of breathing against increased airway expiratory resistance, as in the pronunciation of "sh", are manifested only when exercise metabolism is preferentially anaerobic. EPOC is decreased compared to O_2 deficit at spontaneous breathing, presumably because the products of anaerobic metabolism were removed and aerobically metabolized during steady state exercise due to its low intensity. O_2 deficit and EPOC did not differ with respect to the sound pronounced. Further studies should be directed to explain this finding.

Bonsignore and colleagues (Bonsignore, Morici, Abate, Romano, & Bonsignore, 1998) chose the VEq for O_2 and CO_2 as the main measure of respiratory efficiency. In our study, we found that both VEq for O_2 and CO_2 decreased during physical exertion compared to baseline, indicating that moderate exercise made the respiration more efficient (Plowman & Smith, n.d., 2013); and there were no significant differences between individual BrPs. Differences were indicated, yet not significant: both VEq upon BrP2 and BrP3 during exercise were lower than during spontaneous respiration. These observations can be linked to a study by Francis and Brasher (Francis & Brasher, 1991)

who found a lower Veq for O_2 in subjects wearing mouthguards, indicating improved alveolar ventilation and oxygenation that allows an individual to maintain a certain level of exercise with less loss to the metabolic system; and to a study by Delaney and Montgomery (Delaney & Montgomery, 2005), who found that mouthguards obstruct airflow and thus affect VO_2 and ventilation during strenuous exercise. Again, both studies have demonstrated greater breathing efficiency in subjects using mouth protective devices only at maximum load.

There are some limitations to this research: in all participants the same load (140 W for males and 100 W for females) was applied as moderate exercise, neglecting individual differences, and the correctness of breathing pattern implementation was not controlled as the participant's mouth was covered by a breathing mask.

In conclusion, we found no physiological benefits of phonation applied upon moderate exercise that could advocate its use for economizing breathing at higher metabolic demand. However, decreased oxygen deficit at the onset of moderate exercise upon phonated compared to spontaneous breathing confirmed its positive effects on the anaerobic phase at the onset of exercise. This finding may potentially provide benefits for patients with compromised respiratory function owing to an enhanced proportion of anaerobic metabolism even at moderate exercise loads, however, further studies need to be conducted to test this assumption. On the other hand, "sh" pronouncing breathing may provoke CO_2 retention at higher exercise intensities. Because phonated breathing during exercise is an atypical breathing pattern, it is subjectively rated as uncomfortable compared to spontaneous breathing, yet the latter does not differ from phonated breathing with regard to breathing efficiency. It is therefore probable that in athletes exercising at higher loads phonated breathing may potentially provide benefits in terms of attenuating oxygen deficit.

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THE EFFECT OF RAPID WEIGHT LOSS ON THE HANDGRIP STRENGTH OF NATIONAL-LEVEL WRESTLERS

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ABSTRACT

The effects of rapid weight loss (RWL) in combat sports athletes is an area that is not yet fully discovered. Therefore, the goal of this study was to determine the impact of weight loss on HGS (handgrip strength) in Greco-Roman wrestlers.

This cross-over study included ten athletes examined for HGS during three time points for each hand. The first measurement – baseline (BL), was performed before weight reduction. The second measurement – phase 1 (P1), was taken after high-intensity sports specific training (HISST) combined with RWL. In this phase, participants had to lose 5% of their body mass within three days, after which HISST was carried out (on day 3). The third measurement – phase 2 (P2), was performed seven days after P1, which included HISST with no RWL.

When comparing the HGS values, significantly higher values were observed only when P1 was compared with P2 for the left hand (p=0.039). This means that the grip was significantly stronger after RWL was conducted together with HISST.

This research could be of great importance to combat sports coaches and athletes as it evaluates the effect of RWL on performance parameters. Therefore, the results of our study could serve to improve the wrestlers' weight-reduction plan.

Keywords: *Greco-Roman, performance, weight reduction, wrestling*

UČINKI NAGLEGA ZMANJŠEVANJA TELESNE MASE NA MOČ OPRIJEMA PRI REPREZENTANČNIH ROKOBORCIH

IZVLEČEK

Učinki naglega zmanjševanja telesne mase pri športnikih v borilnih disciplinah so področje, ki še ni povsem raziskano. Zato je bil cilj te študije ugotoviti, kako nagla izguba telesne mase vpliva na moč oprijema pri rokoborcih v grško-rimskem slogu.

V pričujočo navzkrižno študijo smo vključili deset športnikov, pri katerih smo preverjali moč oprijema za vsako roko v treh različnih časovnih obdobjih. Prvo meritev – ki je predstavljala izhodišče – smo opravili pred začetkom zmanjševanja telesne mase. Drugo meritev – 1. faza – smo opravili po visokointenzivni športnospecifični vadbi v kombinaciji z naglo izgubo telesne mase. V tej fazi so sodelujoči morali v treh dneh za 5 odstotkov zmanjšati svojo telesno maso, nato pa opraviti visokointenzivno športnospecifično vadbo (tretji dan). Tretja meritev – 2. faza – je bila izvedena sedem dni po 1. fazi in je vključevala visokointenzivno športnospecifično vadbo brez zmanjševanja telesne mase.

Pri primerjavi podatkov o moči oprijema smo občutno višje vrednosti zaznali med rezultati meritev v 1. in 2. fazi za levo roko, saj so slednji pokazali, da se je moč oprijema občutno povečala po zmanjšanju telesne mase v kombinaciji z visokointenzivno športnospecifično vadbo.

Študija, ki meri učinke naglega zmanjšanja telesne mase na parametre zmogljivosti, prinaša pomembne uvide za trenerje in športnike v borilnih disciplinah in bi lahko pripomogla k izboljšanju programov za zmanjševanje telesne mase pri rokoborcih.

Ključne besede: *grško-rimski slog, zmogljivost, zmanjševanje telesne mase, rokoborba*

INTRODUCTION

To be successful in wrestling, an athlete must possess high levels of physical and psychological readiness. Indeed, wrestling is a very demanding and vigorous sport that consists of two 3-minute rounds, with a break of 30 seconds in between (Yoon, 2002). Thus, both aerobic and anaerobic energy systems are taxed during a wrestling match (Nikooie, Cheraghi, & Mohamadipour, 2017). Specifically, the anaerobic system provides explosive and short bursts of maximal power and strength, while the aerobic system is responsible for sustained effort during the match (Demirkan, Koz, Kutlu, & Favre, 2015). Furthermore, wrestling requires highly developed upper-body strength and power, particularly handgrip strength (Gerodimos et al., 2013; Demirkan et al., 2015).

Handgrip strength (HGS) in hand-to-hand combat sports, including wrestling, is essential for movements such as pulling, pushing, throwing and controlling the opponent, which are important determinants of the match outcome (Cronin, Lawton, Harris, Kilding, & McMaster, 2017). Moreover, possessing high HGS and endurance is very important in the later rounds of the match and can influence the continuation or end of the dominance of the opponent (Franchini, Schwartz, & Takito, 2018). Also, HGS is essential in several wrestling holds because various take-down and defensive maneuvers are based on a strong grip (Gerodimos et al., 2013). Indeed, a very strong relationship was recorded between HGS and success in wrestling (i.e., competition ranking) (García-Pallarés, López-Gullón, Muriel, Díaz, & Izquierdo, 2011; Nikooie et al., 2017). Also, elite male wrestlers had stronger handgrip compared to sub-elite wrestlers (Nikooie et al., 2017). It is important to note that both absolute and relative strength was higher in elite than in sub-elite wrestlers, which supports the hypothesis that handgrip can be observed as a determinant of overall strength in athletes (García-Pallarés et al., 2011).

In combat sports, athletes are categorized into weight classes according to their body mass in order to reduce the difference in strength and size of the competitors. The aim of dividing athletes into weight classes is to create equal competition conditions for each athlete (Castor-Praga, Lopez-Walle, & Sanchez-Lopez, 2021). However, in order to drop the weight into a class where an athlete would have an advantage over the lighter and weaker opponent, rapid weight loss is commonly practiced among combat sports athletes (Khodaee, Olewinski, Shadgan, & Kiningham, 2015; Ranisavljev et al., 2022; Todorović et al., 2021). Rapid weight loss (RWL) stands for a method characterized by losing at least 5% of body weight in fewer than seven days prior to competition (Khodaee et al., 2015). However, such large alterations in body weight, although without conclusive scientific evidence, most likely impact athletes' performance. Namely, RWL leads to detriments on anaerobic performance, which is related to reduced glycogen depletion and buffering capacity (Lakicevic et al., 2020). Reduced muscle glycogen can impair excitation-contraction coupling in the muscle and accelerate the onset of muscle fatigue, which can reduce exercise performance (Ørtenblad, Westerblad, & Nielsen, 2013). Recent studies revealed that RWL leads to significant muscle damage in combat sports athletes and impairs heart rate recovery in national-level wrestlers (Roklicer et al., 2020; Roklicer et al., 2022).

To the best of the authors' knowledge, no study has examined the influence of RWL combined with HISST on HGS in wrestlers. Thus, the aim of this study was to determine the impact of RWL on HGS in wrestlers.

METHODS

Participants

This cross-over study was carried out on a total of 10 male national level Greco-Roman wrestlers (22.44 ± 4.53 years; mean body weight: 73.36 ± 4.42 kg; mean body height: 174.43 ± 3.78 cm). To be included in the experiment, wrestlers had to have at least five years of competitive experience. Additionally, participants were eligible only if they had used RWL methods within the previous two years. Participants were free of injury at the time of the testing. The procedures were fully explained to the participants before conducting the study. Each respondent participated voluntarily by signing the informed consent. Body composition parameters were measured using a body composition analyzer (Omron BF511, Omron Healthcare Ltd., Matsusaka, Japan).

All procedures were carried out in accordance with the Declaration of Helsinki. The study was approved by the ethical board of the University of Novi Sad, Serbia (Ref. No. 46-06-02/2020-1).

Experimental Approach to the Problem

Handgrip strength was measured at three time points. The first measurement – (BL) was conducted before the weight reduction. The second measurement – Phase 1 (P1), was done after the high-intensity sport-specific training (HISST) combined with RWL. For this phase, participants had to lose 5% of their body mass within three days, after which the HISST was carried out (on day 3). The third measurement – Phase 2 (P2), was carried out seven days following P1 and included HISST (after which the measurements were done) with no RWL.

Isometric Handgrip Strength

The maximum grip strength was measured for both hands with a Takei portable dynamometer (Takei Scientific Instruments Co., Tokyo, Japan). Participants stood with the abducted shoulder. The dynamometer was previously adapted to the size of the participant's hands and held with the arms parallel to the body without squeezing/attaching the arm against the body. The position of the hand remained constantly downwards, and the palm did not bend at the wrist joint. Subjects were asked to do a maxi-

mum voluntary contraction on the dynamometer for 5 seconds. All subjects performed three trials for each hand, and the best performance was used for further analysis.

Statistical Analysis

The results are presented as mean and standard deviation. The normality of the distribution was determined by the Shapiro-Wilks test. To compare the means between the handgrip strength measurements, One Way ANOVA for repeated measures with LSD post hoc analysis was conducted. All statistical procedures were done using IBM SPSS Statistics for Windows, 20.0 (IBM Corp 20, Armonk, NY, USA). The significance level was set at $p \leq 0.05$.

RESULTS

The wrestlers' characteristics are presented in Table 1. According to the results obtained, statistically significant differences were observed across the three time points. The values obtained in P1 were significantly lower for body weight, BMI, FM, and VBF, while muscle mass increased significantly compared to the baseline measurement. The results in P2 were significantly higher for body weight, BMI, FM, and VBF, while muscle mass was significantly lower in this phase compared to P1. Basal metabolic rate was not significantly different across the three time points.

Table 1. Descriptive characteristics of body composition of wrestlers (n=10)

	BL	P1	P2
Body weight (kg)	73.36±4.42	69.27±4.12*	72.38±4.17#
BMI (kg/m2)	24.11±0.96	22.62±0.98*	23.64±1.07#
FM (%)	16.37±2.22	12.74±3.15*	14.98±2.47#
MM (%)	42.51±1.41	44.64±2.14*	43.36±1.71#
VBF (%)	6.11±1.05	4.88±1.16*	5.66±1.32#
Basal metabolic rate (kcal)	1717.33±64.98	1677.11±61.49	1704.11±56.43

Values are presented as mean and standard deviation (M±SD); BL – baseline values; P1 – phase one: HISST combined with RWL; P2 – phase two: HISST with no RWL procedures included; BMI – Body mass index (kg/m2); FM – Fat mass (%); MM –muscle mass (%); VBF – Visceral body fat (%); statistically significant difference compared to baseline values, p≤0.001; # statistically significant difference compared to P1, p≤0.01.*

The handgrip strength values for both hands are presented in Table 2. Although the higher values for the right hand are visible in P1 and P2 in comparison to the baseline, the difference remained statistically insignificant. As for the left hand, similar values were obtained during BL and P2. However, according to LSD pairwise comparisons, significantly higher handgrip strength was observed in P1 only when compared to P2, p=0.039 (Figure 1).

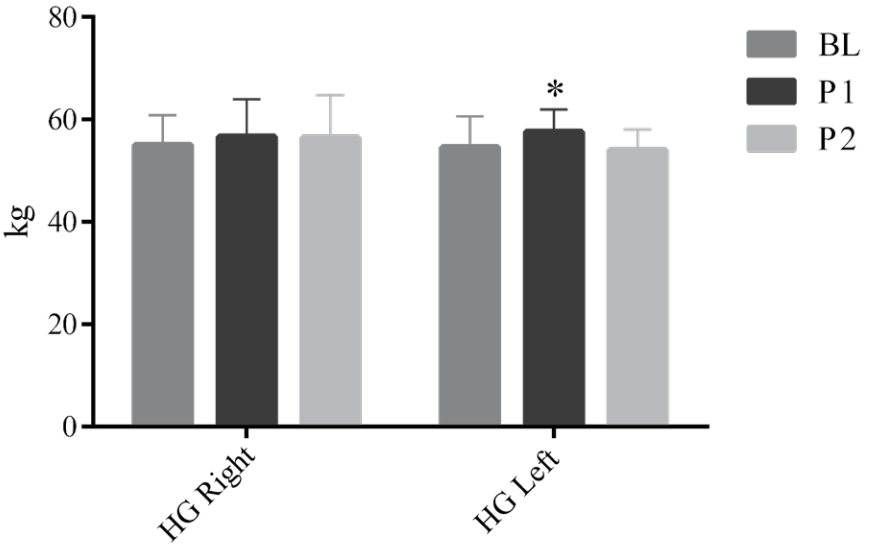

Figure 1. Handgrip strength differences in Greco-Roman wrestlers.

*Legend: * - significantly different compared to P2 (left handgrip) p<0.05; BL – baseline measurement; P1 – phase one: HISST combined with RWL; P2 – phase two: HISST with no RWL procedures included; HG – right and left handgrip strength; kg – kilograms.*

Table 2. Handgrip strength of wrestlers.

	BL	P1	P2	F	p	Partial Eta squared
HG right (kg)	55.55 ±5.81	56.66 ±7.28	56.44 ±8.35	0.104	0.857	0.013
HG left (kg)	54.55 ±6.06	57.55 ±4.44*	54 ±4	1.845	0.199	0.187

*Values are presented as mean and standard deviation (M±SD); BL – baseline values; P1 – phase one: HISST combined with RWL; P2 – phase two: HISST with no RWL procedures included; F – F ratio; HG right – right-hand handgrip strength; HG left – left-hand handgrip strength; *statistically significantly different compared to P2 according to post hoc pairwise comparisons, p≤0.05.*

DISCUSSION

To the author‘s knowledge, this is the first cross-over design study that analyzes the impact of combining RWL with HISST and HISST alone on HGS performance in national-level Greco-Roman wrestlers. The obtained results demonstrated changes in HGS values in the phase when body weight reduction was implemented. Maximum grip strength production significantly increased only for the left hand of the athletes. There are not many previous studies examining the influence of RWL on HGS in wrestlers. Research conducted on elite wrestlers showed a decrease in HGS performance after applying RWL (Jlid, Maffulli, Elloumi, Moalla, & Paillard, 2013). On the other hand, weight loss failed to alter the HGS values in college wrestlers (Serfass, Stull, Alexander, & Ewing Jr., 1984; Marttinen, Judelson, Wiersma, & Coburn, 2011). In contrast to the results of these studies, this research reported a positive effect of RWL on HGS values. Isometric strength production was higher for the left hand during the combined phase of RWL with HISST compared to values observed in P2. The average HGS performance of the right hand was also increased, albeit without statistical significance. Several possible mechanisms may explain these findings. Athletes have probably experienced psychological arousal due to reaching the target weight for the category in which they intend to compete, which potentially leads to improved strength performance. Additionally, changes in body composition may be related to the results shown. The increase in muscle mass, as well as the decrease in FM and VBF during the application of RWL, are probably responsible for the positive alterations in HGS values. Due to the already mentioned importance of HGS in separating more successful wrestlers from less successful ones, coaches and athletes could probably implement RWL before the competition. Of course, the weight loss process must be conducted with some caution due to the negative impact on other health aspects of athletes. Future studies on larger

samples are needed to clearly understand the results obtained in this study. In combat sports, the link between weight loss and HGS has been most investigated in judo. As in wrestling, the previous findings are inconsistent. Some studies have reported that RWL reduces HGS values in judo athletes (Degoutte et al., 2006; Clarys, Ramon, Hagman, Deriemaeker, & Zinzen, 2010; Isacco et al., 2020). However, the weight loss did not change the HGS performance of the left hand in national level judokas (Filaire et al., 2001). Additionally, weight reduction did not affect the maximal isometric strength in Czech judokas, although marginally higher average HGS values were observed for both the left and right hand after the RWL period (Coufalová, Cochrane, Maly, & Heller, 2014). The results are also in conflict in Mixed Martial Arts (MMA). Camarço et al. (2016) failed to find alterations in HGS values after RWL was applied. Contrary, RWL significantly decreased HGS performance in amateur MMA fighters (Alves et al., 2018). All studies demonstrated a negative or no effect of RWL on HGS values in combat athletes. Only the results of our research showed a positive impact of RWL on HGS performance. The cross-over design of the presented study may be a factor that contributed to the final outcome. Some of the future research could focus on the influence of RWL on HGS in combat sports like sambo, taekwondo, or boxing. Finally, this study has several relevant limitations that should be mentioned. First, the study was conducted on a relatively small sample . Second, the respondents were national-level wrestlers. Participants' hand dominance was not reported prior to testing. Future studies should monitor glycogen and various inflammation and muscle damage levels along with subjective levels of physical and/or mental arousal. Additionally, future studies should investigate the impact of RWL on HGS values in elite wrestlers. Finally, athletes were free to choose weight loss methods. Hence, wrestlers most likely used different techniques of RWL.

CONCLUSION

The aim of this study was to determine HGS in national-level wrestlers. Particularly, the impact of RWL on the handgrip strength was measured during baseline and two different phases – P1 and P2. Comparing the HGS values, a significant difference was observed only when P1 was compared to P2 for the left hand. Specifically, the handgrip was stronger after RWL was included along with HISST. This phenomenon may be interpreted as psychological arousal of athletes who have attained the target weight for a certain category they tend to compete in. This research could be of great importance for combat sports coaches and athletes as it evaluates the effect of RWL on performance parameters. Although further studies on this matter would be of great importance, the findings of our study might serve to improve the wrestlers' weight reduction plan.

Conflict of Interest

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

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CORRELATIONS BETWEEN MOTOR AND ANTHROPOMETRIC VARIABLES AND THE PERFORMANCE OF YOUNG COMPETITORS IN ALPINE SKIING

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ABSTRACT

In alpine skiing we encounter many factors that affect the competitor to a greater or lesser extent and must be overcome or exploited in various ways. Broadly speaking, the nature of the activity plays its role just like the equipment, the spectators, the coach, etc., but the most important role is played by the competitor himself. Optimal synthesis is required for successful participation of top competitors with regard to physical, psychological and social skills and characteristics.

During the transformation process (training) we help the competitor with different methods and means to transform from the initial to the final state, which is basically conscious transformation of numerous skills and characteristics of the competitor with impact on their personality as well.

In this study we wanted to establish the extent to which certain anthropometric and motor skill parameters are related to competitive performance of younger boys aged 12 to 13 years in the Rauch Cup in the season 2014/15. Based on the measurements of seven tests of motor skills (MSKOK10 – Ten jumps with both feet, TESJCAS – Squat jump, MS20NVZP – 20m sprint, TREAOPTO – Optojump – Squat jump, MT400 – 400m run, MROS - Equilibrium stability index, and SKI9 – Figures-of-eight around 9 pins) and one measurement of anthropometric dimension (ABMI - Body Mass Index), we used the Pearson correlation coefficient to determine the correlation between individual variables and the performance of a sample of 34 young competitors in alpine skiing. The correlation of the whole set of variables regarding performance was determined using regression analysis. We have established a statistically significant correlation between the number of

achieved points and variables MSKOK10, MS20NVZP, MT400 and SKI9 at the risk level of 1%. In the cases of TREAOPTO, MROSI and TESJCAS the correlation coefficients did not show statistically significant correlation. For the set of motor and anthropometric variables we have established a high and statistically significant linear correlation to the criteria (R=0.76, p=0.003). We have also established that the linear correlation between all motor skill variables and performance is high (R=0.72, p=0.006). The findings of this study show the suitability of the chosen variables in determining the potential success of young alpine skiers.

Keywords: *alpine skiing, young competitors' performance, motor abilities, anthropometry*

POVEZANOST ANTROPOMETRIČNIH IN MOTORIČNIH SPREMENLJIVK Z USPEŠNOSTJO MLAJŠIH DEČKOV V ALPSKEM SMUČANJU

IZVLEČEK

V raziskavi smo ugotavljali, v kolikšni meri so določeni antropometrični in motorični parametri povezani s tekmovalno uspešnostjo mlajših dečkov na tekmovanjih za pokal Rauch v sezoni 2014/15. Na podlagi meritev sedmih testov motoričnega prostora (MSKOK10, TESJCAS, MS20NVZP, TREAOPTO, MT400, MROSI, SKI9) in ene meritve antropometričnega prostora (ABMI), smo s pomočjo Pearsonovega korelacijskega koeficienta ugotavljali povezanost posameznih spremenljivk z uspešnostjo za vzorec 34 mlajših dečkov, ki so bili v smučarski sezoni 2014/15 stari 12 oz. 13 let. Povezanost celotnega sklopa spremenljivk motoričnih in antropometričnih prostorov s tekmovalno uspešnostjo smo ugotavljali s pomočjo regresijske analize. Kriterijsko spremenljivko Tekmovalna uspešnost je predstavljalo skupno število doseženih točk šestih pokalnih tekmovanj za pokal Rauch v sezoni 2014/15. Ugotovili smo, da statistično značilna povezanost med številom doseženih točk in spremenljivko ABMI ne obstaja. Stopnja povezanosti je neznatna in negativna (r = -0,023). Ugotovili smo, da obstaja statistično značilna povezanost med številom doseženih točk in spremenljivkami MSKOK10, MS20NVZP, MT400 in SKI9 pri stopnji tveganja 1 %. V primeru TREAOPTO, MROSI in TESJCAS izračun korelacijskih koeficientov ni pokazal statistično značilne povezanosti. Za sklop vseh motoričnih in antropometričnih spremenljivk smo ugotovili, da je linearna povezanost s kriterijem visoka (R=0,76, p=0,003). Ugotovili smo tudi, da je linearna povezanost med vsemi motoričnimi spremenljivkami hkrati in kriterijem visoka (R=0,72, p=0,006). Ugotovitve raziskave kažejo na ustreznost izbire spremenljivk pri ugotavljanju potencialne uspešnosti mladih alpskih smučarjev.

Ključne besede: *alpsko smučanje, uspešnost mladih tekmovalcev, gibalne sposobnosti, morfologija*

INTRODUCTION

Modern skiing (alpine skiing) is a complex, high-speed winter sport. Dynamic changes and operational structures impose increasing requirements on athletes - a solid base of technical skills, physical, tactical, and psychological training. An alpine skier is first and foremost an athlete whose body should function synchronously, like a perfect mechanism, in the specific conditions of the different disciplines of alpine skiing and depending on a wide variety of environmental variables, to be able to achieve their athletic potential (Kostadinov & Yordanov, 2021). Alpine skiing is a winter sport that involves individual descents on snow slopes with pre-determined ski routes using skis and attached bindings. The competitions are organized according to a certain order, in which all competitors see the results at the end of the competition (Toma et al., 2019). There are many factors that affect the competitor to a greater or lesser extent and must be overcome or utilized in various ways. The skier's successful performance depends on many variables. Alpine skiing is one of the most complex disciplines to analyze as the skier trajectory is curved and the athlete is moving within a broad open space, down the slope according to the directions and finish, the snow/snow base (moving the body upwards and downwards) and gates (left and right movement) (Erdmann et al., 2017). Generally, the natural environment with various weather conditions plays just as important a role in competitive alpine skiing as the equipment, the spectators, the coach, etc. However, the most important are the competitors themselves. Optimal synthesis is required for successful participation of top competitors with regard to physical, psychological and social skills and characteristics. During the transformation process (training) we help the competitor with different methods and means to transform from the initial to the final state, which is basically conscious transformation of numerous skills and characteristics of the competitor with impact on their personality as well (Petrović, Šmitek & Žvan, 1983). According to Petrović et al. (1983), the psychosomatic status is defined as multidimensional and suprasummative in terms of its effects, indicating that a change in a certain factor conditions a change of other factors. Human movement depends on human motor functions/mobility, characteristics, and skills according to Pistotnik (2011). Skills are natural human features, representing the level of utilization of different body management systems for achieving the movement objectives set. It can be said that success in alpine skiing largely depends on the degree of accepted and built specific motor skills (Kuna, Franjko, & Males, 2008). The characteristics are dimensions representing the human appearance and their reaction to the environment, whereas skills or knowledge are defined by learning the acquired movement patterns, which are realized on the basis of abilities and characteristics. Motor skills are indispensable components of human physical activity, enabling the potential for specific efforts and utilization of the body's functional potential. They develop naturally up to a certain level, depending on many factors, and can be perfected through practice (Plastoi, 2018). The anthropometric methods, defined as measurement of the dimensions of the human body, also have a significant impact on successful competitive alpine skiing (Cramer & Rayan, 2012). Hadzic, Bjelica, Georgiev, Vujovic, and Popovic (2014) analyzed the

differences in the basic turn technique as one of the ski school elements with regard to anthropometric characteristics. It has been demonstrated that there is a statistically significant difference in the technique of the basic turn with regard to the anthropometric characteristics of the subjects. Petrović et al. (1983) stated that the ability to kinetically solve spatial problems and timing ability are especially important for alpine skiing, because skiing involves, among other things, different speed combinations of gates and, above all, uneven terrain formation. It could be argued that success, even among young athletes, is mainly the result of properly planned training, talent and hard work. There are only a few who tolerate the psychophysical efforts well and maintain long-term motivation, and even fewer who respond positively to challenges by adapting and making the changes necessary for later top achievements (Bačanac & Škof, 2007). Even in alpine skiing, performance reflects the entire personality of the competitor and must be addressed in a sufficiently complex manner. It consists of several individual skills used under given performance conditions (Ehlenz, Grosser & Zimmermann, 1985). In this study we aimed to establish the extent to which certain anthropometric and motor skill parameters are related to competitive performance of younger male skiers.

METHODS

The measurements were performed on September 20, 2014 at the Faculty of Sports, University of Ljubljana (Slovenia), in the morning. Students and alpine skiing instructors of the Faculty of Sports, University of Ljubljana assisted in measuring, setting up and organizing. As part of the regular measurements, carried out twice a year, several anthropometric, motor, psychological dimensions and other parameters were measured, among which we focused on seven motor and one anthropometric dimension. The measurement was performed in the lobby of the faculty before the subjects headed for warmup to perform motor skill test at the faculty hall, and later for a sprint and 400-meter run at the athletic stadium.

Participants and recruitment

The study included a sample of 34 younger boys who competed in the Rauch Cup in slalom, giant slalom and super giant slalom during the season 2014/15. The overall number of competitors was larger, but only 34 were anthropometrically measured and had their motor skills measured at the Faculty of Sports in October 2014, on account of having achieved a ranking and consequently points at the Rauch Cup. Certain individuals did not take part in the measurements for subjective reasons. Therefore, we excluded from the sample all those who were not the subject of measurements and those who did not score points during the 2014/15 season. 21 subjects were born in 2001, the other 13 in 2002, belonging to the age categories of 12 and 13 years.

Measurement procedures

The measurements performed at the Faculty of Sports covered several different anthropometric and motor skills, of which we focused on the following eight:

- Anthropometric Body Mass Index (ABMI)
- Ten jumps (MSKOK10)
- Squat Jump – Tensiometer (TESJCAS)
- 20-meter sprint – start with legs parallel (MS20NVZP)
- Squat Jump – Optojump (TREAOPTO)
- 400-meter run (MT400)
- Stability Index – Biodex (MROSI)
- Figures-of-eight around 9 pins (SKI9)

The criterion variable is the actual performance of all measured competitors at the Rauch Cup during the 2014/2015 season. It is expressed as a total of points in the Rauch Cup competitions. During this season, 2 slalom, 3 giant slalom and 1 super giant slalom races were successfully held at the Rauch Cup, the results of which were considered in the scoring for the final ranking. In these competitions, the ranked competitors achieved a certain number of points for a certain ranking determined by the Skiing Association of Slovenia.

Statistical analysis

We used the SPSS program - Statistical Package for Social Sciences (IBM Corporation, Armonk, New York, USA) for the statistical data processing. The normality of data was confirmed using the Shapiro-Wilk test. When processing basic statistics of independent variables, we determined the minimum value, the maximum value, the range between the minimum and maximum values, arithmetic mean, and standard deviation. To determine whether we could set the selected variables as comparative performance units of the Rauch Cup, we calculated the Pearson correlation coefficient for each of the eight selected variables in relation to the subjects' performance.

RESULTS

The first part of data presentation displays the calculation of basic statistics for anthropometric and motor variables. In the second part of data analysis, we demonstrated the calculation of the Pearson correlation coefficients between individual anthropometric variables and motor skills in relation to the criterion variable (points at the Rauch Cup competition). The third part represents the calculation of the correlation of all variables with the criterion, for which we performed the regression analysis and

calculated the multiple correlation coefficient. The same principle of data presentation was applied for the set of motor variables.

Table 1. The results of basic statistics of anthropometric and motor variables for younger boys.

	N	RANGE	MIN	MAX	AM	SD
ABMI	36	10.3	15.3	25.6	19.88	2.65
MSKOK10	36	9.64	16.04	25.68	19.54	2.23
TESJCAS	36	346	238	584	365.35	75.61
MS20NVZP	36	1.99	5.59	7.58	6.64	.45
MT400	36	34.58	65.56	100.14	79.08	7.94
MROSI	36	3.2	.6	3.8	1.50	.73
SKI9	36	8.1	28.2	36.3	3182	2.16
TREAOPTO	36	.220	.374	.594	.467	.05

Note: N = number of subjects; Range = range between minimal and maximum value; MIN = minimal value; MAX = maximum value; AM = arithmetic mean; SD = standard deviation. The acronyms of variables (test) are explained in the chapter Independent Variables Sample.

As can be seen from Table 1, the ABMI values differ between the subjects, specifically for 10.3. Such a wide range can be explained by the age of the subjects, as they were born in 2001 or 2002. In this phase of the pre-puberty period, accelerated growth can occur in some individuals while physical development is slightly delayed in others. The results of the basic statistics of motor variables also show that the values for most of the motor skill variables are less scattered, which is mainly indicated by the low values of the standard deviation. A somewhat greater dispersion of results only can be detected in the MROSI variable (AM=1.5; SD=0.73)

AMBI (body mass index) and performance (points) in the Rauch Cup.

The calculation of the Pearson correlation coefficient showed that there is no statistically significant correlation between the number of points achieved and the ABMI variable. The correlation level is insignificant and negative (r = - 0.023).

Table 2. The Pearson correlation coefficient values between motor skill variables and performance (points) in the Rauch Cup.

TEST		POINTS
MSKOK10	r	.577**
	Sig. (2--tailed)	.000
TESJCAS	r	-.106
	Sig. (2--tailed)	.552
MS20NVZP	r	.611**
	Sig. (2--tailed)	.000
MT400	r	-.513**
	Sig. (2--tailed)	.002
MROSI	r	.259
	Sig. (2--tailed)	.139
SKI9	r	-.477**
	Sig. (2--tailed)	.004
TREAOPTO	r	-.161
	Sig. (2--tailed)	.362

*Note: Sig. = statistical significance of correlation; ** = correlation is statistically significant at the risk level of 1%; r = Pearson correlation coefficient.*

Table 2 presents the Pearson correlation coefficients for motor space in relation to performance (points). It shows that there is a statistically significant correlation between the number of points achieved and the variables MSKOK10, MS20NVZP, MT400 and SKI9 at a risk level of 1%. In the cases of TREAOPTO, MROSI and TESJCAS, the calculation of correlation coefficients did not show a statistically significant correlation.

Table 3. The result of the correlation of all anthropometric and motor skill variables with performance (points) in the Rauch Cup.

R	R2	Adjusted R2	Sig F
.752a	.566	.427	.003

Note: R = correlation coefficient; R2 = coefficient of determination; Adjusted R2: adjusted coefficient of determination; Sig F = statistical significance of correlation; a = predictors: constant (POINTS), ABMI, TREAOPTO, MROSI, TESJCAS, MT400, SKI9, MSKOK10.

It is evident from Table 3 that the coefficient of multiple correlation is R = 0.752, indicating that the linear correlation between all variables and the criterion is high. The correlation between all variables and performance is statistically significant (Sig F = 0.003). The coefficient of determination is R2 = 0.566, which means that 56.6% of the performance variance can be explained by motor skill and anthropometric variables.

Table 4: The result of the correlation between all motor skill variables and performance (points) in the Rauch Cup.

R	R2	Adjusted R2	Sig F
.716a	.512	.381	.005

Legend: R = correlation coefficient; R^2 = coefficient of determination; Adjusted R^2 = adjusted coefficient of determination; Sig F = statistical significance of correlation; [a] = predictors: constant (POINTS), TREAOPTO, MROSI, TESJCAS, MT400, SKI9, MSKOK10, MS20NVZP.

The multiple correlation coefficient is R = 0.716, which indicates that a linear correlation between all motor skill variables at the same time and the criterion is high, as can be seen in Table 4. The correlation between all motor skill variables and performance is statistically significant (Sig F = 0.005). The coefficient of determination is R2 = 0.512, which means that 51.2% of the performance variance can be explained by motor skill variables.

DISCUSSION

Studies establishing a correlation between various dimensions of an athlete's psychosomatic status and their performance undoubtedly represent the foundation for potential changes and qualitative improvement in various fields, especially concerning the successful and healthy development of an athlete. Since alpine skiing is a complex,

individual-structural sport, many different factors have an impact on the competitor. Success in this sport depends on an optimal combination of physical, psychological, and social dimensions. It is known that movement skills are the most reliable predictors of potential success, and anthropometric characteristics do not fall behind much in importance.

Through a transformation process, we achieve changes in the psychosomatic status of the competitor. Because it is multidimensional and suprasummative (Petrović et al., 1983), a change in one factor causes a change in other factors. The level of the subjects' development is substantially related to the competitive performance in the category of younger boys, because some of them experience accelerated growth of individual parts of the body at that age. This can have a positive as well as a negative effect on motor skills. Development in individuals may also be delayed, depriving them of movement skills, which can be particularly pronounced in sports. Petrović et al. (1983) state that the transformation process can have an inhibitory effect on certain abilities and characteristics during the growing-up phase. In the present study, we were interested in the direct correlations between motor skills and anthropometric characteristics and competitive performance for the category of younger boys in alpine skiing. The goal was to determine the correlation level between an individual motor skill and anthropometric variables and competitive performance as well as the impact of all selected motor skill and anthropometric variables on competitive performance.

Further, we calculated the correlation between the entire set of motor skill variables and the performance of the competitors at the Rauch Cup. During the analysis of the basic statistics, we determined that the Body Mass Index values vary considerably among the subjects, which is most likely the result of the already mentioned differences in the stages of development. The calculation of the Pearson correlation coefficient showed that the correlation between the Body Mass Index and performance is negligible ($r = -0.023$) and statistically insignificant, which confirms the assumptions regarding the differences in development in the considered age category. We found that in our sample the 20-meter sprint from a high start with legs parallel (MS20NVZP) is mostly related to competitive performance ($r = 0.611$) and that the correlation is statistically significant (Sig $F = 0.000$).

The test assesses the basic movement ability of speed and is also mainly related to explosive power (acceleration at the start). A similar level of correlation ($r = 0.577$) and statistical significance (Sig $F = 0.000$) was achieved by the ten-jump test (MSKOK10). It indicates the repetitive explosive force as a manifestation of the energy component of power. Especially in slalom and giant slalom, this phenomenon is expressed when connecting relatively short turns and relying on repetitive power for speed control and (lateral) relief.

The MT400 ($r = -0.513$) and SKI9 ($r = -.477$) tests, which are negatively correlated to competitive performance, revealed a statistically significant correlation. A 400-meter run expresses speed endurance, which is defined by the energy component of the movement and prevails in efforts of up to two minutes. The test is physiologically related to the duration of the activity on the track. SKI9 is the only test in our study that represents

special motor skills, i.e., agility, which is defined by rapid changes of direction as a manifestation of coordination. It is also defined by explosive power and speed (Petrović et al., 1983), which is also evident if we follow the course of the test. Among the previously presented statistically characteristic correlations, SKI9 is the only variable that belongs to the subspace of the informational component of movement.

Because it is a distinctly skiing test, we expected a similar result. The results of motor skill tests and anthropometric measurements presented so far were not surprising. We find it all the more interesting that the correlation of the variable TESJCAS (squat jump on a tensiometer) is not statistically significant and that it stands in a negative, insignificant correlation with performance (r = -0.016). A particularly interesting fact is that we measured explosive thrust power with this test and expected higher correlation values, similar to those in the ten jumps test. The findings of this study do not comport with the findings of the study conducted by Lešnik and Žvan (2000), who found a statistical significance for two tests of explosive power (triple jump and standing long jump), but for another generation of competitors. The balance and stability test (MROSI) revealed a low (r = 0.259) and statistically insignificant correlation with the criterion variable. Obviously, balance in the considered age categories does not yet affect performance, as can also be seen in the study by Lah (2014), who investigated the impact of balance between the categories of younger and older boys and girls on the performance in alpine skiing. The correlations were insignificant for all four groups of subjects. The last studied test of motor skill dimensions was a squat jump between the bars of the OPTOJUMP device (TREAOPTO), which was defined by reaction speed. It revealed a negligible negative correlation (r = -0.161) and statistical insignificance. For the entire set of all studied variables, we found that there is a statistically significant correlation (Sig F = 0.003) with performance at the competition (R = 0.752). The coefficient of determination was R2 = 0.566, which means that 56.6% of the performance variance can be explained by motor and anthropometric variables. The set of all motor variables, which we additionally calculated, is statistically significantly correlated (Sig F = 0.005) with competitive performance (R = 0.716). We were therefore able to explain the 51.2% of the performance variance with motor skills variables (R2 = 0.512), which represents a slightly smaller share than for the set of all variables.

From the obtained results of the set of all variables and set of motor skill variables, we can conclude that the Body Mass Index (ABMI) itself is not statistically significantly related to the points; however, as a whole (together with the motor skill variables) it clearly contributes to the proportion of explained variance.

The present study rebutted the findings of Lah (2014), who determined a weak and uncharacteristic correlation between balance (MROSI) and competitive performance. For the variable TREAOPTO (reaction speed), and especially for the variable TESJCAS (explosive power), we expected higher correlation values and statistical significance. However, the results of the basic statistics of these three dimensions varied considerably, which we tried to explain with the differences in the development level of the studied age category and with the assumption that not all competitors have the same predispositions, opportunities and desire for successful participation in top alpine

skiing. Since the sample represented an already selected population, De Costa (2009) similarly drew attention to the fact that currently children are directed to alpine skiing based on social criteria and increasingly less on motor skill criteria.

To consider theory and practice, it can be said that the findings of the present study represent a foundation for further research, as balance, reaction speed and explosive thrust tests did not show any statistical significance. In their study, Bandalo and Lešnik (2011) proposed to reduce the number of variables from the battery of tests for determining motor skills and anthropometric characteristics in the future. We support this idea; however, in the future, regular studies in this field are required to determine important motor and anthropometric dimensions and tests, because Bandalo and Lešnik (2012) established in their study that over a period of four years (2007 to 2010) the correlation between anthropometric and motor skill variables and performance varied.

CONCLUSION

We established a statistically significant value of the multiple correlation coefficient (R = 0.752), which means that 56.6% of the variance of the actual performance can be explained by the considered motor skill and anthropometric variables (R2 = 0.566).

Today's (sedentary) lifestyle and greater involvement of young people in other non-sport fields, together with the relatively high costs of skiing and ski training, which often do not allow the parents to enroll their children in ski schools, result in a fundamentally limited selection process. We will not change this fact with our research, but we can conclude that not all competitors who were the subjects of measurement at the Faculty of Sports are part of the skiing circuit on account of extremely positive physical reasons.

On the other hand, having considered a sample of younger boys, we can conclude that the stage of development plays an important role in the separation of the physically more successful from the physically disadvantaged competitors. Therefore, it is necessary to pay special attention to the latter in terms of social and psychological support. We have proposed the idea of managing the mentioned groups of competitors separately during the transformation process, although it is clear that in practice this may be problematic. Undoubtedly, with a proper mindset and efforts we can ensure less discomfort or neglect among young ambitious competitors.

In the future, it will be necessary to monitor the development of young athletes even more systematically. 12 - 13 years is a sensitive period, which is why it is all the more important that the battery of tests is effective and provides information about the athlete necessary for the professionals in the field to guide them properly during the training process. The fact remains that many other areas contribute to competitive performance, such as psychological preparation, personality traits, as well as tactical preparation. In any case, it would be necessary to include in future studies the aspect of skiing techniques, which has already been shown to be necessary in past studies (Puhalj, 2018).

Our findings show that we are on the right track. Therefore, we will continue with the introduction of the most up-to-date measurement methods and try to connect them with the measurements performed in the older age categories of competitors in alpine skiing.

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TIME PASSES – HEALTHY HABITS STAY? A LONGITUDINAL SMALL SAMPLE COMPARISON OF MUSCLE CONTRACTILE PROPERTIES, MOTOR ABILITIES AND LIFESTYLE CHARACTERISTICS OF ATHLETES AND NON-ATHLETES

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ABSTRACT

Introduction: *Because healthy behaviors learned early in life are more likely to be maintained during adulthood, we aimed to investigate longitudinal changes of participants that were regularly involved in extracurricular sport activities (athletes; N = 7; 4 boys) and those that were not (non-athletes, N = 6; 3 boys)*

Methods: *Participants of both groups were invited for re-assessment at the age of 27, in 2019, 12 years after they participated in a 5-year longitudinal study as adolescents (9–14 years of age, in the period 2001–07). We investigated vastus lateralis (VL) and biceps femoris (BF) contractile properties (tensiomyography), maximal running speed (photocells), anthropometric measures (bioimpedance), maximal vertical jumping height (squat and countermovement jumps on a ground reaction force plate), and lifestyle characteristics (GPAQ and EHIS surveys).*

Results: *Based on Cohen's d effect size we found that athletes have lower body mass index, higher maximal running speed, better maximal vertical jumping height, and shorter BF contraction time, not found in VL, compared to non-athletes. Furthermore, athletes also exhibit healthier lifestyle characteristics such as lower sedentary time and higher daily energy expenditure than non-athletes. Athletes follow diet regimens consisting of more regular meals with more protein and indulge less in health-risk behavior (smoking and alcohol consumption). However, the self-perception of health and quality of life was lower in athletes than in non-athletes.*

Conclusion: *EU regulations and the beginning of the COVID-19 pandemics prevented us from conducting a study on a more representative sample. Nevertheless, we could confirm that regular sport participation yields better physical performance*

and a healthier lifestyle but could also have a negative impact on health (injuries) and quality of life.

Keywords: *motor development, tensiomyography, sport, physical exercise, healthy lifestyle*

ČAS MINEVA - ZDRAVE NAVADE OSTANEJO? LONGITUDINALNA PRIMERJAVA KONTRAKTILNIH LASTNOSTI MIŠIC, GIBALNIH SPOSOBNOSTI IN ZNAČILNOSTI ŽIVLJENJSKEGA SLOGA ŠPORTNIKOV IN NEŠPORTNIKOV NA MAJHNEM VZORCU

IZVLEČEK

Uvod: *Namen raziskave je ugotoviti longitudinalne spremembe v skupini preiskovancev, ki so se redno ukvarjali z obšolskimi športnimi dejavnostmi (skupina športnikov; N = 7, 4 dečki), in tistih, ki se niso kontinuirano ukvarjali s športom (skupina nešportnikov, N = 6, 3 dečki).*

Metode: *Udeleženci obeh skupin so bili povabljeni na ponovne meritve pri starosti 27 let, leta 2019, torej 12 let po tem, ko so bili v starosti od 9-14 let, v obdobju 2001-2007 vključeni v petletno longitudinalno študijo. Preučevali smo kontraktilne lastnosti mišic: vastus lateralis (VL) in biceps femoris (BF) (z metodo tenziomiografije), hitrost sprinta z letečim štartom (s fotokamerami), antropometrične podatke (z bioimpedanco), dosežek navpičnega skoka (skoki na tenziometrijski plošči s pomočjo in brez pomoči rok) ter nekatere značilnosti življenjskega sloga (anketi GPAQ in EHIS).*

Rezultati: *Na podlagi velikosti učinka (Cohenove d) smo ugotovili, da imajo športniki v primerjavi z nešportniki nižji indeks telesne mase, večjo hitrost teka, boljšo zmogljivost vertikalnih skokov in krajši čas krčenja BF, kar pri VL nismo ugotovili. Poleg tega imajo športniki tudi bolj zdrave vzorce življenjskega sloga, manj sedijo in več gibajo (večja dnevna poraba energije) kot nešportniki. Nadalje prehrano športnikov sestavljajo bolj redni obroki z več beljakovinami, poleg tega imajo manj zdravju nevarnih praks (kajenje in uživanje alkohola). Kljub temu pa so športniki svoje zdravje in kakovost življenja ocenili nižje kot nešportniki.*

Zaključek: *Regulativni predpisi EU za področje varovanja osebnih podatkov (GDPR) kot tudi začetek pandemije COVID-19 so nas pri izvedbi študije na bolj reprezentativnem vzorcu močno ovirali. Kljub temu smo lahko potrdili, da redno ukvarjanje s športom ohranja boljšo telesno zmogljivost, bolj zdrav življenjski slog, kar pa lahko vpliva na zdravje (poškodbe) in kakovost življenja.*

Ključne besede*: gibalni razvoj, tenziomiografija, šport, gibalna aktivnost, zdrav življenjski slog*

INTRODUCTION

Most research into healthy behavior and predictors of these behaviors generally focuses on individuals' incentives to adopt positive health practices at a single point in time and do not provide a framework for how healthy behaviors may change over time. Frech (2012) indicates several reasons to investigate how and why engagement in healthy behavior changes across pivotal life course stages (Frech, 2012). First, because healthy behaviors learned early in life are more likely to be maintained during adulthood (Lau, Quadrel, & Hartman, 1990; Telama et al., 1997) and because health-promoting behaviors aid in preventing or delaying chronic or life-threatening disease. And secondly, to evaluate whether personal and social resources at one life course stage (for example during adolescence) exert an enduring or cumulative impact on healthy behaviors at later life course stages.

Therefore, sport and sport participation are viewed as an effective activity for solving problems and improving quality of life for individuals and society alike. Not just for increasing self-confidence, self-esteem, and positive body image, building our character in the form of discipline, teamwork, and responsibility, as well as our importance, but also creating motor and sport-specific skills convertible into physical capital and improving health, fitness, and an overall sense of physical well-being (Coakley, 2011).

Researchers have given considerable attention to the athlete development process, e.g., positive youth development through sport (Holt, 2008). Utilization of skeletal muscle mass to produce power is of great importance in sport. However, skeletal muscle is also indispensable for locomotion, maintenance of body posture, thermoregulation, sugar and lipid metabolism and, therefore, for general health. To realize locomotion, the muscles must produce power by generating force and shortening velocity at the same time. The speed of muscle contraction is largely determined by fiber type composition. In children, knowing the fiber type composition may be used to help in formulating an informed decision regarding taking up a sport in which the child most likely will excel. While there are numerous data on the fiber type composition of various skeletal muscle in adults and adolescents, we are aware of only seven cross-sectional studies on the fiber type composition of muscle in children between the ages of 2 months and 11 years (Bell, MacDougall, Billeter, & Howald, 1980; Glenmark, Hedberg, & Jansson, 1992; Kriketos et al., 1997; Lexell, Sjöström, Nordlund, & Taylor, 1992; Lundberg, Eriksson, & Mellgren, 1979; Österlund, Thornell, & Eriksson, 2011; Verdijk et al., 2014). Furthermore, only one study presented longitudinal data of VL composition from adolescence to adulthood (Glenmark et al., 1992) and found lower proportion of slow twitch fibers in VL muscle in girls at the age of 16 and the opposite at the age of 27. Especially where it is very difficult, for ethical reasons, to invasively measure skeletal muscle myosin heavy chain proportion or fiber type composition, tensiomyography (TMG) provides non-invasive information on changes in functional skeletal properties (Valenčič & Knez, 1997). Specifically, it was established that TMG-derived contraction time (Tc) could be used to non-invasively estimate skeletal muscle MHC type 1 proportion (Šimunič, Degens, & Rittweger, 2011).

In the period 2002–07 we followed with TMG screening >300 children in six yearly assessments. Approximately one third (107) were measured on all occasions and analyzed (Pišot et al., 2004; Šimunič et al., 2017; Završnik et al., 2016; Završnik, Pišot, Šimunič, Kokol, & Blažun Vošner, 2017). Briefly, we found that boys in general had slower muscles than girls. During early maturation in the VL muscle there is a slow-to-fast transition that begins between 6 and 10 years of age, which then appears to stabilize to adult proportions. Regular participation in sport was associated with a faster biceps femoris (BF), but not in VL, for both sexes (Šimunič et al., 2017). We also found correlation between muscle contractile properties and the running speed that was biased for both sexes. Specifically, the running speed was less correlated with VL Tc in boys than in girls. However, boys' running speed was more correlated with BF Tc than in girls (Završnik et al., 2016, 2017). Our data thus represent a first non-invasive, if indirect, indication of developmental trends in changes in muscle fiber type composition in children.

The most interesting finding for us was that regular sport participation in children aged between 9 and 14, compared to children without any extracurricular sport participation, impacted Tc in non-gravitational BF muscle but not gravitational VL muscle, in both sexes (Šimunič et al., 2017). However, it remains to be seen whether the continuation of exercise (sport participation) through adolescence to adulthood could further impact Tc in both muscles. Even more, it would be interesting to see the effect of continued sport participation on motor abilities, body characteristics and main characteristics of healthy lifestyle (nutrition, PA, habits) in the later adolescence and early adulthood of participants.

After carrying out a 5-year longitudinal monitoring of skeletal muscle contractile properties and motor abilities in >300 children within two consecutive research projects: (i) *"The role of biomechanical properties of skeletal muscle in the motor development of children"*, 2001–04; and (ii) "*Monitoring of changes in skeletal muscle biomechanical characteristics in early childhood and adolescence*", 2004–07, we invited those same subjects for a follow-up assessment in 2019 with the purpose of longitudinally investigate the changes in skeletal muscle contractile properties, physical activity level, nutrition, and health related habits.

METHODS

In previous analyses we investigated motor abilities development in 9–14 year-old children as a factor of sex and sport participation. Furthermore, in 2019 we invited the subjects to participate again (12 years later), taking the same measurements. Furthermore, at the final assessment we investigated basic lifestyle characteristics which we obtained by a questionnaire including demographic data, physical activity, nutrition and smoking habits. Additionally, the participants were asked about their participation in organized sports, their sport injury history and important life stress events. Results of the first six assessments of vastus lateralis (VL) and biceps femoris (BF) contractile

properties (tensiomyography), flying running speed (photocells), anthropometric measures (bioimpedance), and vertical jumping performance (squat and countermovement jumps on a ground reaction force plate) were previously reported in four scientific publications (Pišot et al., 2004; Šimunič et al., 2017; Završnik et al., 2016, 2017). This manuscript presents data from a 12-year follow-up in a subsample of the same participants.

Participants and recruitment

During the recruitment we focused on inviting the 107 participants who were consistently present for all six annual measurements during the 2002–07 period. The participants came from the Slovene towns of Koper, Izola, Piran, Ljubljana, and Maribor. Due to strict personal data protection legislation (EU 2016/679, General Data Protection - GDPR), we had many problems in re-establishing contacts to recruit participants for follow-up measurements, as we only had a database with the first and last names and their elementary school. The principals of the elementary schools could not provide us with the subjects' contact information, so we had to resort to the "snowball" method and social media. We searched for potential acquaintances to contact the participants and after they agreed to be contacted, we invited them to participate in the follow-up. This was usually done through their social media (Facebook and Instagram) or by a phone call. In addition, our research organization advertised the invitation to participate in the follow-up through various media (official website, Facebook). Despite an enormous amount of time and effort invested, we kept receiving responses of interested candidates, but mostly ones who had not participated in our previous measurements from 2002–07 and thus were not eligible for the follow-up. Over the course of about six months, we were able to recruit 13 participants. We divided these participants into two groups: a group of athletes, who had regularly participated in organized sport activities during the past 12 years (athletes; N = 7; 4 boys) and non-athletes (N = 6; 3 boys). Specifically, it was evident from their questionnaire data that seven of them continuously participated in various sports from the age of 9 to 25 and were classified as athletes, while six of them had not participated in any sports for at least the past 10 years (non-athletes), although five of them had been active during the period of primary school. Table 1 summarizes the proportion of those involved in organized sport activities in three age-periods for both studied groups.

Table 1: Proportion of participants' sport participation in the two studied groups: (i) those who continuously practiced sport from 14 to 26 years of age (athletes); and (ii) those who did not practice sport at all or only until they were 16 years old (non-athletes).

	Athletes	**Non-athletes**
N	**7**	**6**
Sport participation in the age period of 9–14	5 out of 7	5 out of 6
Sport participation in the age period of 14-16	7 out of 7	2 out of 6
Sport participation in the age period of 16-26	7 out of 7	0 out of 6

Measurement procedures

The follow-up measurements consisted of the following test battery: arm strength (dominant hand compression - dynamometer), TMG of two muscles, maximal running speed (7-meter sprint with flying start), maximal vertical jump height, body height, mass, mass index, and composition measurement (fat mass, muscle mass). After the tests, each subject was asked to complete a specific questionnaire consisting of several sets of validated questions (GPAQ, EHIS) to provide data on their current PA status, injury history, health status, and lifestyle to allow capturing possible factors that might influence general fitness (biomechanical muscle characteristics) at each stage of the subject's life (high school, university, and current age).

Tensiomyography (TMG)

The TMG method measured the contractile properties of two skeletal muscles in the dominant site (vastus lateralis – VL, and biceps femoris – BF). Each muscle was stimulated with single electric pulses, rectangular in shape, lasting 1 ms. The pulse amplitude was gradually increased until the maximum response was obtained. We saved the two largest responses for further processing and took the average of both for further analyses. We calculated two contractile parameters for each response: a maximal amplitude (Dm, in mm) to be used for the calculation of contraction time (Tc, in ms) between 10 % to 90 % Dm.

Measurement of body composition

After body mass and height were measured, body mass index was calculated, and composition was measured using a bioimpedance meter (Maltron BioScan 916s, UK). We ensured that participants were calm, normally hydrated, and rested for at least 20 minutes before the measurement. Fat mass was measured via a 4-point measurement.

Maximal running speed

After a standardized 10-minute warm-up, the maximal running speed was measured with a flying start over a distance of 7 meters. We assured plenty of room to accelerate and decelerate before and after assessment gates (Powertimer 300, Newtest, Finland), respectively. Each participant made three attempts and the best result was taken for further analysis.

Maximal vertical jumping height

We measured the height of the vertical jump without using hands (hands on the hips). Each participant performed three countermovement and three squat jumps on a ground reaction force plate (Quattro jump 9290AD, Kistler Ltd., Austria). The best result was taken for further analysis.

Questionnaire

The questionnaire designed for this study consisted of several sets of validated questions and covered basic socio-demographic data, health status and nutrition, physical/sport activity, and aspects of sedentary time. We used an adapted part of the European Health Interview survey – EHIS to assess eating habits (regular diet, type of diet) and indicators of quality of life. Additionally, physical/sport activity was assessed by a self-reported validated questionnaire The Global Physical Activity Questionnaire – GPAQ (Armstrong & Bull, 2006).

Statistics

Due to the small sample size, we did not perform classical parametric statistical analysis. We performed the non-parametric Mann-Whitney test to compare athletes vs. non-athletes only for indicative purposes. Since small samples yield low statistical power and only large effects will end up significant, we rather calculated effect sizes – Cohen's d values – and interpreted main findings based on the effect size (low

< 0.20; moderate 0.20 ≤ Cohen's d < 0.8 and high ≥ 0.8). For comparing correlations between lifestyle characteristics and motor abilities and muscle characteristics, we used the Spearman rho coefficient indicating significant correlations at $p < 0.05$.

RESULTS

We were able to repeat the longitudinal monitoring of the biomechanical characteristics of skeletal muscle only on a sample of 13 (7 male) participants at the age of 27 years: 4 participants from Maribor, and 9 from Koper over 7 testing days executed in January, February, and October 2019.

In all comparisons there were no statistical differences confirmed by the Mann-Whitney test; however, due to lower sensitivity of statistical tests in very small samples, we interpreted effect sizes. Table 2 shows a progressive trend in basic anthropometric data of pooled participants indicating normal growth. When comparing athletes and non-athletes (Table 4), we found that athletes had moderately to significantly lower body mass index (effect size from 0.42 to 1.07) throughout the whole period and lower fat mass (effect size 0.65) at the age of 27 years. This is consistent with lesser sedentary time (effect size 0.55) and higher daily energy consumption (effect size 0.47) compared to non-athletes. Table 3 presents motor abilities in pooled participants. When comparing athletes and non-athletes (Table 4), we could not confirm higher running speed in athletes throughout all periods. However, countermovement and squat jump heights were higher in athletes when compared to non-athletes at the age of 27 (effect size 0.81 and 0.74, respectively). VL Tc was not lower in athletes; it was, however, lower in BF with the largest effect size at the age of 27 years (0.64).

Table 2. Basic anthropometric data of pooled participants.

Age	**9 years**	**10 years**	**11 years**	**12 years**	**13 years**	**14 years**	**…**	**27 years**
N	**13**	**13**	**13**	**13**	**13**	**13**	**…**	**13**
Body mass index / kg/m2	17.1 ± 2.5	17.9 ± 2.6	18.0 ± 2.9	19.5 ± 3.0	20.0 ± 2.7	20.3 ± 2.4	…	22.8 ± 3.3
Body height / m	1.41 ± .06	1.45 ± .07	1.49 ± .07	1.58 ± .07	1.65 ± .08	1.69 ± .08		1.76 ± .09
Body mass / kg	34.3 ± 7.0	37.9 ± 8.2	40.4 ± 9.1	48.9 ± .11	54.8 ± 10.7	58.2 ± 9.7		71.6 ± 14.4

Table 3. Pooled data of selected motor abilities.

Age	**9 years**	**10 years**	**11 years**	**12 years**	**13 years**	**14 years**	**…**	**27 years**
N	**13**	**13**	**13**	**13**	**13**	**13**	**…**	**13**
Running Speed / m/s	5.6 ± 0.5	5.6 ± 0.4	5.7 ± 0.4	6.0 ± 0.4	6.3 ± 0.8	6.2 ± 0.4	…	6.4 ± 0.5
CMJ height / cm	-	-	-	-	-	-	…	29.8 ± 5.6
Squat jump height / cm	-	-	-	-	-	-	…	28.3 ± 5.2

CMJ – countermovement jump

Table 4. Comparison between athletes and non-athletes

Group	**Athletes**	**Non-athletes**	**Effect size***
Number	**7**	**6**	
Body mass index / kg/m2			
9 years	16.7 ± 2.9	17.7 ± 1.9	0.54
10 years	17.3 ± 3.0	18.7 ± 2.2	0.63
11 years	17.4 ± 2.9	18.7 ± 2.9	0.48
12 years	18.7 ± 3.1	21.0 ± 2.4	0.98
13 years	19.4 ± 3.3	20.7 ± 1.8	1.07
14 years	19.9 ± 2.7	20.8 ± 2.0	0.42
…	…	…	…
27 years	21.9 ± 3.7	23.1 ± 2.5	0.65
Fat mass / %			
27 years	22.7 ± 6.4	23.7 ± 3.0	0.33
Running speed / m/s			
9 years	5.5 ± 0.4	5.7 ± 0.5	-0.39
10 years	5.7 ± 0.4	5.6 ± 0.4	-0.15
11 years	5.6 ± 0.4	5.7 ± 0.4	-0.41
12 years	5.9 ± 0.4	6.0 ± 0.4	-0.02
13 years	6.0 ± 0.3	6.1 ± 0.3	-0.39
14 years	6.1 ± 0.4	6.3 ± 0.3	-0.64
…	…	…	…
27 years	6.4 ± 0.5	6.3 ± 0.5	0.31

Group	Athletes	Non-athletes	Effect size*
Number	**7**	**6**	
Countermovement jump height / cm			
27 years	31.6 ± 5.7	27.6 ± 5.0	0.81
Squat jump height / cm			
27 years	29.9 ± 5.3	26.1 ± 7.2	0.74
Contraction time of vastus lateralis / ms			
9 years	20.7 ± 2.5	19.2 ± 2.6	-0.57
10 years	19.0 ± 2.1	17.6 ± 2.1	-0.64
11 years	19.3 ± 4.2	19.2 ± 2.8	-0.01
12 years	21.7 ± 4.4	20.4 ± 2.3	-0.56
13 years	21.6 ± 3.6	22.1 ± 2.4	0.22
14 years	22.7 ± 3.7	23.7 ± 3.3	0.30
…	…	…	…
27 years	21.5 ± 3.0	21.4 ± 2.2	-0.05
Contraction time of biceps femoris / ms			
9 years	32.1 ± 3.5	34.2 ± 7.3	0.29
10 years	31.2 ± 2.9	32.8 ± 9.1	0.17
11 years	32.0 ± 3.5	33.9 ± 6.6	0.29
12 years	31.1 ± 4.5	33.3 ± 8.6	0.26
13 years	29.4 ± 3.7	36.9 ± 13.0	0.58
14 years	29.6 ± 1.8	34.9 ± 12.8	0.41
…	…	…	…
27 years	29.1 ± 2.8	33.9 ± 7.6	0.64
Sedentary time / min			
27 years	335 ± 157	417 ± 147	0.55
Daily energy consumption / MET			
27 years	4663 ± 2823	3346 ± 2780	0.47

*MET... metabolic equivalent; *positive values of effect size denote better results for athletes.*

Data from GPAQ showed higher daily energy consumption (MET) because of sport participation of athletes in parallel to lower daily sedentary time than in non-athletes. Even more, sedentary time at age of 27 years correlates negatively with body mass index ($r = -0.47$) and fat mass ($r = -0.59$), and positively with BF Tc at this same age ($r = 0.50$).

Additionally, the differences in certain socio-demographic factors and lifestyle characteristics between athletes and non-athletes were examined, which are shown in Table 5.

Table 5: Comparison of some lifestyle characteristics of athletes and non-athletes

Group	Athletes	Non-athletes	Effect size*
N	**7**	**6**	
Self-assessment of…:			
General health status	3.8 ± 0.6	4.2 ± 0.6	0.67
Physical capability	3.3 ±0.7	3.3 ±0.9	0.00
Psychological status	3.8 ±0.6	3.8 ±0.6	0.00
General quality of life	3.8 ±0.6	4.2 ±0.3	1.33
Eating habits			
Breakfast	5.7 ±0.67	4.0 ±1.9	0.89
Morning snack	3.2 ± 1.0	2.4 ± 1.6	0.50
Lunch	5.5 ±0.7	5.8 ±0.3	1.00
Afternoon snack	3.3 ± 1.6	2.5 ±1.0	0.80
Dinner	5.2 ±1.4	5.5 ±0.7	0.43
Food consumption			
Whole-grain bread	4.0 ± 1.2	4.3 ± 2.0	0.15
Olive oil	4.3 ± 1.3	5.8 ± 1.0	1.50
Milk and low-fat dairy	3.8 ± 1.2	4.8 ± 2.0	0.50
Cottage cheese, yogurt, cheese	4.2 ± 1.5	4.3 ± 2.0	0.05
Dark chocolate	2.3 ± 1.3	2.0 ± 0.9	0.33
Meat products	3.7 ± 1.2	2.0 ± 1.3	1.31
Red meat	2.8 ± 1.2	3.0 ± 1.3	0.15
Poultry	3.8 ± 1.2	2.5 ± 1.4	0.93
Bacon	2.0 ± 0.9	2.3 ± 1.2	0.25
Fish	2.7 ± 1.0	2.3 ± 0.7	0.57
Fizzy and non-fizzy non-alcoholic drinks	3.0 ± 1.0	3.8 ± 2.2	0.36
Alcohol beverages	2.3 ± 0.4	3.7 ± 0.9	1.56
Fried dishes	2.8 ± 1.0	3.3 ± 1.2	0.42

** effect sizes are presented as absolute values.*

A noticeable difference between the groups was that athletes reported predominantly standing (physical work) while non-athletes, all but one, reported predominantly sedentary work. There were no differences between athletes and non-athletes in terms of subjective assessment of physical fitness, mental well-being, and health concerns, but interestingly athletes rated their general health (effect size 0.67) and their overall quality of life (effect size 1.33) lower than did non-athletes.

Much of the difference between the groups was reflected in eating habits, with athletes eating more regularly and skipping breakfast and afternoon snack less often (effect sizes 0.89 and from 0.50 to 0.80, respectively) than non-athletes. In terms of food choices athletes are more likely to eat meat products (effect size 1.31), especially poultry (effect size 0.93). Non-athletes, on the other hand, are more likely to consume olive oil (effect size 1.50) and alcoholic beverages (effect size 1.56).

DISCUSSION

Based on effect sizes, due to low number of participants, we could conclude that at the age of 27 years athletes had lower body mass index, fat mass, sedentary time, BF Tc and higher running speed, countermovement and squat jump heights and daily energy consumption when compared to non-athletes. Similar trends as at 27 years were also found in the age period from 9 to 14 years, but only for two abovementioned longitudinal variables: body mass index and BF Tc. Interestingly, only running speed was at 9–14 years lower in athletes than in non-athletes, the opposite as at 27 years. At the age of 27, the largest effect size was recorded for countermovement jump height, squat jump height, body mass index, and BF Tc (effect sizes > 0.60).

This is the first study to collect 18 years of longitudinal data on TMG parameters from childhood to adulthood. We have previously reported that children's regular participation in sports was associated with shorter BF Tc, but not with VL Tc, as found here. More specifically, BF Tc differences were observed between sedentary and athletic groups in boys and girls and were significant at 12 years of age (Šimunič et al., 2017). As this sample was a sub-sample of the previous study a similar result could be confirmed for the period of 9-14 years. However, this trend was maintained or even slightly increased with regular sport exercise until the age of 27 years. Although short Tc was confirmed in BF it was not the case for VL Tc, which seems to be independent from regular exercise. A similar situation was observed in adult track and field sprinters where sport participation resulted in a higher proportion of type IIc fibers in the BF, which was also associated with a lower BF Tc (19.5 vs. 30.2 ms in sprinters vs. sedentary subjects, respectively) (Dahmane, Djordjevič, & Smerdu, 2006). It could be that the habitual loading of weight-bearing muscles (as for VL) through normal daily physical activity is already relatively high in non-athletes and that the non-weight bearing muscles are more heavily loaded during exercise (Šimunič et al., 2017). If so, this may explain the grater adaptation to regular exercise in BF than in VL. Our group of athletes consisted of three handball players, two volleyball players, one dancer and one

multisport athlete. When we compare their average BF Tc's at the age of 27 years (29.6 ms) with the averages of other groups of adult athletes, e.g., male sprinters at 19 ms (Šimunič et al., 2017), beach volleyball players at 25 ms (Rodríguez Ruiz et al., 2012), gymnasts at 27 ms (Šimunič et al., 2017), and football players at 28 ms (Rey, Lago-Peñas, Lago-Ballesteros, & Casáis, 2012) they have a longer BF Tc, but a shorter BF Tc than non-athletes with 32 ms (Šimunič, 2012; Šimunič, Pišot, Rittweger, & Degens, 2018). Thus it appears that participation in sports during childhood may lead to a faster profile of BF Tc, an important muscle for fast explosive sports such as football, volleyball, sprinting, and gymnastics as well as for overall knee health (Biscarini, Botti, & Pettorossi, 2013; Guelich, Xu, Koh, Nuber, & Zhang, 2016). To support this, we have previously reported that children who regularly participate in sports also have higher running speed (Volmut, Pišot, & Šimunič, 2016) and that this was negatively correlated with BF Tc (Pišot et al., 2004; Završnik et al., 2016) - but only in boys beyond the age of 13 years. And indeed, we were able to confirm higher sprinting velocity in athletes only at the age of 27 years, and not before, as five of the six participants in the non-athlete group also practiced sports during the age period of 9–14 years.

For all other non-longitudinal variables of body composition and muscle performance, which were not assessed until age 27, differences between the two groups were in favor of the athletes. Specifically, athletes had lower fat mass, which is indicative of a lower body mass index, and had higher jumping performance, an indicator of overall body strength. Regarding lifestyle variables, athletes had lower sedentary time and higher daily energy consumption. Although we have found moderately lower sedentary time in athletes, when compared to non-athletes, it is not always so, as previous studies reported that athletes can be highly active and have high sedentary time, because of an independent relationship between moderate-to-vigorous physical activity time and sitting time (Swartzendruber, Croteau, & Maine, 2020; Weiler, Aggio, Hamer, Taylor, & Kumar, 2015). The relationship among high sedentary time for athletes' health, risk of cardiovascular and metabolic diseases, despite high activity level, remains to be seen.

In their self-reporting, athletes rated their health and quality of life worse than did non-athletes. Although their health status did not reflect any serious medical condition or show any chronic diseases, we can speculate that athletes report lower QoL due to their recent injury experience as these lower scores primarily affect social and global functioning, suggesting that they feel that their injuries limit their ability to participate in sports and social life (McGuine, Winterstein, Carr, Hetzel, & Scott, 2012; Valovich McLeod, Bay, Parsons, Sauers, & Snyder, 2009). It is also evident that athletes eat more regularly, place more emphasis on breakfast, eat healthy snacks with higher intake of animal-sourced protein, and consume less fats and less alcohol. Our findings are consistent with adolescent athletes eating healthier and having more varied diets (von Rosen, Olofsson, Väsbom, & Heijne, 2019).

The major limitation of the study was the small sample number and low response rate of participants for re-testing (11 %). This is a major shortcoming of all longitudinal studies due to the EU regulation of personal data protection, disinterest of participants in attending the later measurements, and certainly in this case the COVID-19 pandem-

ics. Furthermore, we had both sexes in both groups but of similar distribution. Therefore, we have done only effect size estimation without statistical hypothesis testing.

CONCLUSION

Despite the small sample we can identify a trend which confirms that many years of sports participation and regular exercise have positive effects on physical fitness and motor abilities, and especially on the contractile properties of the skeletal muscles. Athletes have lower body mass index, exhibit greater running speed, better jumping performance and shorter contraction time of the posterior thigh muscle. Athletes also spent less time sitting and have higher daily energy expenditure than non-athletes, but this was not reflected on fat mass. The contraction time of the anterior thigh muscles, which did not differ between the groups, confirms our previous findings that the daily stimulus of the postural muscles is large enough to maintain contractile properties, which is not the case for the posterior thigh muscles, which are less used during daily tasks. We also found healthier lifestyle habits in athletes. They practice healthier diet regimes with more regular meals containing more protein (meat products, poultry) as well as fewer health-risk practices (smoking and alcohol consumption); regarding the self-assessed quality of life, athletes reported lower health status and general quality of life, which can be explained by the reported injuries and strict sport regimes of athletes.

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REPORTS AND REVIEWS
POROČILA IN OCENE

REPORTS AND REVIEWS/POROČILA IN OCENE, 137–144

11th INTERNATIONAL SCIENTIFIC AND PROFESSIONAL CONFERENCE "A CHILD IN MOTION"

Portorož, Slovenia, 4–6 October 2021

In the two years that had passed since our previous conference, we overcame a period of lockdowns when it was at times difficult to follow and adapt to all the new rules of work and communication, but despite the new "reality," science and practice met at the 11th International Scientific and Professional Conference "A Child in Motion." This time the working title of the conference, "The lockdown aftermath," suggested what we had experienced missed and learned during this period. We analyzed topics engendered by this situation in scientific and professional language, again enjoying the hospitality of the Grand Hotel Bernardin and the towns of Portorož and Piran.

The two-day program offered 3 plenary lectures and 11 keynote speakers who presented current research from the educational, paediatric, kinesiology, physiological,

socio-psychological, and nutritional fields on the impact of the COVID-19 pandemic on children. Prominent speakers highlighted current evidence on child well-being in the aftermath of the pandemic.

The "Book of Proceedings" contains 35 scientific and 121 professional papers by more than 200 authors and co-authors from over a dozen European countries. The papers present current research findings as well as examples of best practices by teachers and educators in addressing the challenges of physical inactivity, eating habits, social contact, and more, that had arisen as a result of the pandemic and consequent home schooling. The success of this conference would not have been possible without all of our partner organizations and our sponsors. We are proud to have the patronage of the Human Rights Ombudsman of the Republic of Slovenia, Mr. Peter Svetina included among them.

The positive feedback from participants confirms that the added value of on-site conferences is not only the in vivo presentations, but also the excellent opportunity to network, share best practices, and meet new people during the coffee breaks and social events.

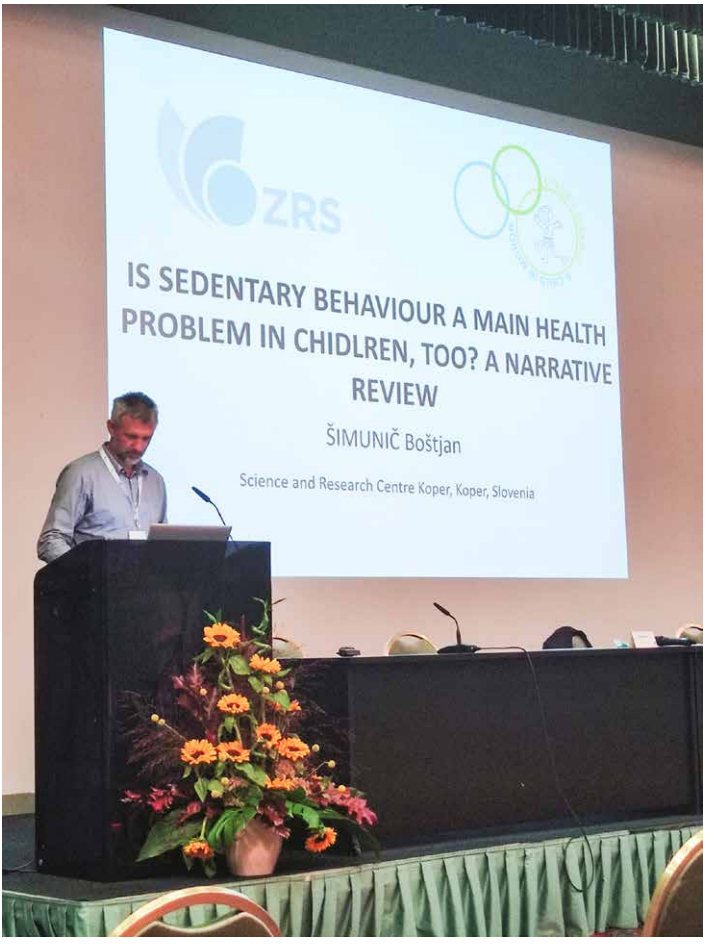
Saša Pišot and Kaja Teraž

REPORTS AND REVIEWS/POROČILA IN OCENE, 137–144

11. MEDNARODNA ZNANSTVENA IN STROKOVNA KONFERENCA OTROK V GIBANJU

Portorož, Slovenija, 4.–6. oktober 2021

V dveh letih, ki so minila od naše zadnje konference, v času restriktivnih ukrepov, ki jim je bilo včasih težko slediti, še težje pa novim pravilom prilagajati delo in sporazumevanje, nam je uspelo, da se ponovno srečamo na 11. mednarodni znanstveni in strokovni konferenci Otrok v gibanju 2021 in uživamo gostoljubje Grand Hotela Bernardin ter obalnih mest Portorož in Piran. Tokratni delovni naslov konference Premagajmo posledice ukrepov omejitve gibanja je izražal, analiziral in nagovarjal teme tega časa, v znanstvenem in strokovnem jeziku.



Dvodnevni program je ponudil tri plenarna in 11 uvodnih predavanj, v katerih so predavatelji predstavili aktualna dognanja, povezana s posledicami pandemije covida-19 na otroke.

Zbornik prispevkov vsebuje 35 znanstvenih in 121 strokovnih prispevkov več kot 200 avtorjev in soavtorjev iz ducata evropskih držav. V prispevkih so predstavljene aktualne ugotovitve raziskav in primeri dobre prakse učiteljev, vzgojiteljev, pediatrov, kineziologov, dietetikov, fiziologov, psihologov, sociologov itd. pri reševanju izzivov na področju telesne (ne)aktivnosti, prehranjevalnih navad, socialnih stikov in drugega, ki so se pojavili kot posledica pandemije in šolanja na domu. Uspeh te konference ne bi bil mogoč brez vseh naših partnerskih organizacij in sponzorjev. V posebno čast pa si štejemo tudi tokratno častno pokroviteljstvo varuha človekovih pravic Republike Slovenije Petra Svetine.

Pozitivni odzivi udeležencev konference potrjujejo, da dodana vrednost konferenc »v živo« niso le predavanja, temveč da so te tudi odlična priložnost za mreženje, izmenjavo dobrih praks in spoznavanje novih ljudi med odmori za kavo in družabnimi dogodki.

Saša Pišot in Kaja Teraž

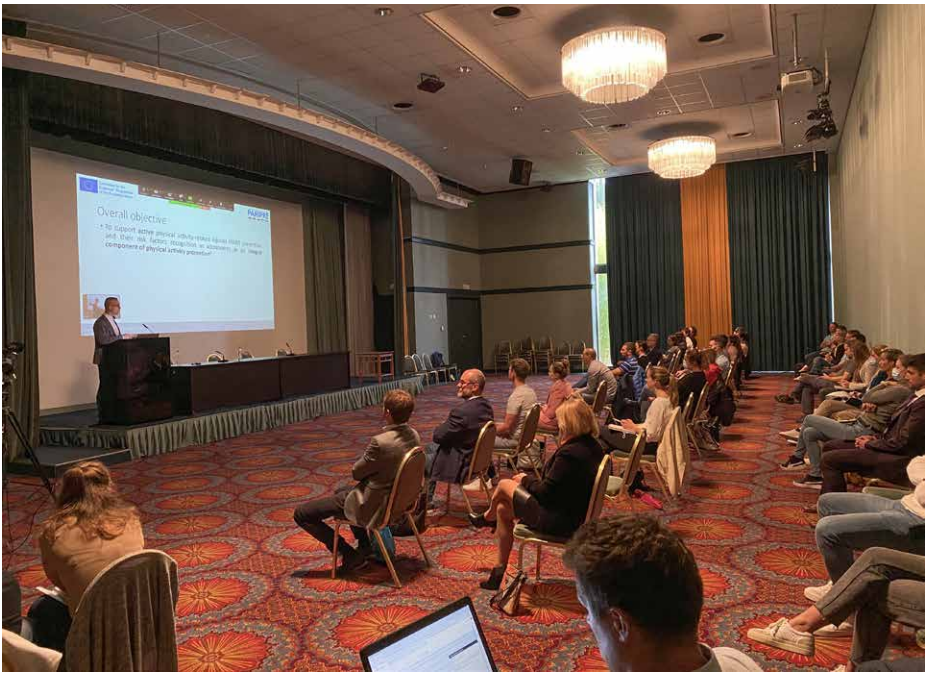
REPORTS AND REVIEWS/POROČILA IN OCENE, 137–144

WORKSHOP REPORT: PHYSICAL ACTIVITY-RELATED INJURIES PREVENTION IN ADOLESCENTS. WHAT DO WE KNOW?

Piran, Slovenia, October 6, 2021

The Institute for Kinesiology Research at ZRS Koper participates in the international project *Prevention of physical activity injuries in adolescents* (PARIPRE), led by the University of Prešov, Slovakia. A total of eight partners, of which on the Slovenian side the Slovenian Sports Union and the National Institute of Public Health are also collaborators, are investigating risk factors and prevention programs to reduce injuries in 12-to-18-year-olds.

At the workshop we presented scientific background on the importance of preventive measures for different stakeholders. Altogether 79 participants from seven countries joined the workshop. The program started with opening remarks from prof. dr. Rado Pišot and prof. dr. Boštjan Šimunič from Science and Research Centre Koper, organizers of the workshop. This was followed by remarks from Vesna Marinko (Ministry of Health RS) who underlined the importance of the topic of physical activity-related injuries prevention in adolescence. Then a project presentation was given by Peter Bakalár from the University of Prešov (Slovakia).



Regular physical activity and sport is one of the most recognized determinants of health protection, particularly for the prevention of major chronic non-communicable diseases. In adolescents, physical activity and sport contribute to healthy musculoskeletal, cardiovascular, respiratory, immune, and metabolic development and help maintain physical fitness and healthy body mass. It is also associated with several psychological and social benefits. Appropriate physical and sporting activity have no harmful effects, but there is an increased risk of injury during exercise, especially in high-intensity sports, but also in low-intensity physical activity if we are poorly prepared for it. Therefore, the prevention of physical activity and sport- related injuries and the identification of risk factors must be an integral part of the promotion of physical activity and sport. An increased risk of injury is also posed by the physical inactivity that is now prevalent in the modern sedentary lifestyle, which has been exacerbated during this COVID-19 era.

This talk was followed with the presentation of sport injuries epidemiology by prof. dr. Jari Parkkari from UKK Institute (Finland). No less than 47% of children are injured at least once in a year, with 50% of injuries occurring in sports clubs, 30% in recreational activities and 20% at school. Boys are more prone to injury than girls. Sports club membership is an underlying risk factor for hospitalization of children after injury, which must be considered as a logical cause-effect relationship. If we disregard the current situation with COVID-19 (where we can see a sharp decrease in participation in sports clubs), we have observed an increase in the number of people involved in sports clubs (in Finland from 46% in 2010 to 62% in 2016 and in Slovenia even 82% in 2019). On the other hand, the physical inactivity of children and young people (at school, at home, during leisure time) is also increasing at an extreme rate, which also affects the increase in the number of injuries during physical and sporting activity and represents a major public health problem.

Afterwards, dr. Mari Leppänen from UKK Institute (Finland) presented *Sport Injury Prevention Strategies and Measures* and a draft of *Recommendations for the prevention of physical activity-related injuries in adolescents*. The latter were discussed among various stakeholders and their comments were considered and incorporated in the final version of the recommendations that was prepared following the workshop. The recommendations were later published in a scientific journal, sent to stakeholders and are available at the webpage: https://www.paripre.eu/wp-content/uploads/2022/02/2021_PARIPRE_Recommendations.pdf.

Boštjan Šimunič

REPORTS AND REVIEWS/POROČILA IN OCENE, 137–144

POROČILO DELAVNICE: PHYSICAL ACTIVITY-RELATED INJURIES PREVENTION IN ADOLESCENTS. WHAT DO WE KNOW?

Piran, Slovenija, 6. oktober 2021

Inštitut za kineziološke raziskave ZRS Koper sodeluje v mednarodnem projektu *Physical activity-related injury prevention in adolescents* (PARIPRE), ki ga vodi univerza v Prešovu, Slovaška. Osem partnerjev, od katerih na slovenski strani sodelujeta še Športna unija Slovenije in Nacionalni inštitut za javno zdravje, proučuje dejavnike tveganja in preventivne programe zmanjševanja poškodb pri mladostnikih, starih od 12 do 18 let.

Na delavnici smo predstavili znanstvena izhodišča preventivnih ukrepov za različne deležnike preventive športnih poškodb. Delavnice se je udeležilo 79 udeležencev iz sedmih držav. Po uvodnih nagovorih prof. dr. Rada Pišota in prof. dr. Boštjana Šimunič iz Znanstveno-raziskovalnega središča Koper je pomembnost teme poudarila Vesna Marinko z Ministrstva za zdravje. Sledila je predstavitev projekta s strani vodje izr. prof. dr. Petra Bakalárja iz univerze v Prešovu (Slovaška). Redna gibalna/športna aktivnost je med najbolj prepoznanimi dejavniki varovanja zdravja, predvsem za preprečevanje vodilnih kroničnih nenalezljivih bolezni. V mladosti gibalna/športna aktivnost prispeva k zdravemu razvoju skeletno-mišičnega, srčno-žilnega, dihalnega, imunskega in presnovnega sistema, pomaga vzdrževati telesno pripravljenost in primerno tele-

sno maso. Povezana je tudi s številnimi psihološkimi in socialnimi koristmi. Ustrezna gibalna/športna aktivnost nima škodljivih učinkov, pri ukvarjanju z njo pa se pojavi povečano tveganje za poškodbe, predvsem med visoko intenzivnimi športi in tudi med nižje intenzivnimi gibalnimi aktivnostmi, če smo slabo pripravljeni nanje. Zato morata biti preprečevanje poškodb pri gibanju in športu in prepoznavanje dejavnikov tveganja sestavna dela spodbujanja gibalne/športne aktivnosti. Povečano tveganje za poškodbe pomeni tudi gibalna neaktivnost, ki je značilna za današnji prevladujoči sedentarni življenjski slog, ki se v času covida-19 še krepi.

Aktualne podatke o športnih poškodbah pri mladih je predstavil prof. dr. Jari Parkkari z inštituta UKK (Finska). Kar 47 % otrok se poškoduje vsaj enkrat v letu dni, pri čemer se 50 % poškodb zgodi v športnih klubih, 30 % med prostim časom in 20 % med šolskim časom. Dečki so poškodbam bolj podvrženi kot deklice. Članstvo v športnih klubih je temeljni dejavnik tveganja za hospitalizacijo otrok po poškodbi, kar pa je treba jemati kot logično vzročno-posledično razmerje. Če odmislimo trenutne okoliščine s covidom-19 (ko beležimo velik upad vključenosti v športne klube), smo bili v zadnjih letih priča povečevanju števila vključenih v športne klube (na Finskem s 46 % v letu 2010 na 62 % v letu 2016 in v Sloveniji celo na 82 % v letu 2019), hkrati pa se izjemno povečuje tudi gibalna neaktivnost otrok in mladostnikov (v šolah, doma, v prostem času), kar tudi vpliva na povečevanje števila poškodb med gibalno/športno aktivnostjo in je velik javnozdravstveni problem.

V glavnem delu je dr. Mari Leppanen z inštituta UKK predstavila osnutek strategij in priporočil *Sport Injury Prevention Strategies and Measures* in *Recommendations for the prevention of physical activity-related injuries in adolescents*. Med interaktivno delavnico smo natančno pregledali vse ukrepe priporočil in jih posodobili. Po končani delavnici smo projektni partnerji naredili čistopis priporočil, jih objavili v znanstveni reviji in z njimi seznanili vse deležnike športnih poškodb. Priporočila so na voljo na spletni strani: https://www.paripre.eu/wp-content/uploads/2022/02/2021_PARIPRE_Recommendations.pdf.

Boštjan Šimunič

GUIDELINES FOR AUTHORS, 145–148

GUIDELINES FOR AUTHORS

1. Aim and scope of the journal:
Annales Kinesiologiae is an international interdisciplinary journal covering kinesiology and its related areas. It combines fields and topics directed towards the study and research of human movement, physical activity, exercise and sport in the context of human life style and influences of specific environments. The journal publishes original scientific articles, review articles, technical notes and reports.

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e) The authors are obliged to prepare two **abstracts** – one short abstract in English and one (translated) in Slovene language. For foreign authors translation of the abstract into Slovene will be provided. The content of the abstract should be structured into the following sections: purpose, methods, results, and conclusions. It should only contain the information that appears in the main text, and should not contain reference to figures, tables and citations published in the main text. The abstract is limited to 250 words.

f) Under the abstract a maximum of 6 appropriate **Keywords** shall be given in English and in Slovene. For foreign authors the translation of the key words into Slovene will be provided.

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h) Each **table** should be submitted on a separate page in a Word document after the Reference section. Tables should be double-spaced. Each table shall have a brief caption; explanatory matter should be in the footnotes below the table. Abbreviations used in the tables must be consistent with those used in the main text and figures. Definitions of symbols should be listed in the order of appearance, determined by reading horizontally across the table and should be identified by standard symbols. All tables should be numbered consecutively Table 1, etc. The preferred location of the table in the main text should be indicated preferably in a style as follows: *** Table 1 somewhere here ***.

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The journal uses the Harvard reference system (Publication Manual of the American Psychological Association, 6th ed., 2010), see also: https://www.apastyle.org). The list of references should only include work cited in the main text and being published or accepted for publication. Personal communications and unpublished works should only be mentioned in the text. References should be complete and contain up to seven authors. If the author is unknown, start with the title of the work. If you are citing work that is in print but has not yet been published, state all the data and instead of the publication year write „in print".

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Examples of reference citation in the text

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Three to six authors:
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Seven or more authors:
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Books
Latash, M. L. (2008). Neurophysiologic basis of movement. Campaign (USA): Human Kinetic.

Journal articles
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Šimunič, B., Koren, K., Rittweger, J., Lazzer, S., Reggiani, C., Rejc, E., … Degens, H. (2019). Tensiomyography detects early hallmarks of bed-rest-induced atrophy before changes in muscle architecture. Journal of applied physiology, 126(4), 815–822. https://doi.org/10.1152/japplphysiol.00880.2018

Book chapters

Šimunič, B., Pišot, R., Mekjavić, I. B., Kounalakis, S. N. & Eiken, O. (2008). Orthostatic intolerance after microgravity exposures. In R. Pišot, I. B. Mekjavić, & B. Šimunič (Eds.), The effects of simulated weightlessness on the human organism (pp. 71–78). Koper: University of Primorska, Scientific and research centre of Koper, Publishing house Annales.

Rossi, T., & Cassidy, T. (in press). Teachers' knowledge and knowledgeable teachers in physical education. In C. Hardy, & M. Mawer (Eds.), Learning and teaching in physical education. London (UK): Falmer Press.

Conference proceeding contributions

Volmut, T., Dolenc, P., Šetina, T., Pišot, R. & Šimunič, B. (2008). Objectively measures physical activity in girls and boys before and after long summer vacations. In V. Štemberger, R. Pišot, & K. Rupret (Eds.) Proceedings of 5th International Symposium A Child in Motion "The physical education related to the qualitative education" (pp. 496–501). Koper: University of Primorska, Faculty of Education Koper, Science and research centre of Koper; Ljubljana: University of Ljubljana, Faculty of Education.

Škof, B., Cecić Erpić, S., Zabukovec, V., & Boben, D. (2002). Pupils' attitudes toward endurance sports activities. In D. Prot, & F. Prot (Eds.), Kinesiology – new perspectives, 3rd International scientific conference (pp. 137–140), Opatija: University of Zagreb, Faculty of Kinesiology.

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