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Kinesiologia Slovenica (KinSI)

Kinesiologia Slovenica (KinSI) is an international forum for scholarly reports on kinesiology, broadly defined. The journal publishes empirical and theoretical contributions related to the science of physical activity, human movement, exercise, and sport. It is aimed at enhancing the knowledge (theoretical and practical) in these fields. Manuscripts which deal with high quality research and comprehensive research reviews will be considered for publication. The journal is open to the use of diverse methodological approaches.

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EDITORS FOREWORD

Dear Readers,

It is with great pleasure and enthusiasm that we present to you the second issue of Kinesiologia Slovenica in the year 2023. As the editors of this esteemed journal, we are thrilled to witness the continuous growth and global recognition that this platform has achieved.

In this issue, we take immense pride in publishing a remarkable collection of 14 articles from the most diversified countries to date. Kinesiologia Slovenica has always strived to foster international collaboration and knowledge exchange within the field of kinesiology, and this issue exemplifies our commitment to embracing perspectives from all corners of the globe.

The authors whose research we showcase hail from Turkey, Kosovo, Portugal, Australia, Slovenia, USA, Abu Dhabi, Serbia, United Arab Emirates, Japan, and Croatia. This truly international representation is a testament to the widespread impact and relevance of kinesiology in different cultural contexts and geographical regions.

The articles selected for this issue encompass a wide spectrum of topics within the realm of kinesiology, ranging from cutting-edge research in exercise physiology, biomechanics, sports psychology, and rehabilitation to innovative studies in physical education and movement science. The diversity of content reflects the richness of this interdisciplinary field and its profound implications for human health, performance, and well-being.

We extend our deepest gratitude to the authors who have contributed their work to this issue. Their dedication and commitment to advancing the understanding of kinesiology have been pivotal in shaping this publication. We also extend our heartfelt appreciation to our esteemed reviewers, whose expertise and critical insights have ensured the high quality and rigor of the articles published herein.

Lastly, we would like to express our gratitude to you, our valued readers and supporters. Without your unwavering interest in Kinesiologia Slovenica, this platform would not be the thriving hub of knowledge and innovation that it has become.

As we move forward, we remain committed to promoting excellence in kinesiology research and providing a platform for scholars from all corners of the globe to share their findings and ideas. We invite you to dive into the pages of this second issue, immerse yourself in the diversity of perspectives, and join us in celebrating the truly global reach of kinesiology.

Thank you for being a part of this remarkable journey with us.

With best regards,

Assist. Prof. Dr. Vedrana Sember

Editor-in-Chief

PREDGOVOR

Spoštovani bralci.

Z velikim veseljem in navdušenjem vam predstavljamo drugo številko Kinesiologie Slovenice v letu 2023. Kot uredniki imenovane revije smo navdušeni nad nenehno rastjo in prepoznavnostjo, kar tudi potrjuje faktor vpliva, ki smo ga prijeli za leto 2022.

V tej številki objavljamo izjemno zbirko 14 člankov iz najbolj raznolikih držav doslej. Kinesiologia Slovenica si že od nekdaj prizadeva spodbujati mednarodno sodelovanje in izmenjavo znanja na področju kineziologije, ta številka pa ponazarja našo zavezo k sprejemanju perspektiv z vseh koncev sveta.

Avtorji, katerih raziskave predstavljamo, prihajajo iz Turčije, Kosova, Portugalske, Avstralije, Slovenije, ZDA, Abu Dabija, Srbije, Združenih Arabskih Emiratov, Japonske in Hrvaške. Ta resnično mednarodna zastopanost je dokaz širokega vpliva in pomena kineziologije v različnih kulturnih kontekstih in geografskih regijah.

Članki, izbrani za to številko, obsegajo širok spekter tem s področja kineziologije, od vrhunskih raziskav fiziologije vadbe, biomehanike, športne psihologije in rehabilitacije do inovativnih študij športne vzgoje in znanosti o gibanju. Raznolikost vsebine odraža bogastvo tega interdisciplinarnega področja in njegove globoke posledice za človekovo zdravje, uspešnost in dobro počutje.

Avtorjem, ki so s svojim delom prispevali k tej številki, se iskreno zahvaljujemo. Njihova predanost in predanost napredku pri razumevanju kineziologije sta bili ključni pri oblikovanju te številke. Prav tako se iskreno zahvaljujemo našim recenzentom, katerih strokovnost in kritični vpogledi so zagotovili visoko kakovost objavljenih člankov.

Navsezadnje bi radi izrazili svojo hvaležnost vam, spoštovanim bralcem in podpornikom. Brez vašega zanimanja za Kinesiologio Slovenico ta revija ne bi bila tako uspešna kot je danes.

Ko gremo naprej, ostajamo zavezani pri spodbujanju odličnosti v kinezioloških raziskavah in zagotavljanju prostora za raziskovalce z vseh koncev sveta. Vabljeni k branju nove številke!

Hvala, ker ste del tega izjemnega potovanja z nami.

Z lepimi pozdravi,

Doc. Dr. Vedrana Sember

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CHANGE OF DIRECTION SPEED UNDER TWO LOADING CONDITIONS AMONG FEMALE POLICE OFFICERS: ASSOCIATION WITH BODY MORPHOLOGY

AGILNOST V DVEH POGOJIH OBREMENITVE MED POLICISTKAMI: POVEZAVA Z TELESNIMI ZNAČILNOSTMI

ABSTRACT

Change of direction speed (CODS) is an important performance ability for police officers. This is even more emphasized when officers perform tasks while carrying their occupational load (e.g., protective vest, weapon, radio, cuffs, etc.). The absolute weight of the equipment remains the same regardless of officer's body size and weight, which is of importance for female police officers whose morphology is different than in males. This study investigated the associations between selected measures of body morphology and CODS among female police officers under two loading conditions. The sample consisted of 29 female police officers (age = 32.00±5.09 yrs, body height = 162.92±5.01 cm, and body mass = 70.88±13.42 kg). Anthropometric variables included height, weight, and body mass index (BMI), while body composition characteristics included percent body fat, (PBF), percentage of skeletal muscle mass (PSMM), and index of hypokinesia (IH). CODS was assessed using the Illinois agility tests under loaded (LIAT) (10 kg vest) and unloaded (IAT) conditions. Participants' CODS times were significantly slower in the LIAT condition ($p < 0.001$). IAT correlated to BMI ($r=0.479$, $p<0.05$), PBF ($r=0.647$, $p<0.001$), PSMM ($r=-0.655$, $p\leq0.001$), and IH ($r=0.462$, $p<0.05$). Similarly, LIAT was associated with BMI ($r=0.446$, $p<0.05$), PBF ($r=0.651$, $p<0.001$), PSMM ($r=-0.672$, $p<0.001$), and IH ($r= 0.503$, $p<0.01$). These findings highlight the need for developing specific physical training programs aimed at improving and maintaining healthy body composition levels among female officers if improved CODS is the goal.

Keywords: agility, tactical athletes, law enforcement, body composition, physical performance

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IZVLEČEK

Agilnost (CODS) je pomembna zmogljivost policistov. Ta je še bolj poudarjena, kadar policisti opravljajo naloge, medtem ko nosijo svoje poklicno breme (npr. zaščitni jopič, orožje, radio, manšete itd.). Absolutna teža opreme ostaja enaka, ne glede na spol, telesno višino in maso policista, kar je pomembno za policistke, katerih morfologija je drugačna kot pri moških. Ta študija je preučevala povezave med izbranimi merami telesnih značilnosti in CODS med policistkami v dveh pogojih obremenitve. Vzorec je sestavljalo 29 policistk (starost = 32.00±5.09 let, telesna višina = 162.92±5.01 cm in telesna masa = 70.88±13.42 kg). Antropometrične spremenljivke so vključevale telesno višino, telesno težo in indeks telesne mase (ITM). Značilnosti telesne sestave pa odstotek telesne maščobe (PBF), odstotek mase skeletnih mišic (PSMM) in indeks hipokinezije (IH). CODS je bil ocenjen s testom agilnosti Illinois, z obremenitvijo (LIAT) (10-kilogramski jopič) in brez obremenitve (IAT). Čas CODS policistk je bil v stanju LIAT bistveno počasnejši ($p < 0.001$). IAT je bil povezan z indeksom telesne mase ($r = 0.479$, $p < 0.05$), PBF ($r = 0.647$, $p < 0.001$), PSMM ($r = 0.655$, $p \leq 0.001$) in IH ($r = 0.462$, $p < 0.05$). Podobno je bil LIAT povezan z indeksom telesne mase ($r=0.446$, $p<0.05$), PBF ($r=0.651$, $p<0.001$), PSMM ($r=-0.672$, $p<0.001$) in IH ($r= 0.503$, $p<0.01$). Te ugotovitve poudarjajo potrebo po razvoju posebnih programov telesne vadbe, namenjenih izboljšanju in ohranjanju zdravih ravni telesne sestave med policistkami, če je cilj izboljšanje CODS.

Ključne besede: agilnost, taktični športniki, kazenski pregon, telesna sestava, telesna zmogljivost

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INTRODUCTION

Law enforcement is a physically demanding occupation (Drain & Reilly, 2019; Lentine et al., 2021). In general, police officers are expected to possess the ability to regularly perform tasks requiring lower and upper body power, speed, strength, agility, flexibility, and endurance (Marins et al., 2019; Maupin et al., 2018). These tasks may include, but are not limited to: foot pursuits of varying distances, changing directions to avoid obstacles or apprehend a suspect, and seeking cover (Anderson, Plecas, & Segger, 2001; Marins et al., 2019; Thomas et al. 2018). In addition to performing these tasks under chaotic and rapidly changing conditions, police officers also need to possess the ability to perform these tasks while wearing duty loads weighing approximately 10 kg (Baran et al. 2018). This duty load is typically comprised of body armor and other essential equipment such as a baton, radio, handcuffs, sidearm, and flashlight (Baran et al., 2018). Although the purpose and significance of officer's wearing their occupational load is well understood, current research suggests that these loads have a negative impact on specific measures of physical performance, such as speed and agility (Kukić et al., 2020; Lyons et al., 2005; Na et al., 2016). Thus, it is of utmost importance to understand the impact physical fitness has on performing occupational tasks and how to enhance performance through physical training.

Numerous studies have reported the deleterious effects of duty load on sprint ability and change of direction speed (CODS) performance among male and female tactical operators (Carlton et al. 2014; Schram et al. 2019; Thomas et al., 2018). Carlton et al. (2014) found significant increases in time to complete a tactical movement and 80 kg dummy drag task when specialist tactical officers were loaded with a 22 kg occupational load compared to an unloaded condition. Additionally, Dempsey et al. (2013) reported that time to complete a simulated vehicle exit and sprint (mean time = 1.95 s loaded, 1.67 s unloaded, $p < 0.001$) and time to complete a mobility battery (mean time = 18.16 s loaded, 15.85 s unloaded, $p < 0.001$) were significantly increased when subjects were wearing stab-resistant body armor weighing 7.65 ± 0.73 kg. However, little evidence exists regarding the impacts of duty load on physical performance within female law enforcement populations specifically.

Although previous research has highlighted the negative effects of duty load on occupational performance, the individual's body mass can also impact sprint ability and CODS (Kukić et al., 2020; Pihlainen et al. 2018; Schram et al., 2019). For instance, Pihlainen et al. (2018) reported that successful completion of an occupationally relevant military simulation test was strongly

related to body fat percentage ($rs = 0.53$, $p < 0.001$) and skeletal muscle mass ($rs = -0.47$, $p < 0.001$). The investigators concluded that as the percent of body fat (PBF) increased, task completion times also increased. In contrast, as skeletal muscle mass increased, completion time on these tasks decreased. Similar findings have been reported within law enforcement populations (Kukić et al., 2020; Lockie et al., 2018). A recent study by Lockie et al. (2018) provided evidence that law enforcement recruits with a greater waist circumference, irrespective of sex, tend to have poorer fitness test performance, while Kukić et al. (2020) found that body composition was a significant predictor of performance in the Illinois agility test (IAT).

Female police officers may have to pursue offenders on foot, while wearing duty loads that are relatively heavier than those carried by male officers (Kukić et al., 2020). These duty loads reduce mobility and are associated with physical performance (Loverro et al. 2015; Na et al., 2016). Also, due to the propensity of females, in general, to possess greater body fat and lower levels of skeletal muscle compared to their male counterparts (Dopsaj et al., 2020), the ability to change direction may be further impacted (Kukić et al., 2020). Therefore, understanding the relationships between fitness measures and load carriage during a CODS task among female officers may help inform physical conditioning requirements to improve occupational performance (e.g., ability to pursue offenders on foot while wearing occupational loads). On this basis, the aims of this research were to investigate the effects of occupational load on a short explosive CODS task among female police officers and determine if body composition measures were related to occupational load carriage requirements during a change of direction task. The authors hypothesized that there would be a strong relationship between body composition and CODS performance in both loaded and unloaded conditions.

METHODS

An applied non-experimental cross-sectional research design was conducted on a random sample of female police officers from the Abu Dhabi Police to investigate the association of lower-body power, and anthropometrics to change of direction speed under two loading conditions. The IAT was performed without load and with a 10-kg loaded vest and correlated with lower-body power. Additionally, five main body characteristics were assessed, height, body mass, body mass index (BMI), PBF, and percent skeletal muscle mass (PSMM) to provide insight into the relationship between these anthropometric measures and performance.

Participants

The sample utilized in this investigation consisted of 27 female police officer (age = 32.2 ± 5.1 yrs, height = 162.8 ± 5 cm, and body mass = 71.31 ± 13.42 kg). It should be noted that the descriptive data for this sample of officers has been reported elsewhere (Orr et al., 2019) but this data was utilized for a different purpose. The mean length of service was 8.3 ± 3.2 years. The assessments of physical abilities were conducted as part of the regular physical conditioning for this agency. Prior to testing, all subjects signed an informed consent, granting permission to utilize the collected data for research and publishing purposes. As such, this research was carried out in accordance with the conditions set forth by the Declaration of Helsinki (Williams, 2008), and with the ethical approval number 440-2 of the ethical board of the University of Criminal Investigation and Police Studies, Serbia.

Protocol

The assessments were conducted over two days, 24-48 hours apart. Anthropometrics and body composition measures were collected on the first day, while power and CODS tests were assessed on the second day. Physical ability testing was preceded by a standard 15-minute warm-up (e.g., low aerobic intensity jogging and calisthenics, bodyweight squats, lunges, and jumps). Following a detailed explanation and demonstration of each test. All subjects performed one practice trial followed by two consecutive experimental trials with the best test trial being recorded as their final score and used for further analysis. The rest periods between consecutive trials were 2 minutes, and between two consecutive tests were 5 minutes, respectively. The subjects first performed the IAT and then Loaded IAT (LIAT) after 5 minutes of rest.

Anthropometrics and body composition

Body characteristics such as height and body mass were assessed using a Seca 769 digital scale with a measuring rod (Hamburg, Germany). BMI, PBF and PSMM were assessed using an 8-channel multi-frequency bioelectric impedance (InBody 720: Biospace Co. Ltd, Seoul, Korea) following previously reported procedures (Dopsaj et al., 2020; Kukić et al., 2020). This device was shown to be valid (r = 0.93), and reliable (ICC = 0.98) (Aandstad et al. 2014). It was also used to track age-related changes in body composition of general public (Dopsaj et al., 2020, 2021) and to differentiate elite athletes by morphological characteristics (Dopsaj et al., 2021). The official InBody service provider (Borf d.o.o, Belgrade, Serbia) calibrated the machine twice a year (once each six months). In short, all measurements were conducted before breakfast

between 08:00 and 10:00 h by experienced examiners and subjects were instructed to fast for 12 hours prior to testing and to refrain from strenuous exercise 48 hours prior testing. Subjects were wearing sports shorts and T-shirt, were barefoot, and had all metal, plastic, and magnetic accessories removed, stood on the device and on the metal spots designated for their feet. In their hands, they held the device's handles with electrodes. Hands were positioned next to the body in slight abduction so the hands do not touch the body. The outcome measures from this device were printed out, but only PBF and PSMM were used for the analyses.

Change of direction speed (CODS)

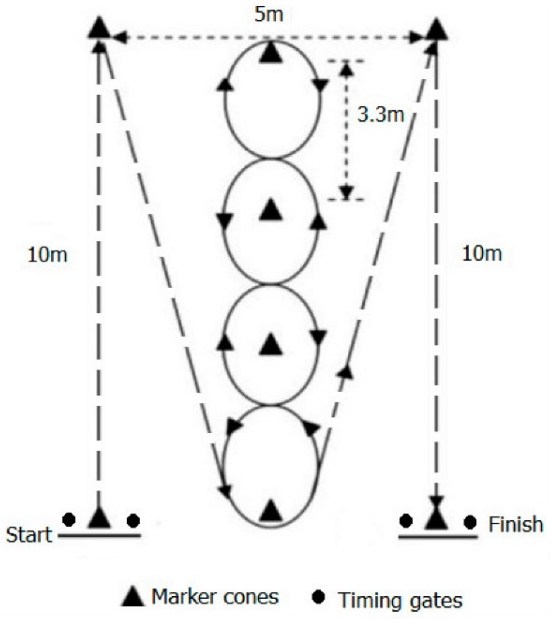
The IAT provides information about the ability to accelerate, decelerate, turn in different directions, as well as run at different angles, and has been used to establish criterion data for males and females (Miller et al., 2006). Hachana et al. (2013) reported a high intra-trial reliability of this test (ICC = 0.96). The IAT was performed in loaded and unloaded conditions. For the loaded condition, the subjects wore an adjustable 10 kg vest (Figure 1). A 400-g vest was loaded with additional 24 small 400-g pouches filled with lead grain that absorbed the impacts of the vest on the body in acceleration, deceleration, and when changing direction. In addition, the vest was tightened to the body by the strap around the waist. The 400-g pouches were equally distributed at the front and back of the upper body. Only one weight of the west was used, without normalizing to participants' body weight because it mimicked the work load an officer needs to carry regardless of their body size and weight.

Figure 1. Representation of the loaded west.

The IAT and LIAT outcomes were recorded using the electronic timing gates (Fitro Lighteight Gates, Fitronic, Bratislava, Slovakia). Precision of the measurement was 0.01 s. The LIAT and

IAT course was marked by cones as previously explained in detail in research on police (Koropanovski et al., 2022; Orr et al., 2019) and as presented in Figure 2. Two cones were used to mark the turning points, while four center cones were placed down the center and spaced 3.3 m apart. The subjects began the test lying prone on the floor behind the starting line. On command, the subjects ascended and ran forward to the first turning cone. The subjects were required to turn around the first turning cone and moved back to the first center cone, where they weaved up and back through the four center cones. The subjects then ran to the second turning cone. After turning around the second turning cone, the subjects were required to run across the finish line. Subjects were instructed to complete the test as quickly as possible. Participants performed the IAT first, rested for 5 minutes and then they performed the LIAT.

Figure 2. Schematic presentation of Illinois Agility Test.



Statistical Analysis

Descriptive statistics were calculated for mean, standard deviation, minimum, and maximum values. A Shapiro-Wilk test was used to assess the normality of data distribution. Paired sample t-test was used to determine the differences between the IAT performance in unloaded and loaded conditions. The IAT, LIAT, and the obtained differences between the conditions were correlated with participants' body composition characteristics. The significance level was set at $p < 0.05$. The magnitude of correlations were defined as small (r = 0.2 - 0.5), medium (r = 0.5 - 0.8), and large (r > 0.8) (Sullivan & Feinn, 2012). All statistical procedures were

conducted in Statistical Package for Social Sciences (IBM, SPSS Statistics 20, Chicago, IL) and JASP (version 0.16.1).

RESULTS

Descriptive statistics for mean, standard deviation, minimum, and maximum values and the Shapiro-Wilk analysis are shown in Table 1. All variables were normally distributed. Six participants could be classified as normal weight (i.e., BMI ≤ 25kg/m^2) and 21 could be classified as overweight or obese (i.e., BMI > 25 kg/m^2) based on classifications by American College of Sports Medicine (Riebe et al., 2018). Accordingly, parametric statistical analyses were conducted for further analysis.

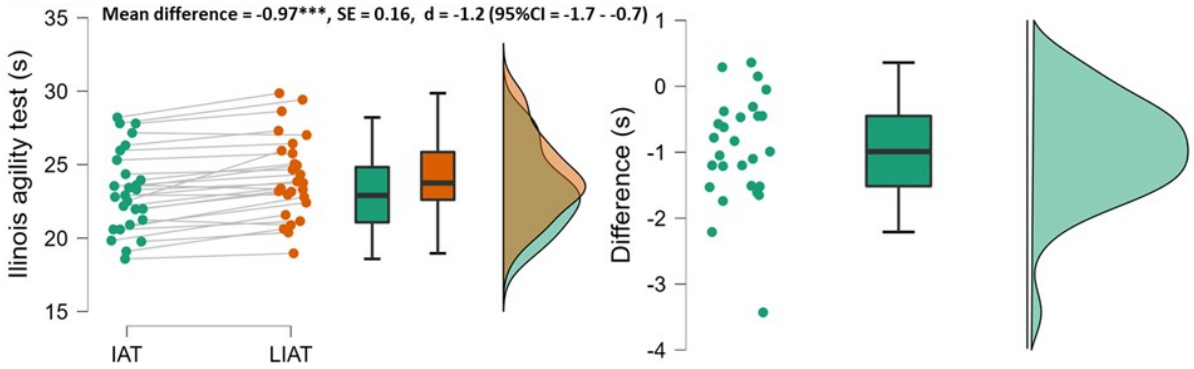
Table 1. Descriptive data for police officers.

Variables	Mean	Std. Deviation	Minimum	Maximum	Shapiro-Wilk
IAT (s)	23.2	2.7	18.6	28.2	0.4
LIAT (s)	24.1	2.8	19.0	29.9	0.8
IATdiff (s)	0.97	0.82	-0.37	3.43	0.2
BM (kg)	71.3	13.4	50.5	109.5	0.3
BMI (kg/m2)	26.9	4.6	20.8	36.6	0.1
PBF (%)	36.2	8.4	15.6	49.8	0.2
PSMM (%)	34.8	4.6	27.4	46.5	0.2
IH (no)	1.3	0.2	0.7	1.8	0.3

Note: IAT – Illinois agility test, LIAT – Loaded Illinois agility test, IADdiff – Difference attained between the IAT and LIAT, BM – Body mass, BMI – Body mass index, PBF – Percent of body fat, PSMM – Percent of skeletal muscle mass, IH – Index of Hypokinesia.

Paired sample t-test showed that the load carried significantly affected the IAT performance as participants performed slower while carrying the load (Figure 3). Only 3 participants performed lower without the load than with the load.

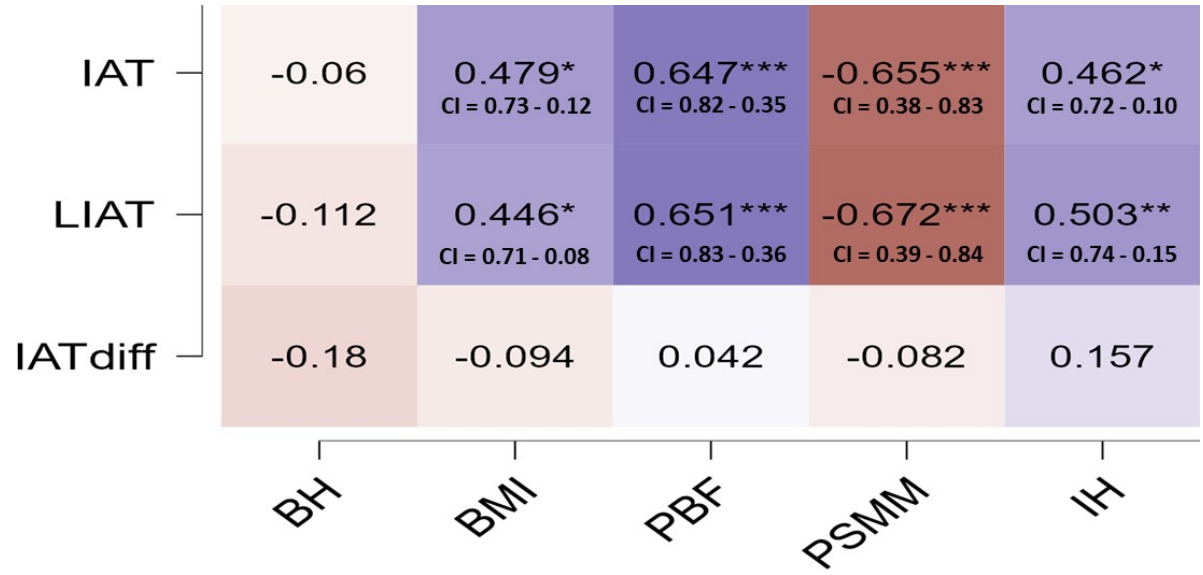
Figure 3. The difference in IAT performance produced by the load carried.



Note: ***Significant at $p < 0.001$. SE – standard error of the difference. IAT – Illinois agility test, LIAT – loaded Illinois agility test.

The correlation analysis revealed that IAT and LIAT performance was significantly correlated to anthropometrics and body composition. Similarities in correlations between anthropometrics and body composition and performance with (LIAT) and without (IAT) load suggests that load carried did not significantly further correlate to anthropometrics and body composition (Figure 3). The IAT and LIAT inversely correlated with PSMM whereby lower PSMM led to slower IAT and LIAT times.

Figure 4. Correlation heat map for body composition and Illinois agility test in unloaded and loaded conditions.



Note: *Significant at $p < 0.05$, **Significant at $p < 0.01$, and ***Significant at $p < 0.001$. CI = 95% confidence interval (upper limit – lower limit). IAT – Illinois agility test, LIAT – loaded Illinois agility test. BH – body height, BMI – body mass index, PBF – percent of body fat, PSMM – percent of skeletal muscle mass, IH – index of hypokinesia.

DISCUSSION

The purpose of this study was to determine if there were significant associations between select anthropometric measures and body composition with IAT and LIAT performance among female police officer. The results from the present study indicate body composition was significantly correlated to CODS ability as measured by IAT and LIAT performance. Specifically, as PBF decreased IAT and LIAT performance improved. Additionally, as PSMM increased IAT and LIAT performance improved. IAT performance was significantly faster than the LIAT performance, whereby performance differences were associated with BMI, PBF, PSMM, and IH. The results of this study may be utilized by Tactical Strength and Conditioning Facilitators to successfully identify demographic-specific exercise modalities and develop conditioning programs to enhance occupational performance within this population. Additionally, the outcomes of this research show the necessity for a focused approach for healthy body composition if improved CODS is the goal.

The ability to perform essential job-related tasks can be the difference between life and death for a law enforcement officer. Furthermore, previous research indicates that tactical personnel with healthy body compositions, and adequate muscular power, strength, and endurance capabilities perform tasks faster (Carlton et al., 2014; Dawes et al. 2016; Kukić et al., 2020; Lockie et al., 2018). These findings agree with previous research conducted by Sekulic et al. (2013) who investigated the sex-specific influence of body composition, speed, power, and balance, on different agility tests within a population of collegiate athletes. To that end, optimal body composition is a recurring theme within many tactical based manuscripts as they are often significantly related to physical ability (Dawes et al., 2016; Kukic et al., 2018; Kukić et al., 2020; Orr et al. , 2018). PBF, PSMM, and IH were related to IAT and LIAT performance which signifies that achieving and maintaining a healthy body composition can have a positive impact on CODS. Practically, higher skeletal muscle mass and lower body fatness provide better contractile potential of skeletal muscles and lower impacts of ballast mass, thus resulting in better performance of CODS tasks. Note that the correlations were somewhat higher when officers carried the load, which further emphasizes the importance of good body composition. The non-existence of correlations between body composition and obtained differences suggests that the effects of load carried were similar regardless of body composition. Therefore, while improvement and maintenance of body composition are of great importance they should be attained through multidisciplinary strength and conditioning programs as nutrition and diet

management alone may not be sufficient to improve muscular strength with the latter known to be of importance in police officers required to wear and carry load (Orr et al., 2022).

A notable limitation associated with this study is that the reported findings only apply to IAT and LIAT performance. This is primarily due to the fact that other CODS tests were not conducted in the organization from which this data were drawn and as such not investigated. With CODS tests being unique (i.e., IAT requires an individual to start in a prone position whereas a 5-0-5 test requires an individual to start in a standing position) the transferability, while generally applicable, may have some limitations. An additional limitation associated with this study is that nutrition was not controlled and that the samples' body composition could include wider range of body fatness and body muscularity.

CONCLUSION

The results of this study highlight the relationships between CODS and body composition in a female, general duties, law enforcement cadet population. Furthermore, these relationships are significantly influenced by BMI, PBF, and PSMM. In the future, these findings can be used by law enforcement agency administration and staff to develop an evidence-based strength and conditioning program to enhance both the preparedness and performance of female general duties law enforcement officers. The presented analysis identified significant correlations between anthropometric and body composition measures and CODS performance under loaded and unloaded conditions. Understanding how to adequately assess physiological contributors to performance, prepare multidisciplinary strength and conditioning programs for female police officers, and effectively implement those programs are of high importance for future job task performance and the reduction of injury. Altogether, the findings from this analysis should provide support to tactical organizations to implement physical training programs aimed at attaining and maintaining healthy body composition ranges, as well as improving fitness and performance.

Acknowledgment

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Declaration of Conflicting Interests

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SPRINT INTERVAL TRAINING IN HYPOXIA AND EXERCISE PERFORMANCE – A SHORT REVIEW

UČINKI ŠPRINTERSKE INTERVALNE VADBE V HIPOKSIJI NA ŠPORTNO SPOSOBNOST – PREGLEDNI ČLANEK

ABSTRACT

Hypoxia is often used during training to augment metabolic load and heighten physiological adaptations with the aim of exercise performance improvements. The recently established altitude training method »sprint interval training in hypoxia« (SIH) requires individuals to perform multiple 30 s Wingate sprints under hypoxia, interspersed with 3–5 min recovery periods. As the execution of repeated supramaximal efforts in hypoxia does not seem to be compromised, it was hypothesized that SIH might further augment exercise performance compared to sprint interval training in normoxia (SIT). To elucidate the usefulness of hypoxia during sprint interval training for exercise performance a systematic review of the available literature was conducted. The PubMed, SportDiscus™, and Web of Science online databases were searched for original articles – published up to March 2023 – assessing changes in exercise performance following SIH and SIT. Six studies (randomized controlled trials (RCTs)) were identified, evaluating SIH interventions lasting 2–6 weeks. Currently, the available scientific literature does not suggest that SIH additively augments exercise performance in comparison to SIT. The potential changes in anaerobic thresholds after SIH, but not after SIT require further investigation to fully elucidate the subsequent effects on exercise performance. Nevertheless, there is evidence to support beneficial peripheral adaptations known to increase the oxidative and glycolytic capacity, especially in type II, fast-twitch fibers, following SIH, but not SIT. These local adaptations could potentially enable superior improvement in exercise performance after long enough SIH training protocols. Future RCTs on SIH and, particularly, on the performance-related underlying mechanisms seem warranted.

Keywords: altitude, sport, physiology, Wingate test

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IZVLEČEK

Z namenom izboljšanja športne sposobnosti se športniki danes poslužujejo predihovanja hipoksičnega zraka med športno vadbo, kar poveča presnovno obremenitev in potencialno vodi v večje fiziološke prilagoditve. Nedavno uveljavljena »šprinterska intervalna vadba v hipoksiji« (SIH) od posameznikov zahteva zaporedno izvajanje 30-sekundnih Wingatovih šprintov v hipoksiji, ki jim sledi 3–5 min odmora. Ker se je izkazalo, da izvajanje ponavljajočih se supra maksimalnih naporov v hipoksiji ni kompromitirano, je za pričakovati, da bo SIH v primerjavi s šprintersko intervalno vadbo v normoksiji (SIT) v večji meri izboljšala športno sposobnost. Da bi ugotovili učinkovitost dodajanja hipoksije k šprinterski intervalni vadbi za namene izboljšanja športne sposobnosti, smo opravili sistematičen pregled razpoložljive literature. Izvirne članke – objavljene do marca 2023 – na raziskovalno tematiko smo iskali v spletnih zbirkah podatkov PubMed, SportDiscus™ in Web of Science. Vključitvenim kriterijem je ustrezalo šest raziskav (randomiziranih kontroliranih poskusov (RCT)), ki so raziskovale učinkovitost intervencij SIH in SIT v trajanju od 2 do 6 tednov. Trenutno razpoložljiva znanstvena literatura ne nakazuje, da SIH v primerjavi s SIT v večji meri izboljša športno sposobnost. Ugotovljeno povečanje anaerobnega praga po koncu SIH, zahteva nadaljnje preiskave, da lahko v celoti razjasnimo posledične učinke na športno sposobnost. Kljub temu obstajajo dokazi, da SIH privede do koristnih perifernih prilagoditev, ki povečujejo zmogljivost oksidativnih in glikolitičnih procesov, zlasti v hitrih mišičnih vlaknih tipa II. Tovrstne prilagoditve v mišični funkciji pa bi po dovolj dolgih protokolih SIH lahko rezulitarale v večjem izboljšanju športne sposobnosti. V prihodnosti se zahtevajo predvsem novi RCT, ki bodo ugotavljali temeljne mehanizme odgovorne za izboljšanje športne sposobnosti po koncu SIH.

Ključne besede: višina, šport, fiziologija, Wingate testiranje

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INTRODUCTION

Athletes and coaches are constantly looking for training innovations to help them augment performance. In recent years, in addition to endurance athletes (Millet et al., 2010), hypoxic training has also grown popular within team sports (Girard et al., 2017), which are characterized by the fact that their seasons are normally long incorporating numerous important competitions throughout the year. Implementing long-term altitude models such as "live high–train high" (LHTH) and "live high–train low" (LHTL) in-season is challenging, as weekly competitions do not allow for 2 week-long training blocks at altitude (Millet et al., 2010). Also, traveling to mountain regions is not always feasible (travel time, athlete engagement, expenses) and can be limited to top athletes or squads with sufficient time and resources. With the desire to minimize travel constraints and disruption to the athlete's usual training routine, the "live low–train high" (LLTH) method was developed over the last few decades (Girard et al., 2020). LLTH model enables the athletes to live at a low altitude (in "normoxia"), while they perform (part of) their training under continuous or intermittent hypoxic conditions lasting ≤3 $h \cdot day^{-1}$ (cumulative daily hypoxic dose ≤6 $h \cdot day^{-1}$) for 2 to 5 exercise sessions per week (McLean et al., 2014). As the model is performed for only a short period of the day, exercise methods within the LLTH model can apply stronger hypoxic stimuli simulating altitudes up to 6000 m above sea level (Bartsch et al., 2008). At the same time, these exercise methods do not detrimentally affect sleep quality and regeneration, usually observed during prolonged living at higher altitudes (Millet et al., 2010).

Technological improvements enabled new tools and techniques for the implementation of different methods of the LLTH model at low altitudes and/or at sea level; with either decreasing atmospheric pressure (hypobaric hypoxia [HH]) for example in hyperbaric chambers or reducing the fraction of oxygen in the inspired air (F_IO_2; normobaric hypoxia [NH]) by nitrogen (N_2) dilution and/or oxygen (O_2) filtration such as within hypoxic rooms, tents, and corridors (Girard et al., 2013; Wilber, 2007). An interesting alternative to hypoxic exercise is also the technique of voluntary hypoventilation, in which by maintaining a low volume of air in the lungs during an exercise, O_2 diffusion from the lungs into the blood is reduced (Woorons et al., 2010). Additionally, with this technique, athletes can achieve similar hypoxic conditions within the body, as they normally experience at natural altitudes or under NH (Woorons et al., 2014).

A recent review of the LLTH altitude modalities outlined 6 new innovative hypoxic training methods as follows: (1) ischemic preconditioning (IPC), (2) blood flow restriction training

(BFR), (3) repeated sprint training in hypoxia (RSH), (4) voluntary hypoventilation training (VHL), (5) sprint interval training in hypoxia (SIH) and (6) resistance training in hypoxia (RTH) (Girard et al., 2020). While IPC, BFR, RSH, VHL, and RTH have already been reviewed elsewhere (Brocherie et al., 2017; Feriche et al., 2017; Holfelder & Becker, 2018; Incognito et al., 2016; Wortman et al., 2021), the SIH method did not receive much research interest.

Within the LLTH there are essentially two main sprint training protocols: RSH - characterized by repeated maximal exercise bouts of short duration (≤10 s) interspersed with brief recovery periods (≤60 s or exercise-to-rest ratio ≤1:4) and SIH comprised of longer sprints (usually 30-s Wingate sprints) with 2–5 min passive or active recovery (Buchheit & Laursen, 2013; Girard et al., 2017).

Up-to-date, sprint interval training (SIT) has been recognized as an effective and time-efficient training strategy for enhancing skeletal muscle oxidative capacity (Gist et al., 2014) and exercise performance (Koral et al., 2018; Sloth et al., 2013) to same or even larger extent than larger volume moderate-to-vigorous intensity continuous endurance training. Additionally, repeated SIT (8 × 30 s sprint training with 1.5 min recovery) is potentially more beneficial than 6 s sprint training (15 × 6 s sprints with 1 min recovery) in normoxia (Mohr et al., 2007). The training method induces a cascade of physiological adaptations, predominantly occurring in the muscle tissue – i.e. increased oxidative (Gibala et al., 2006) and glycolytic enzyme activity (Puype et al., 2013), muscle buffering capacity, glycogen content (Burgomaster et al., 2005) and increased skeletal muscle capillarization (De Smet et al., 2016) – all of which can augment exercise performance via enhanced O_2 uptake (VO_2) and O_2 transport capacity. Furthermore, improvements in exercise performance resulting from vascular and mitochondrial adaptations (Little et al., 2010; Rakobowchuk et al., 2008), improved growth hormone responses (Kon et al., 2015), and insulin sensitivity (Richards et al., 2010), have reinforced SIT as a powerful training stimulus in elite and recreational athletes (Gibala et al., 2006; Sloth et al., 2013) as well as in clinical populations (Whyte et al., 2010).

One of the earliest investigations on the potential benefits of SIH training indicated that exposure to moderate or severe hypoxia (F_IO_2=16.4–13.6 %) had no detrimental effects on the performance of repeatable 30-s Wingate tests, most likely due to sufficiently long 4–5 min recoveries between sprints (Kon et al., 2015). Additionally, highly-trained athletes could repeat 6 × 30 s Wingate tests (with only 1.5 min recoveries) in simulated hypobaric hypoxia up to 2150 m without compromising their mean or peak power outputs (Breenfeldt Andersen et al.,

2020). So far, SIH was mostly performed in the form of Wingate sprints, which consist of 30 s maximal cycling sprints on a specialized bicycle ergometer with a resistance set to 7.5% of the participant's body mass (0.075 kg·kg bm^{-1}), while additional hypoxic air mixture during SIH exercise was supplied by using hypoxicators and/or altitude rooms (Wilber, 2007). In the case of specific requirements of team sports, special hypoxic marquees would also be feasible for athletes to perform 50–70 m running sprints, sports games and even swimming (Girard et al., 2013).

The addition of hypoxic stress during the high-intensity interval and repeated sprint training has already been proposed as a mechanism to further enhance exercise performance (Faiss, Girard, et al., 2013; Faiss, Leger, et al., 2013). Additionally, preliminary research supports the notion that performing SIT in hypoxia may further enhance the magnitude of physiological adaptation when compared to equivalent training performed in normoxia (Breenfeldt Andersen et al., 2020). Higher arterial deoxygenation and consequently reduced O_2 flux during sprinting in hypoxia provides additive stress, which results in increased metabolic demands during exercise, and increased relative stress during recovery, both potentially leading to greater exercise adaptations (Faiss, Leger, et al., 2013). It was shown that performing repeated supramaximal efforts in hypoxia requires an increased fraction of glycolytic ATP production due to a hypoxia-induced drop in oxidative energy turnover (Girard et al., 2017). To support this, a single session of SIH (3 × 30 s Wingate sprints) caused a greater decrease in muscle glycogen content compared with the same exercise under normoxia without interfering with the power output (Kasai et al., 2021). Furthermore, since each 30 s exercise bout of SIT requires a ∼55% contribution from aerobic metabolism (Billaut & Bishop, 2009), this typically elicits greater performance decrements when training in hypoxia vs. normoxia. However, prolonged recovery periods (3–5 min) during SIH might reduce the stress on the anaerobic metabolism for energy restoration and facilitate near-complete recovery to maintain sprint training-specific stimuli (Millet & Faiss, 2012). This work-to-rest ratio (∼1:8) enabled preserved specific training stimuli associated with SIT, e.g., upregulated O_2 signaling genes and fast twitch fiber recruitment (Millet & Faiss, 2012), whilst increasing the metabolic disturbances required for adaptations to glycolytic pathways (Puype et al., 2013).

Previous well-controlled studies provided some evidence that high-intensity training in hypoxia augmented blood perfusion, mitochondrial biogenesis, and hypoxia-inducible factor-1α (HIF-1α) mRNA content (Brocherie et al., 2017; Faiss, Leger, et al., 2013; Zoll et al., 2006). Since HIF-1α is of paramount importance in the regulation of the genes controlling the expression of

proteins involved in glycolysis and pH regulation (Porporato et al., 2011), it can be hypothesized that SIH will induce a higher expression and activity of glycolytic enzymes, buffer capacity, and glycogen content, which in turn could enhance the performance in "glycolytic" exercise events such as a 400-meter dash, by contributing to a beneficial fiber-type shift (De Smet et al., 2016).

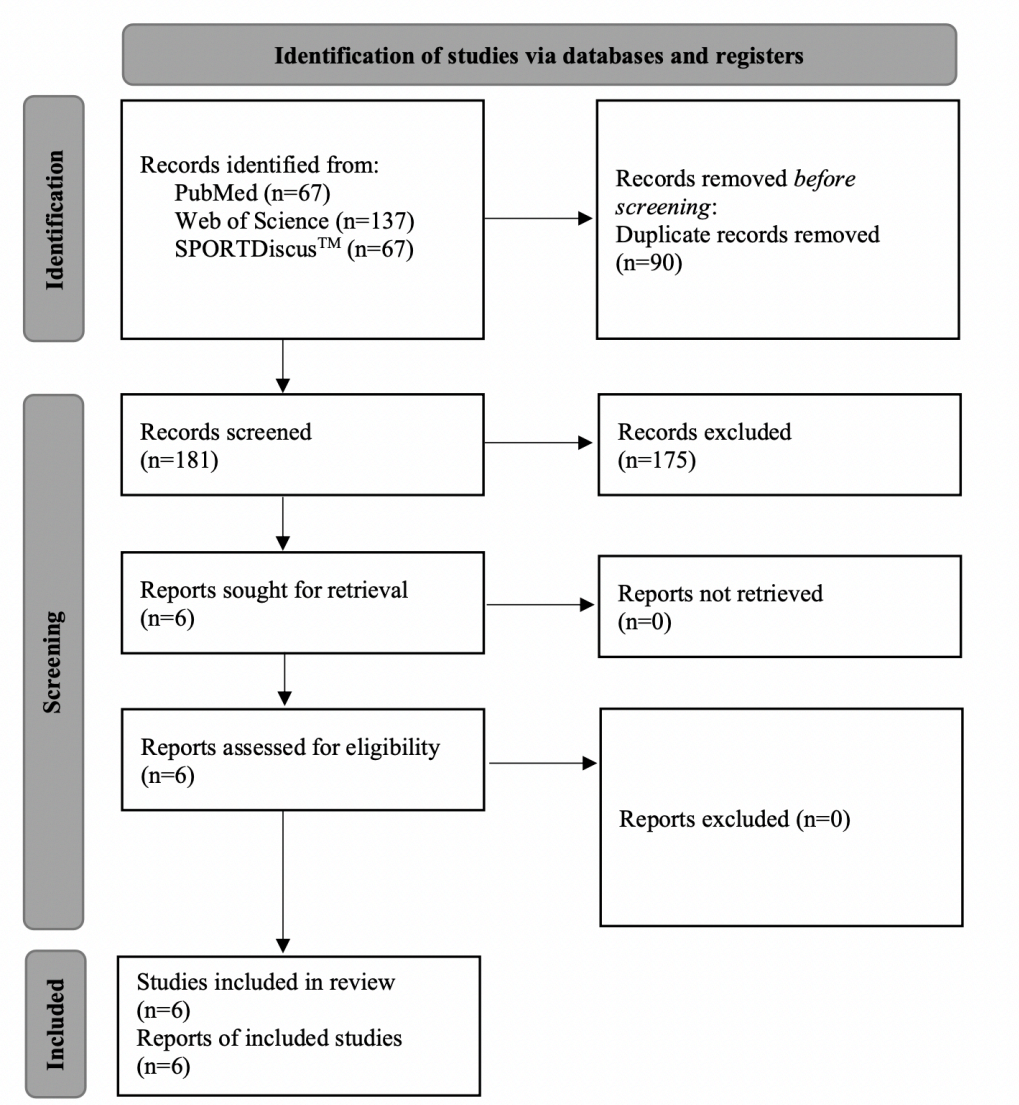
Based on previous studies conducted in normoxia it seems reasonable to speculate that SIH might be another potent exercise stimulus to boost exercise performance either at sea level or at different altitudes. Very few studies to date focused on the potential beneficial effects of SIH that could be modulated predominantly by increased metabolic stress in hypoxia. Past reviews (Girard et al., 2020; Millet et al., 2019) and one meta-analysis (Brocherie et al., 2017) provide some evidence of the potential use of innovative hypoxic training methods, and how these must be applied to enhance exercise performance. In this systematic review, we aimed to examine the SIH literature, assess evidence of its efficacy and subsequently provide guidelines on how SIT should be implemented to enhance exercise performance. The scope of this review has been limited to the inclusion of studies using the repeated Wingate protocol based on its recent frequent use and apparent impact despite the very low training volume.

METHODS

A systematic review of the available scientific literature was conducted in line with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines (Page et al., 2021) for studies evaluating the effects of SIH versus SIT interventions on exercise performance outcomes. An electronic literature search included articles published up to March 2023 using the following three online databases: Web of Science, PubMed, and SPORTDiscus™. The following terms were searched for: (hypoxi* OR altitude*) AND (sprint interval train* OR high-intensity intermittent train* OR Wingate test*), while the terms (patient* OR obes*) were excluded (using NOT). Also, the following filters were applied to each database: PubMed – *Text availability (Full text) OR Age (adult 19–44 years OR young adult 19-24 years)*; SPORTDiscus™ – *Academic Journals AND Language (English)*; Web of Science – *Document Type (Article) AND Category (Sport Science OR Physiology)*. Results were limited to full-text English papers only. The search was performed by two authors (DT and TD) with the EndNote reference manager (Clarivate™, London, United Kingdom). Articles were first screened by title and then by abstract using the eligibility criteria (mentioned below).

After screening titles and abstracts, the full text was retrieved for all potentially relevant articles and assessed according to the selection criteria. Reference lists for all selected articles were then screened and searches were supplemented by reviewing the reference lists of recent reviews on the broader area (Brocherie et al., 2017; Girard et al., 2020; Millet et al., 2019). A flow diagram of the search is presented in Figure 1.

Figure 1. The PRISMA flowchart on studies evaluating the effects of SIH compared to SIT on exercise performance.



To assess the effects of SIH versus SIT the following inclusion criteria were considered: (1) randomized controlled trials (RCTs) or matched control trials; (2) short-term (≤3 h·day^{-1}) hypoxia exposure throughout a training period ≥5 days; (3) training intensity was classified as »all out«, »maximal« or »supramaximal« or »≥100% VO_{2max}«; (4) SIT in the work-to-rest ratio of 30 s:3–5 min was completed; (5) exercise performance was assessed in normoxic or hypoxic

conditions; and (6) subjects were trained and adults, aged between 18 and 45 years. Studies were excluded according to the following criteria: (1) hypoxic exposures lasted for >3 $h \cdot day^{-1}$; (2) subjects were previously acclimatized to hypoxia (e.g. high-altitude natives); (3) submaximal training intensity and (4) animal/clinical subjects. "Exercise performance" was defined as any physical test leading to several outcomes, as follows: maximal incremental exercise test (MAXInc) assessing maximal oxygen uptake (VO_{2max}), time to exhaustion during MAXInc (T_{lim}), power output at VO_{2max} (P_{max}), aerobic (AT) and anaerobic threshold (AnT), power output at AT (P_{AT}) and AnT (P_{AnT}), power output at a lactate (La^-) concentration of 4 mmol $La^- \cdot L^{-1}$ (P_{LT4}), Wingate anaerobic test (WAnT) assessing maximal (PPO) or mean (MPO) power output, fatigue index (FI) and sprint decrement score (SDS), time to exhaustion (TTE) tests, time trials (TT), and repeated sprint ability (RSA) tests.

RESULTS

A search of electronic databases revealed 271 relevant records (Figure 1). Electronic searches returned 67, 137, and 67 results for PubMed, Web of Science, and SPORTDiscus™, respectively. Out of all 271 relevant records, 90 duplicate records were removed. Based on a review of the title or abstract or lack of any inclusion criterion, 175 articles were dismissed. Six full-text articles were evaluated and included in the present review. Each study was read and coded for descriptive variables (Table 1): reference, participants (training status and sex), training protocol (intervention [weeks × sessions·$week^{-1}$], training protocol [sets × reps × duration, recovery between sprints], training mode), type of hypoxia used (NH or HH), experimental groups and design of the study, performance measures and meaningful differences.

SIT studies carried out in hypoxia used a wide variety of training modalities, including differences in exercise mode, degree of hypoxia, number of exposures per week, weeks of training, and performance outcome variables. Four studies included recreationally active participants (De Smet et al., 2016; Puype et al., 2013; Richardson & Gibson, 2015; Richardson, Reif, et al., 2016), while two studies included well-trained athletes (Takei et al., 2020; Warnier et al., 2020). Out of 6 studies, only two included female participants (Richardson & Gibson, 2015; Richardson, Reif, et al., 2016). SIH training protocols of the included studies lasted from 2–6 weeks with 2 or 3 exercise sessions·$week^{-1}$. The SIT training units were consistently performed on a cycle ergometer, including 4–9 × 30 s Wingate sprints, with 4–4.5 min

intermediate recoveries. For the simulation of a hypoxic environment, all of the included studies used NH facilities, where participants were exposed to simulated altitudes ranging from 2000 m to 4000 m (F_IO_2=16.7–13.0 %). All trials used a randomized controlled design, while three studies also included a control group, performing regular daily recreational activities (Puype et al., 2013; Richardson & Gibson, 2015; Richardson, Reif, et al., 2016). One study included a group in which participants combined SIH training with the ingestion of exogenous nitrates (De Smet et al., 2016), while one study included groups performing SIH training at different altitudes (Warnier et al., 2020).

Due to the disparity in the performance tests used, a comparison is difficult to make. Performance tests based on time, i.e. MAXInc exercise tests (De Smet et al., 2016; Puype et al., 2013; Richardson & Gibson, 2015; Richardson, Reif, et al., 2016; Warnier et al., 2020), 10 min and 30 min TT (De Smet et al., 2016; Puype et al., 2013), ~10 min submaximal TTE at 80% of VO_{2max} (Richardson & Gibson, 2015; Richardson, Reif, et al., 2016) or power output, single and multiple 30-s Wingate sprints (De Smet et al., 2016; Richardson, Reif, et al., 2016; Takei et al., 2020) have been used. Maximal incremental tests asessed several differents variables as follows: VO_{2max}, T_{lim}, P_{max}, P_{LT2}, P_{LT4}, AT, AnT, P_{AT} and P_{AnT} (De Smet et al., 2016; Puype et al., 2013; Richardson & Gibson, 2015; Richardson, Reif, et al., 2016; Warnier et al., 2020). During the TTs, the time to accomplish 600 kJ (Warnier et al., 2020), or total work produced during 10-min (Puype et al., 2013) and 30-min TT (De Smet et al., 2016) were measured. The TTE test required participants to insist on cycling at a corresponding power output of 80% VO_{2max}, until volitional exhaustion when determined as when cadence fell below 40 rpm (Richardson & Gibson, 2015; Richardson, Relf, et al., 2016). Furthermore, one study tested subjects performing MAXInc and 10-min TT under both hypoxic and normoxic environmental conditions (Puype et al., 2013). Detailed characteristics of the included studies are presented in Table 1.

Table 1. Detailed characteristics of the studies evaluating changes in exercise performance following SIH and SIT training periods.

Reference (year)	**Participants (Training status [M or F])**	**Training Protocol**	**Hypoxia (NH [F_IO_2[a]]/HH (m))**	**Groups (Design)**	**Performance measures**	**Meaningful differences (SIH vs. SIT)**
(De Smet et al., 2016)	Recreationally active M	5 weeks × 3 sessions·week^{-1} 4–6 × 30 s, 4.5 min recovery Cycling on a cycle ergometer	F_IO_2=15% NH	SIH: 9 SIH+N[b]:9 SIT: 9 (RCT)	MAXInc VO_{2max} T_{lim} P_{max} P_{LT2} P_{LT4} 30-min cycling TT MPO WAnT MPO	 No difference No difference No difference No difference No difference No difference No difference
(Puype et al., 2013)	Recreationally active M	6 weeks × 3 sessions·week^{-1} 4–9 × 30 s, 4.5 min recovery Cycling on a cycling ergometer	F_IO_2=14.5% NH	SIH: 10 SIT: 9 CON: 10 (RCT)	MAXInc HYP VO_{2max} T_{lim} P_{LT4} MAXInc NOR VO_{2max} T_{lim} P_{LT4} 10-min TT HYP MPO 10-min TT NOR MPO	 No difference No difference *9% increase in SIH* No difference No difference *7% increase in SIH* No difference No difference
(Richardson & Gibson, 2015)	Recreationally active M (n=15) F (n=12)	2 weeks × 3 sessions·week^{-1} 4–7 × 30 s, 4 min recovery Cycling on a cycling ergometer	F_IO_2=15% NH	SIH: 14 SIT: 14 CON: 14 (RCT)	MAXInc VO_{2max} TTE (80% VO_{2max}) time	 No difference No difference
(Richardson, Reif, et al., 2016)	Recreationally active M (n=27) F (n=15)	2 weeks × 3 sessions·week^{-1} 4–7 × 30 s, 4 min recovery Cycling on a cycling ergometer	F_IO_2=15% NH	SIH: 14 SIT: 14 CON: 14 (RCT)	MAXInc VO_{2max} P_{max} AnT P_{AnT} TTE (80% VO_{2max}) time WAnT PPO MPO FI	 No difference No difference *9.5% increase in SIH* No difference No difference No difference No difference No difference

Reference (year)	**Participants (Training status [M or F])**	**Training Protocol**	**Hypoxia (NH [F_IO_2[a]]/HH (m))**	**Groups (Design)**	**Performance measures**	**Meaningful differences (SIH vs. SIT)**
(Takei et al., 2020)	University sprinters M	2 weeks × 3 sessions·week^{-1} 3 × 30 s, 4.5 min recovery Cycling on a cycling ergometer	F_IO_2=14.5% NH	SIH: 6 SIT: 6 (RCT)	3 × 30 s WAnT PPO MPO Total work SDS[d]	 No difference No difference No difference No difference
(Warnier et al., 2020)	Well-trained endurance athletes M	6 weeks × 2 sessions·week^{-1} 4–9 × 30 s, 4.5 min recovery Cycling on a cycling ergometer	2000 m (F_IO_2=16.7%) 3000 m (F_IO_2=14.5%) 4000 m (F_IO_2=13.0%) NH	SIH (2000 m): 8 SIH (3000 m): 8 SIH (4000 m): 7 SIT (sea-level): 7 (RCT)	MAXInc P_{max} P_{AnT} 600 kJ TT time WAnT PPO MPO FI	 No difference No difference No difference No difference No difference No difference

Notes. Published studies on SIH (n=6). The significantly ($p<0.05$) greater benefits of SIH vs. SIT are presented in italics. F: females, M: males, HYP: hypoxia, NOR: normoxia, NH: normobaric hypoxia; HH: hypobaric hypoxia, F_IO_2: fraction of inspired oxygen, SIH: sprint interval training in hypoxia, SIT: sprint interval training in normoxia, CON: control group without SIT training, RCT: randomized controlled trial, MAXInc: maximal incremental exercise test, VO_{2max}: maximum oxygen uptake, P_{max}: power output at VO_{2max}, T_{lim}: time to exhaustion during MAXInc, AT: aerobic threshold, AnT: anaerobic threshold, P_{AT}: power output at AT, P_{AnT}: power output at AnT, LT_2: lactate concentration of 2 mmol $La^-·L^{-1}$, LT_4: lactate concentration of 4 mmol $La^-·L^{-1}$, P_{LT2}: power output at LT_2, P_{LT4}: power output at LT_4, WAnT: Wingate anaerobic test, PPO: maximal power output, MPO: mean power output, FI: fatigue index, SDS: sprint decrement score, TT: time trial, TTE: time to exhaustion test.

[a]Where (simulated) altitude was not reported, we estimated it according to the fraction of inspired oxygen (F_IO_2)

[b]nitrate supplementation (6.45 mmol $NaNO_3$ administered 3 h before each session)

[c](Bangsbo et al., 2008)

[d](Girard et al., 2011)

DISCUSSION

Compared to the studies evaluating similar innovative hypoxic methods – RSH (Brocherie et al., 2017) and VHL (Holfelder & Becker, 2018) – studies on SIH, in general, did not demonstrate significant improvements in exercise performance compared to equivalent training methods conducted under normoxic conditions. Although SIT training in normoxia is a time-efficient and effective training method for increasing both aerobic and anaerobic exercise performance (Hazell et al., 2010; Sloth et al., 2013) the addition of hypoxic stimulus to SIT exercise does not seem beneficial for further augmenting exercise performance. Nevertheless,

it is important to emphasize that the completion of 30-s Wingate sprints in oxygen-deprived environments during SIH was not associated with larger performance decrements – lower PPO and MPO, total work produced, or increased FI – when compared to SIT.

Studies on SIH generally examined whether the addition of hypoxic stimuli to SIT sessions enables any further improvements in aerobic performance. The present studies analysis revealed that SIH did not enable any significant increase in VO_{2max}, T_{lim} or P_{max} during maximal incremental exercise test (De Smet et al., 2016; Puype et al., 2013; Richardson & Gibson, 2015; Richardson, Reif, et al., 2016; Warnier et al., 2020), the performance of 10-min, 30-min, and 600 kJ cycling TTs (De Smet et al., 2016; Puype et al., 2013; Warnier et al., 2020), and TTE at an intensity of 80% VO_{2max} (Richardson & Gibson, 2015; Richardson, Reif, et al., 2016) when compared to SIT, both in normoxic and hypoxic testing conditions (Puype et al., 2013). Both SIH and SIT equally increased VO_{2max} and P_{max} by about 10% after 5 weeks of training (De Smet et al., 2016), while a smaller specific block of SIH had the potential to improve aerobic capacity by slightly more than 10% (Richardson & Gibson, 2015). Contrary to the general trend of no additional effect on aerobic performance compared to SIT, SIH resulted in a significantly increased AnT (Richardson & Gibson, 2015; Richardson, Reif, et al., 2016) and the P_{LT4} (Puype et al., 2013), which indicates up-regulation of muscular aerobic capacity and suggests that improved oxidative phosphorylation after SIH had occurred. In support of these findings, 6 weeks of SIH increased the estimated AT from the pre-test at 2000 m and 4000 m, while no such changes were observed after SIT (Warnier et al., 2020). Importantly, it was also observed that both SIH and SIT augmented VO_{2max} by about 6.5% in normoxic, but not in hypoxic testing conditions (Puype et al., 2013), which suggests that SIH would be potentially beneficial for improving aerobic performance in normoxic conditions only.

Since SIT also targets the improvement of anaerobic exercise performance, studies included in this review investigated the effects of SIH on the ability to perform individual or repeatable 30-s Wingate tests (De Smet et al., 2016; Richardson, Reif, et al., 2016; Takei et al., 2020; Warnier et al., 2020). Using SIH compared to SIT failed to provide any significant increase in PPO, MPO, total work, or decrease in FI or SDS during the single or repeatable 30-s Wingate tests in recreationally active participants (De Smet et al., 2016; Richardson, Reif, et al., 2016), as well as in endurance and sprint athletes (Takei et al., 2020; Warnier et al., 2020). Despite relative gains in PPO and MPO for each of the three sprint bouts being greater in the hypoxic compared to the normoxic training group after 2 weeks of training, differences were still non-

significant (Takei et al., 2020). Interestingly, De Smet and colleagues observed about a 6% larger increase in MPO of the 30-s Wingate test in the hypoxic group which ingested exogenous nitrates compared to normoxic and hypoxic groups, although differences were non-significant (De Smet et al., 2016). This finding suggests that short-term oral nitrate supplementation in conjunction with SIH may be a valid strategy to further augment anaerobic performance, due to nitrate-induced effects on increased blood flow, improved contractility of fast-glycolytic muscle fibers (Ferguson et al., 2013; Hernandez et al., 2012), and increased rate of post-exercise muscle phosphocreatine (PCr) resynthesis (Vanhatalo et al., 2014). Furthermore, Warnier et al. observed a main time effect for the Wingate PPO only in the group which trained at the altitude of 4000 m, while no effect was observed for groups training at altitudes of 2000 m, 3000 m, and sea level, respectively (Warnier et al., 2020). Similar observations were also observed after RSH periods (Kasai et al., 2015). It was hypothesized that muscle PCr content may be increased in response to repeated sprinting in hypoxia, and turn, induce a greater improvement in PPO (Faiss, Girard, et al., 2013), but later studies did not support that hypothesis, observing a similar increase in muscle PCr content between RSH and RSN (Kasai et al., 2017). Warnier et al., therefore, hypothesized that the greater increase in PPO observed during the Wingate test after training at 4000 m altitude (F_IO_2=13.0%) is probably not related to changes in energy metabolism, but to changes in muscle structure or recruitment (Warnier et al., 2020). Additionally, hypoxic conditions were already shown to induce a higher expression of fast-twitch fibers (De Smet et al., 2016), increased spinal excitability, and also the number of recruited motor units (Delliaux & Jammes, 2006). Since a study using less severe hypoxic conditions (F_IO_2=14.5%) did not detect any change in PPO during a Wingate test (Takei et al., 2020), it is reasonable to speculate that higher hypoxic stimuli during SIH protocols might provoke greater adaptations in muscle contractility and energy metabolism and consequently augment anaerobic performance.

Due to the non-fulfillment of the inclusion criteria, we did not include one study (Gatterer et al., 2018), which performed a trial comparing the effects of SIH (4 sprints × 30 s, 4.5 min recovery) with the effects of RSH (3 sets × 5 sprints × 10 s, 20 s and 5 min recovery between repetitions and sets) on running and cycling performance in team athletes. After 3 weeks of training (3 sessions·week^{-1}) at an altitude of 2200 m, no significant differences in performance of the Yo-Yo IR2 test, 6 × 17 m back and forth running sprints, 30-s Wingate test, and 5 × 6 s repeated cycling sprints, were observed between the experimental groups, although both training methods significantly improved performance from the baseline values. The study

revealed that both RSH and SIH training improve sea-level performance to a similar extent, without observed significant differences. Nevertheless, considering the medium to large effect size observed, cycling power output and La^- concentrations data indicate that RSH compared to SIH might be favorable for performance improvements and increases in anaerobic contribution, respectively. The somewhat higher overall training volume during RSH compared to SIH (overall sprinting time: 1350 s vs. 1080 s for RSH and SIH, respectively) might have underlined these differences. Based on the results of the study, it seems that the two training regimes can interchangeably be used to achieve superior training adaptations in exercise performance. However, as this study lacked a normoxic control group it is impossible to speculate the exact additive and independent effect of hypoxia.

As SIT is a particularly potent variation of interval training, performed at intensities ≥100% of the power output or speed at an individual's VO_{2max} (Weston et al., 2014), training effort, in particular, requires substantially higher absolute power outputs. Such intensities, however, require higher recruitment of type II, fast-twitch fibers and extensive use of non-oxidative substrate metabolism; fueled exclusively by intramuscular substrates (PCr and glycogen) with little or no contribution from fat-based fuels (Gibala & Hawley, 2017). The addition of hypoxia to SIT exercise results in the slowing of VO_2 kinetics at the beginning of the maximal 30-s sprint, increasing the magnitude of the O_2 deficit incurred during each sprint and placing even more demand on anaerobic sources and the activation of type-II, fast-twitch muscle fibers to maintain ATP production and quickly provide sufficient power outputs, respectively (Girard et al., 2017). Because of these characteristics, 6 weeks of SIH provided a significant 59% increase in phosphofructokinase (PFK) enzyme activity, while no such effect was observed after SIT (Puype et al., 2013). Additionally, both SIT and SIH elevated monocarboxylate transporter 1 protein (MCT-1) – membrane transporters responsible for co-transport La^- and hydrogen (H^+) ions (Girard et al., 2011) – content by ~70% compared to the baseline levels (Puype et al., 2013). De Smet et al. also observed increased muscle carnosine content (physicochemical buffer capacity of muscle) by ∼13% only in hypoxic groups, although differences were non-significant. Additionally, 5 days of combined RSH and SIH markedly augmented muscle glycogen content in a hypoxic group only (Kasai et al., 2017). In addition to earlier findings, SIH training with simultaneous supplementation of exogenous nitrates, compared to SIH and SIT alone, significantly increased the proportion (+45–56%) and fiber-specific cross-sectional area (+11%) of type IIa, fast-twitch oxidative muscle fibers in *m. vastus lateralis* (De Smet et al., 2016). Since anaerobic glycolysis accounts for about 50% of the total ATP production

during a 30-s all-out exercise bout (Putman et al., 1995). De Smet et al., therefore postulated that a higher proportion of type IIa muscle fibers, providing a higher capacity for glycolytic ATP production, should be ergogenic during a 30-s sprinting exercise (De Smet et al., 2016). Mechanistically, observed adaptations after SIH only, can in combination increase the anaerobic breakdown and muscle buffering capacity, enabling potentially greater exercise adaptations after SIH periods.

It was hypothesized that superior adaptations after SIT compared to continuous endurance exercise is a reflection of stimulation of various signaling pathways – greater AMP-activated protein kinase (AMPK) phosphorylation, increased gene expression of peroxisome proliferator-activated receptor δ coactivator 1 α (PGC-1α) (Gibala & Hawley, 2017). Since exposure to hypoxia and interval high-intensity exercise stimulates similar signaling pathways (Faiss, Leger, et al., 2013; Zoll et al., 2006), the combination of physiological stressors experienced within SIH would potentially contribute to greater adaptations connected with the above-mentioned signaling pathways.

During a maximal 30-s sprint aerobic energy production to ATP resynthesis count up to 55% of the whole energy supply (Billaut & Bishop, 2009), with its significantly increasing role towards the end of individual 30-s sprints and repeated trials (Gastin, 2001; Parolin et al., 1999). Because of the decreased oxygen availability for aerobic energy production during exercising in hypoxia, it is expected that sprinting in hypoxia would induce greater physiological adaptations in aerobic metabolism. It was already found that RSH enhances muscle perfusion (Faiss et al., 2015), while the same hypoxic training method can result in a decrease (Faiss, Leger, et al., 2013) or an increase (Brocherie et al., 2017) in factors involved in mitochondrial biogenesis. The study evaluating SIH-induced mitochondrial function reported that SIH training did not affect changes in muscular O_2 extraction and mitochondrial function of peripheral blood mononuclear cells (a measure estimating physical ability similar to skeletal muscle mitochondrial function (Tyrrell et al., 2015)). Authors proposed that O_2 flow per cell count seems to be less affected by SIH training (Gatterer et al., 2018). Nevertheless, it seems that SIH still provides some increase of aerobic capacity with which muscles can increase the oxidation of produced La^- within mitochondria. This is supported by observations of increased La^- clearance from the blood after the end of each consecutive 30-s sprint interval (~9–17% decrease in blood La^-) after a two-week-long SIH exercise protocol (Takei et al., 2020). Additionally, these findings can be supported by the practical finding of increased power

outputs at an AnT, which reflects lower synthesis or higher oxidation of La^- in muscle fibers at a given submaximal exercise intensity (Puype et al., 2013; Richardson, Relf, et al., 2016).

Although some beneficial findings encourage the use of SIH for further improving aerobic capacity, De Smet et al. found that maximal citrate synthase (CS) activity after 5 weeks of SIT exercise increased by 54% in the normoxic group and by just under half that (22–25%) in the hypoxic groups (De Smet et al., 2016). This is in line with previous reports, where SIT in normoxic conditions increased CS activity (Sloth et al., 2013), while SIH did not augment adaptations in muscle oxidative capacity (Faiss, Leger, et al., 2013). Additionally, Gatterer et al., observed improved de- and re-oxygenation during repeated sprinting, indicating enhanced O_2 extraction and restoration of O_2 levels for the RSH group only (Gatterer et al., 2018). Since the major benefit of increased re-oxygenation during short recovery periods is a faster resynthesis of PCr (McMahon & Jenkins, 2002), the mechanism could contribute to performance improvements. It was purposed, that the generation of peak power during the first few seconds of an all-out sprint might be more likely responsible for the adaptations to SIT, than the total work completed during a 30-s bout (Hazell et al., 2010). Consequently, the availability of PCr during repeated sprints might be the most important factor because it is mainly responsible for the high power output during the initial 10 s of maximal exercise (Bogdanis et al., 1996). Currently, available literature did not evaluate if SIH in comparison whit SIT increases muscle oxygenation and PCr restoration, which would potentially improve exercise performance. Therefore, future studies should examine SIHs effects on muscle oxygenation status during the repetition of high-intensity efforts, since SIT in normoxia was shown to improve the slope of slow VO_2 component, which authors associated with greater O_2 extraction (Bailey et al., 2009).

As expected, only minor hematological changes were observed after SIH training periods, as such short durations and a relatively low altitude dosage were not likely to induce erythropoiesis (Richardson, Relf, et al., 2016; Warnier et al., 2020). After two weeks of SIH training (3 sessions·week^{-1}) hemoglobin concentration was significantly different from pre to post-training, however, this increase was not different between training groups. In contrast to this, hematocrit values were not different from pre to post-training or between groups (Richardson, Relf, et al., 2016). To further support these findings, 6 weeks of SIH training (2 sessions·week^{-1}) resulted in unchanged hemoglobin mass, hemoglobin concentrations, hematocrit, and plasma volume, while there were also no differences between hypoxic and sea-level groups (Warnier et al., 2020). Additionally, red blood cell volume increased after both the SIH and SIT training

program, but none of the group increases was significant. The common cumulative hypoxic dose of SIH training periods is sufficiently too low (~40–50 hours) to increase hematological adaptation since 100 hours of cumulative exposure to hypoxia (real or simulated altitude of ~2500 m) increases the hemoglobin mass by about 1% (Garvican et al., 2012). In a practical sense, it follows that for a meaningful 2,5% increase in hemoglobin mass, it is necessary to aim for at least 250 cumulative hours of hypoxic exposure, e.i. 20–25 days spent at a (simulated) altitude between 2000 m and 2500 m (Garvican-Lewis et al., 2016).

Based on the findings we can summarize that although both SIH and SIT improve aerobic and anaerobic performance compared to baseline values, the addition of hypoxic stimuli to SIT does not seem to further augment exercise performance, therefore the alternative implementation of SIH in athlete's training routines may not be as meaningful as the implementation of RSH method (Brocherie et al., 2017; Millet et al., 2019). Nevertheless, the use of SIH may be more effective in improving submaximal aerobic performance, since SIH provided lactate-related adaptations that were not observed after identical training in normoxia (Puype et al., 2013; Warnier et al., 2020). Despite these observations, it is important to bear in mind that these adaptations did not reflect further improvements in submaximal exercise performance, i.e. improved performance during the TT (De Smet et al., 2016; Puype et al., 2013; Warnier et al., 2020), or TTE test (Richardson & Gibson, 2015). The evidence though suggests that a SIH-related increase in anaerobic threshold is probably not sufficient enough to enhance submaximal exercise performance.

It was suggested, that observed non-significant differences in exercise performance after SIH, can be attributed to a low hypoxic stimulus, added to SIT since most studies simulated altitudes from 2000–3000 m (Warnier et al., 2020). Future studies should therefore determine if high altitudes (≥4000 m) can elicit greater physiological stress and therefore larger adaptations in aerobic and anaerobic exercise performance than the SIH training performed at moderate altitudes.

Several limitations have to be addressed when interpreting the results of the identified studies. First, only three studies included a control group, though it is difficult to conclude if observed changes are the result of SIT, hypoxic exposure, or its combination. Second, a lack of prescribing a blinding procedure for the hypoxic condition was evident and some of the studies. Thirdly, articles included in this review investigated the effects of SIT on subjects characterized as “healthy recreationally active adults or top athletes”. However, the potential for SIH to elicit

exercise improvements can be also observed in other populations. Included studies used the various durations of training interventions, which leaves much to be determined regarding the impact of participation in SIH on not only improvements in exercise performance but also on the time course of physiological adaptations, participant adherence, and injury rates. The time course of physiological adaptations may be further elucidated through testing different lengths of training interventions that specifically examine central and peripheral changes at various time points throughout the trials. Also, alterations in the gene expression level can explain the underlying regulatory mechanism responsible for the muscular adaptations induced by SIH, therefore, it is desired that future studies investigate its effects on the aforementioned adaptations.

It can be identified that SIT in hypoxia augments adaptation during a 6-week training period (Puype et al., 2013) however SIT in hypoxia over a 2-week training intervention may offer little additional benefit when compared to equivalent training in normoxia (Richardson & Gibson, 2015; Richardson, Relf, et al., 2016). In this training modality, the dose-response relationship remains to be fully determined in hypoxia, though it is known that 2 weeks is a sufficient period to elicit adaptations in normoxia (Burgomaster et al., 2008; Burgomaster et al., 2005).

Future studies should determine whether SIH can be similarly an effective and time-efficient training method compared to continuous exercise methods performed in hypoxia (continuous training in hypoxia, interval training in hypoxia (McLean et al., 2014)) as observed in normoxia (Gist et al., 2014; Sloth et al., 2013). Additionally, it should be explored if SIH is a feasible training strategy for acclimatization to real altitude, since acclimatization periods due to a reduced aerobic capacity at altitude, require reduced training volumes to be to avoid overtraining. Furthermore, the majority of included RCTs required participants to perform sprints on a cycle ergometer, while no SIH study included any other exercise type, such as running, rowing, double-polling, etc. Despite stationary cycling being a non-weight-bearing activity, coupled with the minimal eccentric contraction of leg muscles, which seems to mitigate the risk of injury and discomfort; new well-designed RCTs using various modes of SIH are needed to increase the knowledge of effects across different exercise types. Nevertheless, studies of various populations and all age ranges are necessary to determine the impact of SIH in clinical and older populations.

CONCLUSION

The hypothesis driving the current review – that performing SIT in hypoxic conditions might yield specific physiological adaptations to boost exercise performance was not fully confirmed. In particular, this systematic review indicates that SIH does not further augment exercise performance in healthy recreationally active, or top athletes when compared to SIT performed in normoxia. Accordingly, it seems that SIH is not a superior training method for improving exercise performance compared to its normoxic counterpart, therefore, the training method does not appear as meaningful as other new LLTH training methods (RSH, VHL, BFR, RTH). However, SIH did show some potential for inducing beneficial physiological adaptations which could potentially facilitate aerobic and anaerobic energy turnover in skeletal muscles and are usually not expressed to the same extent after the SIT exercise periods. Observed cellular and molecular adaptation might augment oxidative and glycolytic capacity, especially of fast-twitch muscle fibers, and could, therefore, contribute to the improvement in explosive, high-intensity, and submaximal endurance efforts. The use of longer recovery periods in SIH would potentially allow for more complete PCr resynthesis, myoglobin saturation, higher muscle La^- and H^+ ions efflux as well as the re-establishment of ion-homeostasis (which are all important fatigue-modulating factors (Girard et al., 2011)) before the start of consecutive sprints, which can augment the activation of fast-twitch muscle fibers, and prolong the maintenance of high muscle forces during exercise in hypoxia. With these properties, athletes can achieve a complete restoration of sprinting performance during exercising in hypoxia, which enables them to exert greater metabolic load and consequential improvements in aerobic and anaerobic performance. The finding of our review is of particular interest for disciplines requiring longer high power outputs, such as in very explosive sports (400 m sprints, cycling, skiing, etc.). Additionally, our findings reinforce SIH for athletes sojourning to moderate altitude and aiming to maintain training quality and avoid overtraining, by reducing the volume and increasing the intensity of training.

Declaration of Conflicting Interests

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

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INCIDENCE AND SUCCESS RATES OF OFFENSIVE PLAYS IN 3X3 BASKETBALL: COMPARISONS BY STARTING ACTIONS AND AGE/SEX CATEGORIES

POJAVNOST IN USPEŠNOST OFENZIVNIH IGER V KOŠARKI 3X3: PRIMERJAVE PO ZAČETNIH AKCIJAH IN STAROSTNIH/SPOLNIH KATEGORIJAH

ABSTRACT

This study compared offensive plays' incidence and success rates in 3x3 basketball by starting actions and age/sex categories (senior men, senior women, under-18 men, and under-18 women). One hundred and ninety-one games from the FIBA 3x3 Under-18 World Cup 2019 and the FIBA 3x3 World Cup 2019 were analyzed. Offensive plays were classified into three types according to their starting actions: check-ball offensive plays (CBOP), transition offensive plays (TOP), or offensive rebound offensive plays (OROP). Offensive plays resulting in a successful field goal or an earned free throw were considered successful. Pearson's chi-squared test was used to compare the success rates of offensive plays between starting actions and between categories. The Benjamini-Hochberg method was applied to ensure a significance level of 0.05. Cohen's w was calculated as an effect size for the chi-squared test. TOP occurred with the highest frequency (55.1-57.5% of the totals) in all four categories, followed by CBOP (28.1-31.2%) and OROP (11.9-14.7%). The success rates of OROP (39.2-49.2%) were significantly higher ($p < 0.05$, $w = 0.07$-0.14) than those of TOP (28.5-36.4%) and CBOP (32.1-35.0%) in all categories. Improving the success rate of TOP is crucial to increase the chance of winning a game because TOP accounts for more than half of the total offensive plays. While the incidence of OROP was the lowest among the three offensive plays, the success rate of OROP was higher than that of TOP and CBOP, indicating the importance of acquiring offensive rebounds in 3x3 basketball.

Keywords: game-related statistics, notational analysis, performance analysis, team sports

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IZVLEČEK

Ta študija je primerjala pogostost in uspešnost napadalnih iger v košarki 3x3 glede na začetne akcije in starostno/spolne kategorije (starejši moški, starejše ženske, moški do 18 let in ženske do 18 let). Analiziranih je bilo sto enaindevetdeset tekem s svetovnega prvenstva FIBA 3x3 do 18 let 2019 in svetovnega prvenstva FIBA 3x3 2019. Napadalne igre so bile glede na začetna dejanja razvrščene v tri vrste: napadalne igre z vračanjem žoge v igro (CBOP), napadalne igre s prehodom (TOP) ali napadalne igre z odbojem (OROP). Napadalne igre, ki so se končale z uspešnim zadetkom ali pridobljenim prostim metom, so se štele za uspešne. Pearsonov hi-kvadrat test je bil uporabljen za primerjavo uspešnosti napadalnih iger med začetnimi akcijami in med kategorijami. Za zagotovitev stopnje pomembnosti (0.05) je bila uporabljena metoda Benjamini-Hochberg. Cohenov w je bil izračunan kot velikost učinka za test hi-kvadrat. V vseh štirih kategorijah se je najpogosteje pojavil TOP (55.1-57.5 % vseh primerov), sledita CBOP (28.1-31.2 %) in OROP (11.9-14.7 %). Stopnje uspešnosti OROP (39.2-49.2 %) so bile bistveno višje ($p < 0.05$, $w = 0.07$-0.14) kot stopnje TOP (28.5-36.4 %) in CBOP (32.1-35.0 %) v vseh kategorijah. Izboljšanje uspešnosti TOP je ključnega pomena za povečanje možnosti za zmago na tekmi, saj TOP predstavlja več kot polovico vseh napadalnih iger. Čeprav je bila pogostost OROP med tremi napadalnimi igrami najmanjša, je bila uspešnost OROP višja od uspešnosti TOP in CBOP, kar kaže na pomembnost pridobivanja napadalnih odbojev v košarki 3x3.

Ključne besede: statistični podatki povezani z igro, analiza tekem, analiza uspešnosti, ekipni športi

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INTRODUCTION

3x3 is among the disciplines of basketball that debuted as an Olympic sport at the Tokyo 2020 Olympic Games (Snoj, 2021b). The basic concept of 3x3 basketball is similar to that of traditional 5-on-5 basketball: breaking through the defense by passing and dribbling, and shooting at the basket. However, there are some differences in game structures between 3x3 and 5-on-5 basketball due to the fact that 3x3 has only one basket and several different rules (Table 1).

Table 1. Main differences between 3x3 and traditional 5-on-5 basketball.

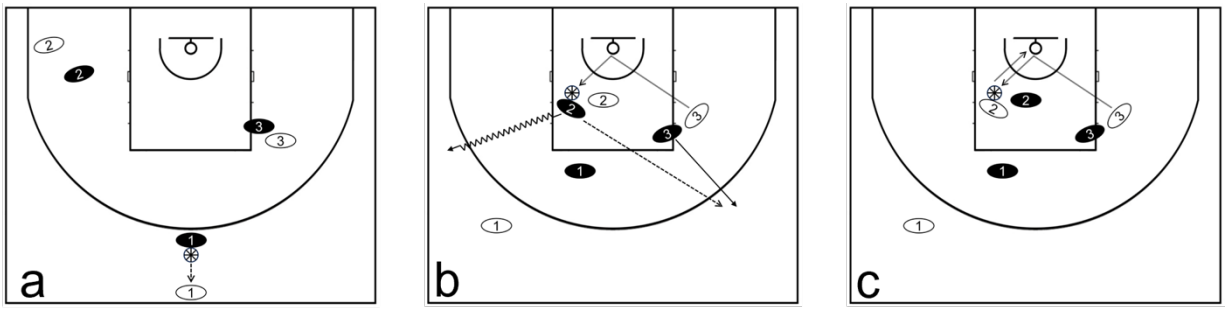
	3x3	Traditional 5-on-5
Number of baskets	One	Two
Number of players on the court	Three players for each team	Five players for each team
Scoring rules	One point for a successful free throw or a successful field goal attempted from inside the arc Two points for a successful field goal attempted from outside the arc	One point for a successful free throw Two points for a successful field goal attempted from inside the arc Three points for a successful field goal attempted from outside the arc
Game duration	One period of 10 min	Four periods of 10 min
Shot clock	12 sec	24 sec
How the game is restarted following a dead-ball situation	Check-ball	Inbounding the ball from outside the court
Clearing the ball	The new offensive team that gains possession of the ball inside the arc must return the ball behind the arc by passing and/or dribbling before attempting a field goal.	No need to clear the ball
How the ball is played by the non-scoring team following a successful field goal or a last free throw by the opposing team	Picking up the ball inside the court and clearing the ball before attempting a field goal	Inbounding the ball from outside the end line

From a tactical point of view, one of the crucial differences is starting actions of offensive plays. Offensive plays in 3x3 basketball can be classified into three types according to their starting actions: check-ball offensive plays (CBOP), transition offensive plays (TOP), or offensive rebound offensive plays (OROP).

CBOP is an offensive play that starts from a check-ball (passing the ball from the defensive player to the offensive player at the top of the arc at the start of a game or when restarting from a dead-ball situation) (Figure 1a). The play check-ball does not exist in 5-on-5 basketball. Since CBOP starts from a dead-ball situation, offensive teams have enough time to prepare for the offense and can execute well-organized plays. In contrast, TOP consists of offensive plays when

the offensive team gains possession of the ball while it is in play: picking up the ball inside the court after a successful field goal or a free throw by the opposing team, securing a defensive rebound, or stealing the ball from the opposing team. TOP requires advanced decision-making abilities because there is less time to prepare for the offense. In addition, the rules state that if a transition occurs inside the arc (most of the time, it does occur inside the arc), the new offensive team must return the ball behind the arc before attempting a field goal (Figure 1b). This action is called "clearing the ball" and is specific to 3x3 basketball. Finally, OROP is an offensive play that starts with an offensive rebound. There is no difference between 3x3 and 5-on-5 basketball in OROP because attempting a field goal without clearing the ball is allowed after an offensive rebound (Figure 1c).

Figure 1. Examples of a check-ball (a), a transition offensive play requiring clearing the ball (b), and an offensive rebound offensive play (c) in 3x3 basketball.



a: Passing the ball from the defensive player (black team) to the offensive player (white team) at the top of the arc at the start of a game or when restarting from a dead-ball situation. b: The defensive player #2 (black team) got a defensive rebound of a missed shot by the offensive player #3 inside the arc. The new offensive team (black team) must return the ball behind the arc by passing and/or dribbling before attempting a field goal. c: The offensive player #2 (white team) got an offensive rebound of a missed shot by the offensive player #3. The white team can attempt another shot without clearing the ball.

Comparing CBOP and TOP, the former seems easier to execute a planned offensive play because it has time to prepare before attacking. However, the same is true for defensive teams because they also have time to prepare before the play. On the other hand, in the case of TOP, offensive teams may not have sufficient time to prepare before attacking, but they have the advantage of being able to attack before the defensive team is fully prepared.

The number of studies on 3x3 basketball has been increasing in recent years (Boros et al., 2022; Conte et al., 2019; Erčulj et al., 2019; Ferioli, Conte, et al., 2023; Ferioli, Rampinini, et al., 2023; Figueira et al., 2022; Madarame, 2023; McGown et al., 2020; Montgomery & Maloney, 2018). However, to the author's knowledge, only one study (Ortega et al., 2021) has analyzed offensive plays by classifying them by starting actions. The study by Ortega et al. (2021) is

valuable in understanding 3x3 offense, as it analyzed not only the starting action of the offensive play but also other details of the play, such as the area of the court where the play was executed and the number and types of passes made before attempting a shot. However, the study is limited in its generalizability because it only analyzed four games. In addition, while Ortega et al. (2021) only analyzed senior men's games, previous studies on 3x3 basketball have reported age and/or sex differences in game-related statistics (Erčulj et al., 2019; Ferioli, Conte, et al., 2023; Madarame, 2023) or in physical demands (Ferioli, Rampinini, et al., 2023; Štirn et al., 2022). Therefore, this study aimed to compare offensive plays' incidence and success rates in 3x3 basketball by starting actions and age/sex categories.

METHODS

A play-by-play database of 191 games from the FIBA 3x3 Under-18 World Cup 2019 and the FIBA 3x3 World Cup 2019 was created through a notational analysis. While the total number of games was 192 (48 games in each category), one game from the under-18 women's tournament was not included in the analysis due to the lack of official game footage before 3:02 remaining in the game. An experienced researcher coded each play chronologically using a specially designed Microsoft Excel spreadsheet while viewing the publicly accessible game footage on the FIBA 3x3's official YouTube channel (https://www.youtube.com/fiba3x3). If it was impossible to identify a play from the footage (e.g., the camera wasn't following it), it was classified as "unclear" and excluded from the analysis. Offensive plays were classified into three types according to their starting actions: TOP, CBOP, or OROP. Offensive plays resulting in a successful field goal or an earned free throw were considered successful.

After a minimum interval of one month from the initial measurement, eight games (two from each category) were randomly selected using the R function "sample" to assess intra-rater reliability. The plays from these games were then re-coded, and Cohen's kappa was calculated using the R function "kappa2" in the "irr" package, resulting in a value of 0.985.

Statistical analyses were performed using R version 4.0.5 for Windows (R Core Team, 2021). Pearson's chi-squared test (the R function "assocstats" in the "vcd" package) was used to compare the success rates of offensive plays between starting actions and between categories. When performing the chi-squared test, the CBOP data were limited to plays in which the shot clock was reset to 12 seconds, ensuring that the remaining time on the shot clock did not affect the results. The Benjamini-Hochberg method (Benjamini & Hochberg, 1995) was applied using

the R function "p.adjust" to ensure a significance level of 0.05. Cohen's w (Cohen, 1988) was calculated as an effect size for the chi-squared test ($w < 0.10$, trivial; $w = 0.10$-0.29, small; $w = 0.30$-0.49, medium; $w \geq 0.50$, large).

RESULTS

The total counts and percentages of offensive plays in each category are shown in Table 2. TOP occurred with the highest frequency in all four categories, followed by CBOP and OROP. The ratios of the three offensive plays were similar across categories, ranging from 55.1 to 57.5% for TOP, 28.1 to 31.2% for CBOP, and 11.9 to 14.7% for OROP.

Table 2. Total counts and percentages of offensive plays in each category.

		Men		Women	
		Senior	Under-18	Senior	Under-18
TOP	Count	1968	2102	2056	1984
	%	57.5	57.2	57.5	55.1
CBOP	Count	1018	1030	1094	1124
	%	29.7	28.1	30.6	31.2
OROP	Count	439	540	427	495
	%	12.8	14.7	11.9	13.7

TOP, transition offensive play; CBOP, check-ball offensive play; OROP, offensive rebound offensive play.

The success rates of OROP were significantly higher than those of TOP and CBOP in all categories ($p < 0.05$, $w = 0.07$-0.14) (Tables 3 and 4). However, there was no difference between the success rates of TOP and CBOP ($p = 0.07$-0.96, $w = 0.00$-0.04) (Tables 3 and 4).

Table 3. Success rates of offensive plays by starting actions and age/sex categories.

		Men		Women	
		Senior	Under-18	Senior	Under-18
TOP	Successful	717	728	639	565
	Unsuccessful	1251	1374	1417	1419
	Success rate (%)	36.4	34.6	31.1	28.5
CBOP	Successful	301	298	318	293
	Unsuccessful	569	566	591	620
	Success rate (%)	34.6	34.5	35.0	32.1
OROP	Successful	216	263	202	194
	Unsuccessful	223	277	225	301
	Success rate (%)	49.2	48.7	47.3	39.2

TOP, transition offensive play; CBOP, check-ball offensive play; OROP, offensive rebound offensive play.

Table 4. Results of pairwise comparisons of success rates between starting actions.

		TOP vs. CBOP		TOP vs. OROP		CBOP vs. OROP	
		p	w	p	w	p	w
Men	Senior	0.45	0.02	0.00*	0.10†	0.00*	0.14†
	Under-18	0.96	0.00	0.00*	0.12†	0.00*	0.14†
Women	Senior	0.07	0.04	0.00*	0.13†	0.00*	0.12†
	Under-18	0.08	0.04	0.00*	0.09	0.02*	0.07

TOP, transition offensive play; CBOP, check-ball offensive play; OROP, offensive rebound offensive play. *p < 0.05; †small effect size (w = 0.10-0.29).

The success rates of CBOP did not differ among the categories (p = 0.30-0.96, w = 0.00-0.03) (Tables 3 and 5). While the effect sizes were trivial, the success rates of TOP were significantly higher in the men's than in the women's tournaments (p < 0.05, w = 0.04-0.09) (Tables 3 and 5). The success rates of OROP were significantly lower in the under-18 women's tournament than in the other three categories' tournaments (p < 0.05, w = 0.08-0.10) (Tables 3 and 5).

Table 5. Results of pairwise comparisons of success rates between categories.

	TOP		CBOP		OROP	
	p	w	p	w	p	w
Senior men vs. U18 men	0.35	0.02	0.96	0.00	0.94	0.01
Senior men vs. Senior women	0.00*	0.06	0.94	0.00	0.72	0.02
Senior men vs. U18 women	0.00*	0.09	0.37	0.03	0.01*	0.10†
U18 men vs. Senior women	0.03*	0.04	0.94	0.01	0.80	0.01
U18 men vs. U18 women	0.00*	0.07	0.39	0.03	0.01*	0.10†
Senior women vs. U18 women	0.12	0.03	0.30	0.03	0.03*	0.08

TOP, transition offensive play; CBOP, check-ball offensive play; OROP, offensive rebound offensive play. *p < 0.05; †small effect size (w = 0.10-0.29).

DISCUSSION

This study compared offensive plays' incidence and success rates in 3x3 basketball by starting actions and age/sex categories. The results showed that TOP occurred with the highest frequency, followed by CBOP and OROP. The incidence of each type of offensive play is not constant across all games because it depends on the number of fouls, violations, and offensive rebounds. Overall, however, similar ratios were observed in all four categories. This result

indicates that increasing the success rate of TOP, which occurs most frequently, is essential for winning a game.

Comparisons of TOP success rates among the categories showed no age difference. However, there were sex differences: the success rates of TOP were significantly higher in the men's than in the women's tournaments. This result is unexpected because it would be more convincing to assume an age difference rather than a sex difference, given that TOP requires advanced abilities in decision-making and execution. For example, a previous study on 5-on-5 basketball reported that the number of assists per 100 possessions, considered an indicator of decision-making abilities, increases in an age-dependent manner (Madarame, 2018). This study could not specify the cause of the sex difference in the success rates of TOP. It should be noted, however, that while there were significant sex differences, the effect sizes were trivial. In addition, the absence of sex differences in the success rate of CBOP suggests that women can still improve their success rates of TOP.

Comparing CBOP and TOP, the former seems easier to execute a planned offensive play because it starts from a dead-ball situation. In addition, when comparing the success rates, the present study limited the CBOP data to plays in which the shot clock was reset to 12 seconds: offensive teams were able to use the entire 12 seconds to attack the basket. In contrast, while offensive teams can use 12 seconds in TOP, they cannot use the entire 12 seconds to attack the basket in most cases because they have to clear the ball before attacking the basket. However, no category showed a significant difference in success rates between CBOP and TOP. This result suggests that CBOP does not benefit only one side, offensive or defensive teams. Ortega et al. (2021) reported the incidence and success rates of offensive plays by classifying offensive plays into six types according to starting actions: after a basket, check-out, steal, ball interception, defensive rebound, or offensive rebound. The number of offensive plays analyzed by Ortega et al. (2021) was 315. When multiplying the number of plays by the reported incidence and success rates and recalculating the success rates as in the present study, the success rates of TOP and CBOP were 43.9% and 34.1%, respectively, in which TOP outperforms CBOP by ten percentage points. Since the previous study included only four games in the analysis, it is possible that the characteristics of chosen games or a particular team strongly influenced the results.

The success rate of OROP was significantly higher than that of CBOP and TOP in each category. This result is in line with Ortega et al. (2021), in which the success rate of offensive

plays after an offensive rebound was the highest among the six starting actions. The highest success rate of OROP is likely because OROP usually starts from under the basket. Having the ball under the basket increases the chances of making a successful field goal or drawing a foul. In 5-on-5 basketball, placing at least one offensive player who does not go for an offensive rebound is prevalent to prevent a fast break of the opponent team. However, since there is only one basket in 3x3, it is recommended that all offensive players go for an offensive rebound (Snoj, 2021a). Acquiring offensive rebounds is valuable because it increases the number of offensive plays. In addition, the high success rate in OROP indicates the importance of acquiring offensive rebounds. While significant differences were observed in each category, the effect sizes were trivial in the under-18 women's tournament. A comparison of OROP success rates among the categories also showed that the success rate in the under-18 women's tournament was significantly lower than that in the other categories. A previous study has shown that the success rate of paint shots was significantly lower in under-18 women than in senior men, senior women, and under-18 men (Madarame, 2023). While OROP does not always result in a paint shot, the lower success rate of pain shots may partly explain the lower success rate of OROP in under-18 women.

Although this study analyzed a substantial number of offensive plays in 3x3 basketball, if there is a limitation, it is that the data were collected from only one tournament for each category. Future studies collecting data from multiple tournaments for each category would increase generalizability.

CONCLUSION

Improving the success rate of TOP is crucial to increase the chance of winning a game because TOP accounts for more than half of the total offensive plays. The success rate of TOP was lower in the women's than in the men's tournament; however, the absence of sex differences in the success rate of CBOP implies that women can still improve their success rate of TOP. While the incidence of OROP was the lowest among the three offensive plays, the success rate of OROP was higher than that of TOP and CBOP, indicating the importance of acquiring offensive rebounds in 3x3 basketball.

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Declaration of Conflicting Interests

The author has no conflicting interests to declare.

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IS THE RACEWALKING BIOMECHANICS SIGNIFICANTLY INFLUENCED BY COACHING?

ALI VADBA POMEMBNO VPLIVA NA BIOMEHANIKO TEKMOVALNE HOJE?

ABSTRACT

While there is a significant number of analyses of influence of coaching and training content on performance, detailed analyses linking teaching the technique and biomechanics indicators in literature are rather scarce. The purpose of the study was to determine the differences between two groups of racewalkers in the selected variables describing their gaits. The research method consisted of measuring ground reaction forces as well as kinematics of motion recorded by video cameras and the OptoJumpNext system of 14 athletes from two distinct training groups of athletes walking at individually determined speed. To identify the differences in 9 key variables between the two groups, a two-sample unpaired T-test was performed, which was also controlled by Cohens' effect size indicator. The main finding of the study is that 5 key variables unrelated to walking speed were statistically different between the two groups, with Group A (predominantly "M"-shaped) having a lower ratio of peak ground reaction force (GRF) to GRF at 70% of the contact phase (p=0.0000), lower ratio of total GRF at the end and beginning of the interval 70% - 80% (p=0.0006), greater pelvic rotation (p=0.0056) and a more upright posture with lower forward pelvic tilt (p=0.0001) and lower backward thoracic tilt (p=0.0000). There were no significant differences between the two groups in two variables describing upper body movement i.e. arm-swing angle and thoracic rotation. Another variable (peak GRF) was also statistically different between the two group (p=0.0000), but this variable is related to the walking speed, which was not identical for the two groups. In conclusion, differences in the selected biomechanical indicators, that are trainable according to literature, may have been influenced by apparently different training approaches applied within the two groups of athletes. We suggest that, although the gait in racewalking is rather strictly defined by the rules, the above variables can and should be controlled and influenced by training to develop a smooth racewalking technique with lower peak ground reaction forces.

Keywords: racewalking gait, training groups, ground reaction forces, kinematics

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IZVLEČEK

Medtem ko obstaja veliko število analiz vpliva vsebine treniranja in vadbe na uspešnost, pa je podrobnih analiz, ki bi povezovale poučevanje tehnike in biomehanskih kazalnikov v literaturi precej malo. Namen raziskave je bil ugotoviti razlike med dvema skupinama tekmovalcev v tekmovalni hoji pri izbranih spremenljivkah, ki opisujejo njihovo hojo. Raziskovalna metoda je obsegala merjenje sil reakcije tal ter kinematike gibanja, posnetih z video kamerami in sistemom OptoJumpNext 14 športnikov iz dveh različnih vadbenih skupin atletov, ki so hodili z individualno določeno hitrostjo. Za ugotavljanje razlik v 9 ključnih spremenljivkah med obema skupinama je bil izveden dvosmerni neparni T-test, ki je bil kontroliran tudi z velikostjo učinka (Cohenov koeficient). Glavna ugotovitev študije je, da se je 5 ključnih spremenljivk, ki niso povezane s hitrostjo hoje, statistično razlikovalo med obema skupinama, pri čemer je imela skupina A (pretežno v obliki črke "M") manjše razmerje med največjo silo reakcije tal (GRF) in GRF pri 70 % kontaktne faze (p=0.0000), nižje razmerje med skupno GRF na koncu in začetku intervala 70-80 % (p=0.0006), večjo rotacijo medenice (p=0.0056) in bolj pokončno držo z manjšim nagibom medenice naprej (p=0.0001) in manjšim nagibom prsnega koša nazaj (p=0.0000). Pri dveh spremenljivkah, ki opisujeta gibanje zgornjega dela telesa, tj. kotu zamaha roke in rotaciji prsnega koša med skupinama ni bilo pomembnih razlik. Tudi druga spremenljivka (največja GRF) se je statistično razlikovala med obema skupinama (p=0.0000), vendar je ta spremenljivka povezana s hitrostjo hoje, ki pri obeh skupinah ni bila enaka. Skratka, na razlike v izbranih biomehanskih kazalnikih, ki jih je glede na literaturo mogoče vaditi, so lahko vplivali očitno različni pristopi k vadbi, uporabljeni v obeh skupinah športnikov. Predlagamo, da kljub temu, da je hoja pri tekmovalni hoji dokaj strogo določena s pravili, je mogoče in treba zgornje spremenljivke nadzorovati in nanje vplivati z vadbo, da bi razvili gladko tehniko tekmovalne hoje z manjšimi največjimi silami reakcije tal.

Ključne besede: tekmovalna hoja, vadbene skupine, sile reakcije tal, kinematika

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INTRODUCTION

Race walking is an integral part of the international long-distance competition program at World Track and Field Championships and Olympic Games. Although the name is reminiscent of walking as a pedestrian, the speed of movement in racewalking is much closer to running. However, the biomechanics of racewalking differ significantly from walking and running due to the specific rules (World Athletics, 2022) that require foot contact with the ground visible to the human eye throughout the gait as well as knee extension in the first phase of the stride.

The rules of racewalking define the technical requirements of the racewalking gait rather narrowly, which therefore seems very stereotypical (Preatoni et al., 2010). This gait is also not gender-specific, and there are no significant differences between kinetic and kinematic variables between female and male (elite) athletes when speed is taken into account (Hanley and Bissas, 2016). Nevertheless, studies have shown that individual differences in technique and style can be quite large, especially between less experienced athletes (De Angelis and Menchinelli, 1992), (Neumann et al., 2006), (Hanley et al., 2014). The most obvious difference studied is the shape of the vertical ground reaction force (GRF) curve, i.e., the 'M' and 'N' shapes, which can be associated with different racewalking styles (Fenton, 1984), (Pavei et al., 2019). However, due to the fact that there are much less racewalkers than runners, there is not much research on the biomechanics of racewalking and also there is a problem with sample size.

Pavei et al. (2014) conducted review of literature on the racewalking biomechanics and cited 16 papers focused on racewalking kinematics, 5 paper dealing with joint power and efficiency, only 4 papers analysing ground reaction forces and no more than 3 papers with combined analytical methods. Only 3 studies included more than 20 participants (while conducted using solely cameras), 6 studies had number of participants in the range 11-20 and 19 papers reported analyses with up to 10 participants (Pavei et al., 2014). Some conclusions can be drawn from a large number of studies on the biomechanics of long-distance running (Bowser et al, 2018; Chan et al., 2018; Doyle et al., 2022). Although running technique and style appear to be relatively uniform, significant differences in individual biomechanical variables between runners have become apparent with advances in analytical tools. Several studies have found differences in running style between recreational athletes and elite athletes who run as part of their (other) sport. In a systematic review of the impact of the foot strike technique on running injuries, Burke at al. (2021) isolated 13 studies with altogether 2564 participants, whereby 11

studies included recreational, collegiate, and military participants. Apart from that, Hanley et al. (2022) identified two characteristic groups of runners among the English Premier League soccer players, namely air runners ("gazelles") with shorter contact times, longer flight times, higher peak vertical forces, and greater vertical displacement compared to ground runners ("grizzlies").

A number of intervention studies have been conducted on the effects of different training methods compared to a control group, showing that differences in biomechanical variables, i.e., running style, can lead to differences in running economy and ground reaction forces, both of which are important for long-term athletic performance (Trowell et al., 2020). It is believed that coaches use somewhat different training methods when teaching running and racewalking technique and style, and also use specific strength and conditioning methods that may lead to individual biomechanical differences between athletes, which can also be considered an intervention (Saunderset al., 2004). However, there is very little comparative research on the biomechanics of different "real-world" training groups in running and racewalking, and there is no clear evidence that belonging to different training groups leads to significant differences in biomechanics, while researchers have predominantly concluded that elite athletes appear to have adopted their running style through a process of self-optimization (van Oeveren et al., 2021).

There is reason to believe that the effects of coaching are more pronounced in racewalking than in running for two main reasons. First, most track and field clubs have only one coach who specialises in racewalking because the number of athletes in racewalking is much smaller than in running, so the training methods are more unique than for runners, who typically change coaches several times at a young age until they join a group of elite runners. Unlike in running, coaches in racewalking usually spend many years teaching athletes the particular technique of locomotion and training their strength and conditioning to develop specific skills to achieve a competitive pace while following the rules that define an "unnatural" or restricted form of locomotion while keeping the risk of injury low (Hanley et al. 2014).

The purpose of this study is to determine if there are significant differences in the selected biomechanical variables between the two different groups of racewalkers that can be attributed to coaching, i.e., the different approach to teaching the racewalking gait. The research included 3 kinetic variables (peak GRF in the first phase of the stride, ratio of the peak GRF in the first phase of the stride and GRF at 70% of the single support phase, ratio of GRF at the end and

beginning of the interval 70% -80% of the single support phase) and 7 kinematic variables (duration of the flight phase, ratio of the phases of the rear support and front swing, arm swing, thoracic rotation, pelvic rotation, thoracic tilt and pelvic tilt). Potential significance of this study is to contribute to the scarce research into impacts of coaching on technical performance within athletics, with practical implications to suggest which key indicators of racewalking biomechanics should be monitored and influenced in supporting the development of young athletes.

METHODS

Participants

The presented analysis is one of the results of larger research into racewalking biomechanics including 26 participants from 4 countries. While analysing a number of selected indicators that may be important for identifying smooth and efficient racewalking technique, we noticed rather large differences in some important indicators describing motion of the athletes from different countries i.e., training groups led by different coaches. Therefore, we isolated 14 athletes from two distinct training groups (A and B) with the same gender structure (3 females and 4 males) and similar average age of the athletes (19.3 ± 4.5 years for Group A and 20.3 ± 6.5 years for Group B). Athletes in Group A were slightly taller (173 ± 3.5 cm) than those in Group B (169 ± 9.3 cm), while body mass index was similar (20.8 ± 2.0 kgm^{-2} and 20.3 ± 1.9 kgm^{-2}, respectively) (Table 1).

Table 1. Basic data on participating athletes (averages with standard deviations, tests of distribution normality and differences between the two groups of athletes).

	Group A			Group B			T-test p-values	Mann-Whitney U-Test Prob>|z|
	Mean (st.dev.)	Kurtosis	Skewness	Mean (st.dev.)	Kurtosis	Skewness		
Age (years)	19.3 *(±4.5)*	5.30	2.24	20.3 *(±6.5)*	6.75	2.58	0.7436	0.6436
Body mass (kg)	62.4 *(±7.0)*	2.25	-1.36	58.1 *(±9.8)*	-1.86	0.15	0.3725	0.3379
Height (cm)	173 *(±3.5)*	1.08	0.75	169 *(±9.3)*	-1.72	0.40	0.2840	0.3379
Body mass index (kgm^{-2})	20.8 *(±2.0)*	1.31	-0.78	20.3 *(±1.9)*	3.68	1.78	0.6228	0.2774
Speed in competition (ms^{-1})	3.14 *(±0.2)*	1.69	1.33	3.41 *(±0.3)*	1.84	-1.22	0.0728	0.0476
Competitive results (a)	787 *(±176)*	0.92	0.12	876 *(±139)*	2.79	-1.66	0.3114	0.1797

(a): Best result achieved in racewalking in the last 12 months prior to testing, in terms of comparable scores, according to the Scoring Tables of Athletics, 2022 Revised edition, 2022 World Athletics

All presented variables are identified as having normal distribution for both groups while, as suggested by Kline (2023), data severely deviate from normality if the values of skewness and kurtosis are above 3 and 10, respectively. Using parametric T-test as well as non-parametric Mann-Whitney U-Test (due to the small sample size), no statistically significant differences between the two groups were identified, apart from competitive speed, according to the performed non-parametric test. Although most athletes from both groups were internationally competitive, the structure of the sample from the two countries was not identical in terms of the level of athletic results, and athletes from Group B had 8.6% higher competitive speed, while it was not possible to have participants with identical levels of performance because the total number of active athletes in racewalking is very small.

Protocol of data collection

Athletes were instructed to restrain from heavy training sessions 3 days before the test. Before the test, anthropometric variables were measured according to the International Biological Program (IBP). Body weight, height, and leg length were used in this study.

The test field was 3 x 1.5 metres, with a force platform (Kistler, Winterthur model 9286 600x400 mm) in the centre and an OptoJumpNext system (Microgate, Bolzano, Italy) on the sides of the field (5 m). To capture the motion images in all 3 planes, cameras (Panasonic DMC-FZ200, Osaka, Japan) were placed in front of the test field, on the right side perpendicular to the athletes' direction of motion, and above the test field. The motion images were filmed at 200 frames/s. After a 15-minute warm-up period, athletes repeatedly racewalked through the 45-metre track and test field until they completed 12 correct trials (6 for each leg) within the specified speed range and with correct positioning of the leg in the centre of the force platform, without any noticeable change in the walking style. Walking speed was set within +/- 5% of the individually determined speed achieved in the year prior to testing in the racewalking disciplines in which the athletes specialised to capture the biomechanics of their individual competitive speed. The speed was determined for senior athletes based on their results in the 50-km disciplines, for the U20 and male U18 athletes in the 10-km disciplines, and for the others in the 5-km racewalking disciplines. While the percentage of failed attempts was 55% (38% due to excessive speed and 17% due to incorrect positioning of one leg), a total of 370 attempts were made to achieve the required 168 correct shots.

Ground reaction force data were extracted as comma-separated values (CSV) files and aggregated to 1/10 s level for further data analysis. To avoid the effects of background noise, a

threshold of 20 N in the vertical GRF was defined as foot strike and toe-off. Data recorded by the cameras were processed in Kinovea software and combined with data exported from the force plate and OptoJumpNext software to create a comprehensive database in which each individual trial represents a single row of all data for that trial. Force plate data were collected using LabChart software and the PowerLab A/D converter (AD Instruments, Dunedin, New Zealand). The sampling frequency was 2000 Hz. Data were filtered to select 3 of 6 recordings that were closest to the average GRF curves using the least squares method. Final variables were calculated as simple averages of the data for these 3 trials and normalized to body weight.

Statistical analysis

The analysis focused on the selected 3 kinetic variables and 7 kinematic variables (Table 2). The peak value of the total (resulting) GRF in the first phase of the step (as a percentage of body weight) was used. The ratio between the peak GRF in the first phase of the step and GRF at 70% of the contact phase was defined as the numerical interpretation of the shape (M or N) of the GRF curve. The third kinetic variable was defined as the ratio of GRF at the end and at the beginning of the interval from 70%-80% of the contact phase, while the slope of the GRF curve can be an important indicator of how the athletes were able to maintain the force to the ground immediately before toe-off. The kinematic variables, i.e., duration of flight phase, the rear support and front swing phases ratio, arm swing, thoracic and pelvic rotation, and thoracic and pelvic tilt, were selected as variables considered as important and specific for race walking.

Table 2. Variables and measuring methods.

Variables	Units	Description	Measuring methods
Kinetic variables			
Peak GRF in the first phase of the stride	Percentage of body weight	Total resultant GRF (% of body weight); indicator of risk of contracting injuries	Measured by Kistler force plate
Ratio of the peak GRF in the first phase of the stride and GRF at 70% of the single support phase	Ratio	Total resultant GRF; indicator of the shape (M or N) of the GRF curve	
Ratio of GRF at the end and beginning of the interval 70% -80% of the single support phase (GRF curve slope)	Ratio	Total resultant GRF, indicator of the slope of the GRF curve immediately before the toe off	
Kinematic variables			
Duration of the flight phase	Milliseconds	Time lapse when no foot contact with the surface	Measured by OptoJumpNext
Ratio of the phases of the rear support and front swing	Ratio	Ratio of distance between back leg toe and the vertical line connecting center of the mass and ground and distance	Captured by the camera placed on the side of the testing field and processed using the Kinovea software

		between that line and front leg heel in the double support phase	
Arm swing	Degrees of angles	Maximal angle between upper arms projection in the sagittal plane	Captured by the camera placed on the side of the testing field and processed using the Kinovea software
Thoracic rotation	Degrees of angles	Angle between the line through acromions and coronal plane.	Captured by the camera placed above the testing field and processed using the Kinovea software
Pelvic rotation	Degrees of angles	Angle between the line through iliospinale and coronal plane.	Captured by the camera placed above the testing field and processed using the Kinovea software
Thoracic tilt	Degrees of angles	Angle between the line through acromion and illiospinale and coronal plane in the midstance	Captured by the camera placed on the side of the testing field and processed using the Kinovea software
Pelvic tilt	Degrees of angles	Angle between the line through trochanterion and illiospinale and coronal plane in the midstance	Captured by the camera placed on the side of the testing field and processed using the Kinovea software

All presented variables (Table 3) are identified as having normal distribution regarding skewness and kurtosis. One variable (duration of flight phase) had the F-test ratio of variances between two groups above the critical value and for this variable, T-test was not performed. For other 9 variables, the unpaired two-sample T-test was performed to investigate whether there were significant differences in the key variables between the two groups of athletes, also using Cohens' effect size test. Apart from that, having regard to the small sample size, the parametric analysis was complemented with non-parametric Mann-Whitney U-Test. Considering the differences in speed between the two groups, the coefficient of determination was calculated for all variables in a linear regression with over ground speed. The significance level (probability of rejecting the null hypothesis if true) for all analyses was set at $p < 0.05$ and for Cohens' effect size critical value was set at $d \geq 0.8$. Data analyses were performed using Microsoft Excel Data Analysis tools and Stata 18.0 software package.

Table 3. Descriptive analysis of the variables.

Variables	Group A			Group B			F-test for ratio of sample variances (critical value = 2.58
	Mean (st.dev)	Kurtosis	Skewness	Mean (st.dev)	Kurtosis	Skewness	
Kinetic variables							
Peak GRF in the first phase of the stride (% BW)	1.80 *(±0.16)*	0.00	0.98	2.40 *(±0.23)*	0.49	0.07	2.11
Ratio of peak GRF in the first phase of the stride (% BW) and GRF at 70% of single contact phase	1.32 *(±0.17)*	-0.02	0.72	1.89 *(±0.25)*	0.58	0.98	2.06
Ratio of total GRF at the end and beginning of the interval 70% - 80% of single contact phase	0.74 *(±0.06)*	1.96	-0.18	0.64 *(±0.08)*	-1.59	-0.01	2.01
Kinematic variables							
Duration of the flight phase (ms)	36.3 *(±10.2)*	-0.09	-0.42	50.8 *(±18.0)*	-0.51	-0.42	3.10*
Ratio of phases of rear support and front swing	2.07 *(±0.34)*	0.85	0.79	2.36 *(±0.39)*	-1.05	0.17	1.34
Arm-swing angle (degrees)	80.7 *(±15.7)*	-1.22	-0.41	78.5 *(±13.8)*	-1.31	0.07	1.30
Thoracic rotation (degrees)	17.3 *(±6.0)*	0.18	-0.81	17.3 *(±7.5)*	-1.55	0.22	1.53
Pelvic rotation (degrees)	15.4 *(±5.4)*	0.39	-0.80	9.9 *(±4.1)*	-0.57	0.50	1.76
Thoracic tilt (degrees)	-7.6 *(±3.9)*	-0.56	-0.70	-18.8 *(±3.9)*	-0.39	0.31	1.01
Pelvic tilt (degrees)	5.6 *(±4.1)*	-0.70	0.73	13.0 *(±4.4)*	-0.75	-0.43	1.16

Legend: * denotes F-test value which is above the critical value.

Ethics

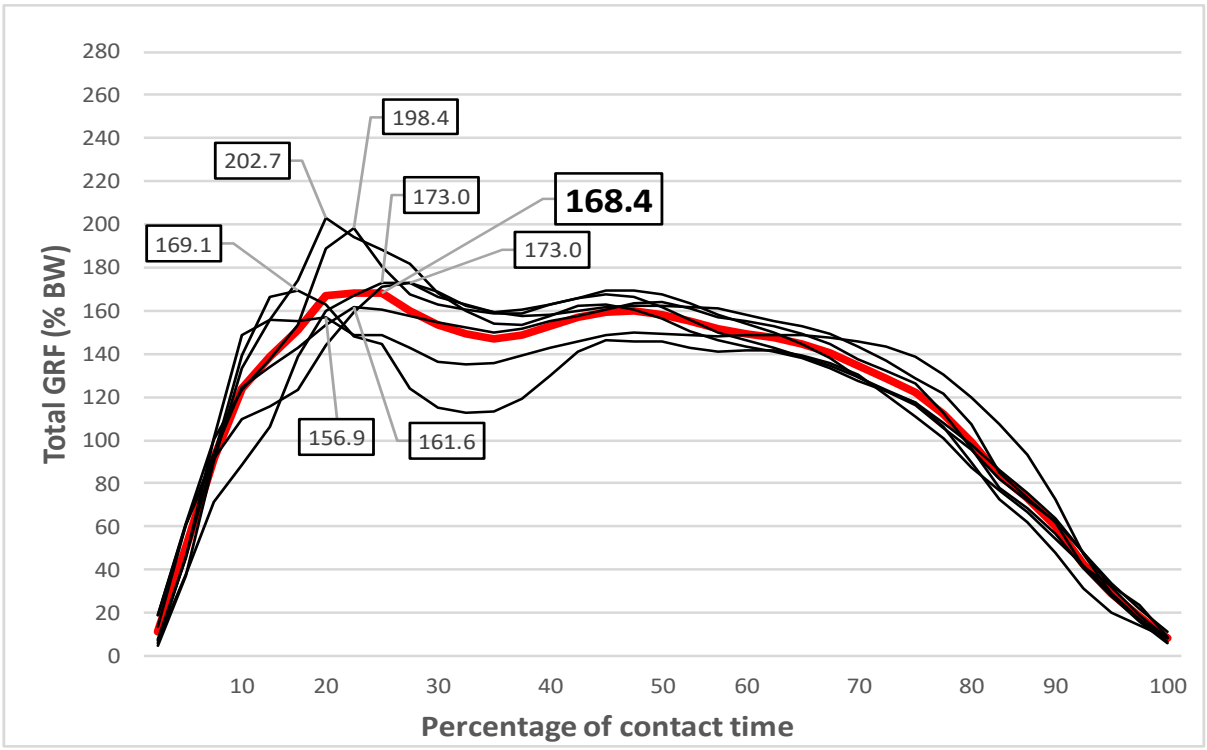
The Scientific and Ethical Committee of the Faculty of Kinesiology in Zagreb, Croatia, approved the study protocol before recruitment of participants (Approval No. 60/July 2019), and the research was conducted in accordance with international ethical standards and adhered to the current Declaration of Helsinki of the World Medical Association. Adult athletes and parents of minor athletes signed an informed consent form to participate in the study.

RESULTS

The differences in the shape of the total GRF curves (relative to body weight) between the two groups of racewalkers were striking. In Group A, 6 out of 7 athletes had the "M"-shaped type of GRF curves, while in Group B, 6 out of 7 athletes had predominantly "N"-shaped GRF

curves. To illustrate this, we calculated the average GRF curves for both groups of the athletes. Group A athletes (Figure 1) have a very low peak total GRF (168.4% of body weight) and they maintain the force towards ground throughout the midstance, where the second maximum occurs, not much lower than the first one. Towards the toe-off, the Group A athletes show the steep curve only in the last 25% of the contact time.

Figure 1. Total GRF (% of body weight) for Group A athletes.



The peak total GRF for the athletes in Group B (Figure 2) was "N"-shaped" with very large maximum (227.5% BW). These athletes are not able to retain the force throughout the stride and the midstance GRF is much lower than maximum, while there was a steep decline after the maximum, a period of maintenance of the GRF towards the midstance and very high curve slope beginning approximately from the midstance.

Figure 2. Total GRF (% of body weight) for Group B athletes.

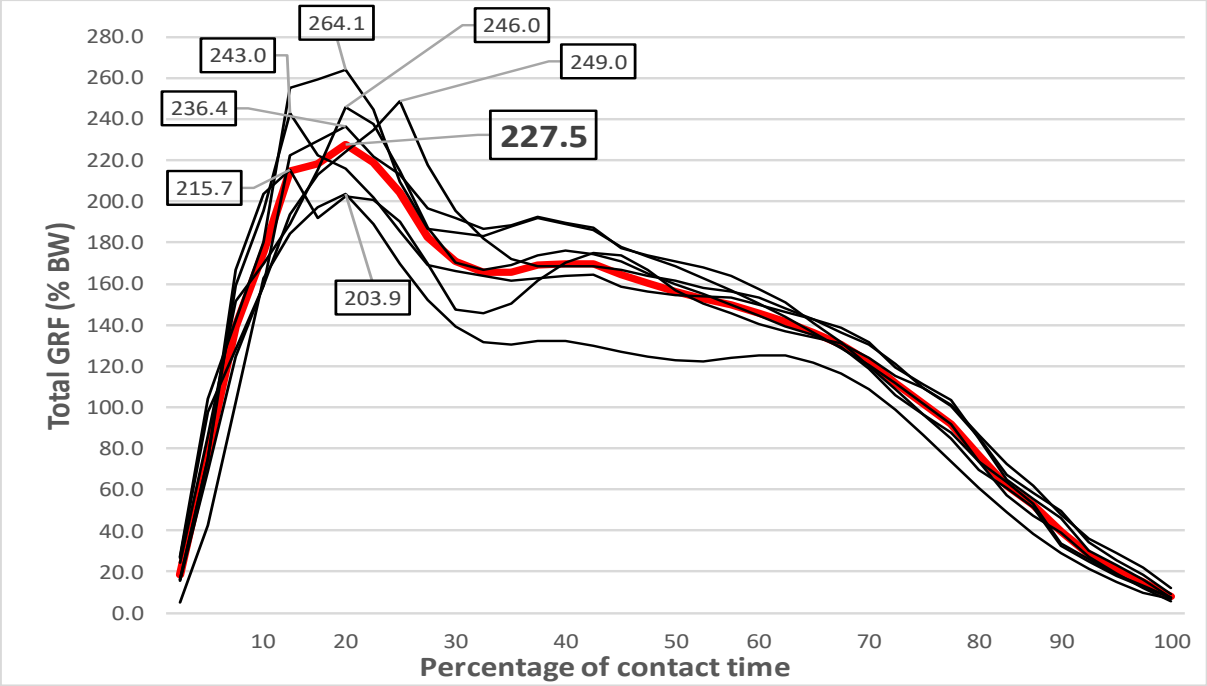


Table 4 summarises the main findings of the analysis of the differences between the 2 groups of racewalkers in the 9 selected variables. By simply calculating the relative differences, that is the average values for Group B expressed as index values (Group A = 100) it is evident that only for 2 variables (arm swing and thoracic rotation) the differences were less than 10%. For 2 other variables (ratio between the rear support and front swing and the curve slope), the differences were moderate (10%-30%). For other 3 variables (peak GRF in the first phase of the stride, the curve shape and pelvic rotation) the differences were high (30%-50%). For 2 variables the differences were extreme with the Group B athletes having forward pelvic tilt 2.3 times larger and backward thoracic tilt 3.2 times larger than the Group A athletes.

Table 4. Main findings of the research.

Variables	Group B mean (Group A mean = 100)	T Test (p-values)	Cohens' Effect Size	R^2 in regression with speed	Mann-Whitney U -test Prob>|z|
Kinetic variables					
Peak GRF in the first phase of the stride (% BW)	133.7	0.0000	3.11	0.34*	0.0000
Ratio of peak GRF in the first phase of the stride (% BW) and GRF at 70% of single contact phase (curve shape)	143.2	0.0000	2.65	0.14	*0.0000*
Ratio of total GRF at the end and beginning of the interval 70% - 80% of single contact phase (curve slope)	85.8	0.0006	-1.48	0.06	0.0018
Kinematic variables					
Ratio of the phases of the rear support and front swing	113.7	0.0489	0.78*	0.13	0.0506*
Arm-swing angle	97.3	0.6949*	-0.15*	0.02	0.6623*
Thoracic rotation	100.0	1.0000*	0.00*	0.02	1.0000*
Pelvic rotation	64.7	0.0056	-1.14	0.09	0.0087
Thoracic tilt	316.9	0.0000	-2.44	0.15	0.0000
Pelvic tilt	233.3	0.0001	1.76	0.09	0.0004

Legend: "R^2 in regression with speed" are values of coefficients of determination, describing the proportion of the variation in the analyzed variables predictable from speed over ground of participants. Denoted with "*" are values that have R^2 values larger than 0.25, T-test p-values larger than 0.05, those with Cohens' Effect Size lower than 0.8 as well as those with Mann-Whitney U-Test values larger than 0.05.

According to the performed T-test, there were no significant differences between the two groups for two variables describing upper body movement (arm swing angle and thoracic rotation). For the variable on the ratio of the phases of the rear support and front swing, T-test p-value was slightly within the set critical value (0.05), while the Cohens' effect size test resulted with the value very close but still below critical (0.8) so difference between the 2 groups cannot be considered as statistically important. These 3 variables were also outside the critical values to indicate statistical differences between the two groups of athletes according to the non-parametric Mann-Whitney U-Test.

Further 5 variables (2 kinetic and 3 kinematic variables) have clear statistically significant differences between the two groups of athletes. Not surprisingly, the variables representing the shape and slope of the GRF curve are significantly different between the two groups, with Group A (predominantly "M"-shaped group) having a much lower ratio of peak GRF to GRF at 70% of the contact phase and less steep GRF curve in the 70% - 80% interval, which is also evident from the presented figures. Regarding the kinematic variables, the larger pelvic rotation angle, smaller forward pelvic tilt, as well as much smaller posterior thoracic tilt of the Group A athletes are significantly statistically different than for the Group B athletes.

Withstanding the fact that there was a difference of 8.6% in the average speed of movement between the two groups, which could affect the conclusions, it is important to note that all 5 variables that are statistically significantly different between the two groups, as well as 3 variables that are not, are not statistically influenced by the speed, with R^2 in regression with speed lower than 0.15. The remaining variable (peak GRF in the first phase of the stride) is moderately related to the speed of movement (R^2=0.34) and, although this variable is statistically significantly different between the two groups, this shall be interpreted with caution.

DISCUSSION

The aim of the presented study was to investigate if certain biomechanical indicators are statistically different between two distinct groups of racewalkers. We concluded that out of 9 variables under review, 5 variables unrelated to walking speed (GRF curve overall shape and slope in 70% - 80% of the contact phase, pelvic rotation, thoracic and pelvic tilt) were statistically different between the two groups, as well as another variable (peak GRF) related to walking speed, which was not identical for the two groups.

Racewalking is a unique gait that is intermediate between running and walking, with greater pelvic rotation and peak moments of hip flexion and extension, and two distinct peaks of vertical ground reaction force, with the first peak being greater (Norberg, 2015). Although a visible flight phase is not allowed by the regulations, electronic devices record the occurrence of a short flight phase at competition speed in all international athletes. In elite racewalkers, flight time is positively correlated with racewalking speed (r = 0.46) and loading peak forces (r = 0.47) (Hanley and Bissas, 2016). In our study, flight time was also moderately correlated with speed (R^2 = 0.38) and was on average much longer (40%) in the "N"-shaped group than in the "M"-shaped group, while the difference in speed was only 8.6%. Similarly, the difference in peak GRF was 33.7% higher in the "N"-shaped group than in the "M"-shaped group. This increase of GRF for 1 unit of velocity increase was above the 2.22 average in our study, and much above the 0.23 value in a similar study (Pavei and La Torre, 2016). However, in the cited study, increase of speed was analysed for individual elite athletes, each of whom walked in a different speed range, whereas our study included less experienced athletes that walked in a single, individually determined narrow speed range matched to their competitive speed. These

considerations, together with the analysis presented, lead to the conclusion that the variable of peak relative GRF may also be group-specific, while exhibiting satisfactory T-test statistics.

Fenton (1984) found that 4 of 7 well-trained racewalkers exhibited the "N-shaped" GRF curve with a characteristic peak at GRF in the first 25% of the support phase and a sharp drop in the last 25% of the support phase. For 3 less trained subjects, he described the "M-shaped" curve with an earlier occurrence of the peak GRF, a sharp drop to a low level thereafter, and a distinct second peak at about 75% of the support phase. Since the first group was better trained than the second, he concluded that their walking style was more advanced and "fluid". In a more recent study (Pavei and La Torre, 2016), 7 of 15 racewalkers had an "M-shaped" (vertical) GRF curve and 8 athletes had an "N-shaped" curve, and the outcome level of the two groups of athletes could not be clearly distinguished, which is contrary to the results of Fenton (1984). The cited authors hypothesised that the shape of the GRF curves was a result of the learned style of racewalking being specific to the training group, while differences in style and specific abilities could be the cause. However, they did not have enough subjects from the same clubs, so they could not prove this assumption. Our study could be a formal proof of this assumption, because out of 14 racewalkers from 2 training groups, 6 in one group had an N-shaped curve and 6 in the other group had an M-shaped curve. The variable representing the shape of the GRF curve numerically (ratio of peak GRF to GRF at 70% of the contact phase) and the variable focusing on the slope of the curve in the interval of 70%-80% of the contact phase were clearly statistically different between the 2 groups.

It should be emphasised that previous studies focused mainly on the vertical component of the GRF, while our work focused on the entire GRF, following the principal component analysis approach, which takes into account the entire time series of the three-dimensional GRF data (Kim, Dai, Lu, Lu and Chou, 2022) and focused on the shear stress from the resultant GRF (Gruber, Edwards, Hamill, Derrick and Boyer, 2017), (Yu et al., 2021), which is also interpreted as the sum of all forces that determine the load during dynamic movements (Shimokochi and Shultz, 2008). The reason for this focus is that the risk of injury (an important issue in training) is not only related to the vertical component of the GRF but also to the other two components (Shelburne, Pandy, Anderson and Torry, 2004), (Napier, MacLean, Maurer, Taunton and Hunt, 2018). A smoother GRF curve (with less sharp peaks) is beneficial for walking efficiency due to less velocity fluctuations (Hanley and Bissas, 2013).

In our analysis, the group with the N-shaped GRF curve had a 35% lower pelvic rotation angle than the M-shaped group, whereas there were no significant differences between the two groups in thoracic rotation and arm swing angle (variables describing upper body movement). These results are consistent with recent research on the role of the upper body in racewalking (Gravestock, Tucker and Hanley, 2021), which found no correlation between upper body joint positions and pelvic motion with speed, but only a positive correlation between pelvic rotation and stride length. Apart from this, the N-shaped group in our study had more forward pelvic tilt (13.0 versus 5.6 degrees) and much more posteriorly tilted thorax (18.8 versus 7.6 degrees), whereas the M-shaped group had a more upright trunk posture. In racewalking pelvic tilt is thought to be reduced by the development of strong abdominal muscles (Gravestock, Tucker and Hanley, 2021), which is consistent with Drake's (2003) conclusion that a lack of trunk stability limits optimal flexion and extension of the hips, resulting in a bent knee or visible flight phase, which are clear technical errors in racewalking. The forward flexed upper body is also one of the few characteristics (along with rapid leg swing and short ground contact) that distinguish distance runners from East Africa from athletes from other regions (Tawa and Louw, 2018).

While comparative studies of biomechanical indicators of two or more training groups are very scarce in practice, there are a large number of so-called "intervention studies" that have shown that running style and running economy are 'trainable' parameters (Jones and Carter, 2000) and can be greatly improved in the short to medium term by a strength training program (Balsalobre-Fernández, Santos-Concejero and Grivas, 2006), plyometric training, resistance and interval training (Moore, 2016), and high-frequency running (Quinn, Dempsey, LaRoche, Mackenzie and Cook, 2021). There is also evidence that (verbal) coaching instructions can have an immediate effect on running style change, with a 17% reduction in peak GRF, which is an important risk factor for the occurrence of running injuries (Ó Catháin, Richter and Moran, 2022) as well as racewalking injuries (Qipeng, Zhengye, Dewei, Cui and Wei, 2013) with the most common injuries (43% of injuries in elite athletes at 12 months) occurring in the posterior tight muscles and tendons (Hanley, 2014). Also, intervention studies not including runners and racewalkers indicate that the most important differences identified in our research can be influenced by coaching i.e. applying specific tailor-made exercises. Wehner et al. (2021) conducted meta-analysis and four out of five studies demonstrated a significant improvement of thoracolumbar spine flexibility following the Tai Chi training. Also, Dimitrijević et a. (2022)

reported that different correction methods have a positive effect on subjects with lumbar lordosis (thoracolumbar flexion), according to 10 studies they included in meta-analysis.

Not only in running, but also in racewalking, kinematics can be influenced by training content (Witt and Gohlitz, 2008; Gravestock, Tucker and Hanley, 2021; Drake, 2003). Therefore, learned movement patterns specific to training in different training groups could be behind the differences in variables describing gait in racewalking discussed in this article, whereby racewalking is not a "natural" movement mode and is learned and trained with much greater effort than running or walking as a pedestrian. In conversation with the coaches of the two groups under review it became evident that the Group A (predominantly "M"-shaped) had a high share of multisport activities (running, cycling, kayaking) in total training volume (some 30%). They also had large content (up to 30%) of technical exercises, specific strength workouts, especially focused on stimulating thoracolumbar rotation and reducing thoracolumbar flexion while also reducing flight time and excessive GRF. Athletes within the Group B (predominantly “N” shaped) had much higher weekly racewalking mileage especially focused on competitive speed with multisport activities and technical exercises performed only occassionaly. As illustration of the measurable outcome of the difference in the contents of technical workouts between the groups, 3 athletes from the 2 groups each participated in European championships in the year prior to testing and Group A racewalkers did not receive any red card from the judges, while all 3 of the Group B racewalkers received at least 1 red card.

A potential problem with the N-shaped GRF curve is, as mentioned before, that higher peak at the heel contact leads to higher risk of strain-related injuries (Hanley et al. 2014), which leads us to practical implications of this study's findings, i.e., that coaches should consider instructing young racewalkers to maintain an upright body position, provide adequate pelvic rotation, maintain force toward the ground longer throughout the gait, and avoid excessive flight phase to maintain a lower peak GRF.

CONCLUSION

The results of our research strongly suggest that there are significant differences between two distinct groups of racewalkers, particularly in pelvic rotation, pelvic and thoracic tilt, as well as in the shape and slope of the GRF curve. According to the findings of research by other scholars, these indicators are connected to a smooth racewalking technique and can be influenced by

instructional coaching. We therefore conclude that the reported differences in contents and focus of training between the analysed groups may have influenced the identified statistically significant and functionally important differences in the selected variables describing the racewalking gait. These characteristics can and should be controlled and modified in racewalking coaching to develop a motion technique within the set rules of racewalking, without excessive peak ground reaction forces, which is important for racewalking economy and injury prevention.

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SHOULD I REPORT ABUSE? - ATTITUDES TOWARD DOPING TESTING AND ANONYMOUS REPORTING IN THE WHISTLEBOWER PROGRAMME

ALI NAJ PRIJAVIM ZLORABO? – STALIŠČA DO DOPINŠKIH TESTIRANJ IN ANONIMNE PRIJAVE V PROGRAMU ŽVIŽGAVKA

ABSTRACT

Despite all endeavours to prevent it, the use of performance-enhancing substances continues to occur in sports and social science research suggests that doping prevalence is likely much higher than what is found through testing. One of the ways to uncover doping violators is through reporting illicit drug use, through "doping whistleblowing" – the readiness to do so depends highly on the level of our moral development and the motivation to do so. It was exactly this method, which helped uncover some of the biggest doping scandals in sport in the past few years and our purpose in this study was to examine attitudes toward drug testing and anonymous reporting and see, if we can predict an athlete's intention to report anonymously based on attitudes toward drug testing. 255 top athletes and coaches from Estonia and Slovenia-two small, athletically successful countries-participated in this study, 176 male and 79 female, 156 athletes and 99 coaches from team and individual sports. They filled out an attitudes questionnaire about drug testing and an anonymous report. The participants filled out a questionnaire online. We used t – test to compare subgroups of participants and correlation and linear regression to look for relations between doping attitudes and willingness to make an anonymous report. Comparisons of subgroups of participants revealed that female participants are more likely to believe that taking banned substances should be punished but are less likely to make an anonymous report. We also found that coaches seem to be better informed about the issue of doping than athletes and trust NADO more than athletes. We found several correlations between attitudes toward doping testing and those toward anonymous report and we tried to predict the willingness to make an anonymous report. We found several predictors, which were different for men and women. NADOs play an important role in creating conditions, which will enable people to report doping anonymously, but it has to be done both through education and through rigorous testing. This will ensure that whistleblowing can become an active part of the fight for clean sport.

Keywords: doping attitudes, anonymous report, doping abuse, moral development

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IZVLEČEK

Ne glede na ves trud za preprečevanje zlorabe, je uporaba substanc, ki bi lahko izboljševale izvedbo, v športu prisotna, družboslovne raziskave kažejo, da je te zlorabe še precej več, kot jih odkrijejo s testiranji. Eden od načinov za odkrivanje dopinga je uporaba tako imenovanih »dopinških žvižgačev«, pripravljenost za prijavo zlorabe pa je odvisna od motivacije in stopnje našega moralnega razvoja. Prav s pomočjo žvižgačev so namreč v preteklih letih odkrili nekaj največjih dopinških škandalov. Namen naše raziskave je bil preveriti stališča do dopinških testiranj in anonimne prijave in ugotoviti, ali lahko na podlagi teh stališč napovemo pripravljenost narediti anonimno prijavo o kršitvi. V raziskavi je sodelovali 255 vrhunskih športnikov in trenerjev iz Estonije in Slovenije, dveh majhnih, a športno uspešnih držav. Od tega jih je bilo 176 moških in 79 žensk in 156 športnikov in 99 trenerjev, tako iz ekipnih kot individualnih športov. Izpolnili so vprašalnik o dopinških testiranjih in anonimni prijavi, reševanje je potekalo preko spleta. S t-testom smo primerjali podskupine udeležencev, s korelacijo in linearno regresijo pa smo preverjali odnose med stališči do dopinških testiranj in pripravljenostjo narediti anonimno prijavo. Ugotovili smo, da so ženske bolj prepričane, da bi morali jemanje prepovedanih substanc kaznovati, so pa manj naklonjene temu, da bi same prijavile kršitev preko anonimne prijave. Ugotovili smo tudi, da imajo trenerji mnenje, da so bolj ozaveščeni o dopingu kot športniki in v primerjavi s športniki bolj zaupajo nacionalnim protidopinškim agencijam. Našli smo tudi več povezav med stališči in pripravljenostjo narediti anonimno prijavo in poskušali smo predvideti, na podlagi česa bo pripravljenost za anonimno prijavo večja. Ti prediktorji so bili drugačni za moške kot ženske. Nacionalne protidopinške agencije imajo ključno vlogo pri omogočanju anonimnih prijav, pri tem pa morajo delovati tako na področju izobraževanja in rednih testiranj – tako lahko zagotovijo, da bodo lahko žvižgači postali aktivni del boja za čist šport.

Ključne besede: stališča do dopinga, anonimna prijava, doping, moralni razvoj

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INTRODUCTION

Anti-doping policies were developed to protect the right of athletes to train and compete in a doping-free environment, and testing is an important tool to secure this right. Although the rules are enacted and enforced regardless of athletes' perceptions of the effort, anti-doping authorities rely on the support and trust of athletes to effectively prevent doping in elite sport and to legitimise the rather extensive anti-doping programme (*World Anti-Doping Code*, 2015). In securing the athletes' right to doping-free sport, doping controls are an important measure (Overbye, 2016).

Doping controls (tests) are conducted to obtain analytical evidence of an athlete's compliance (or non-compliance) with the Code's strict prohibition on the presence/use of a prohibited substance or prohibited method. "Any Athlete may be required to provide a Sample at any time and in any location by an Anti-Doping Organisation with testing authority" (*World Anti-Doping Code*, 2015, pp. https://www.wada-ama.org/en/athletes-support-personnel/anti-doping-process).

Despite scientific advances that make it possible to detect increasingly refined substances and ongoing efforts to strengthen doping controls, the use of performance-enhancing substances (PES) continues to occur in sports. While the proportion of anti-doping rule violations detected by doping controls is less than 2% (WADA, 2016), social science research suggests that doping prevalence is likely much higher (Whitaker et al., 2014). Some studies suggest prevalence rates as high as 35% and question the effectiveness of current doping control systems.

The number of tests at the global level increased significantly until the early 2010s, when optimization through intelligent (evidence-based) testing was recommended (*World Anti-Doping Code*, 2015). Annually, about 280 thousand tests (both urine and blood tests) are performed worldwide, but the percentage of positive cases is not increasing and each year less than 2% of doping tests performed show a positive test result.

Recent studies (Overbye, 2016)suggest that current policies have led to a different kind of inconsistency and new forms of inequality for athletes. Different countries have somewhat different standards and athletes can be treated diffenerently, as different countries implement the code differently, including international standards for doping control and testing – they are not the same in all countries (Overbye, 2016). Wagner and Hanstad (2011) have shown, that national implementation of the Code takes different forms.

Overbye (2016) studied, how elite athletes perceive and trust the functioning of the doping control system in their sport. She found that about one-third of athletes disagree to some extent that the number of tests and the selection of athletes for doping control are appropriate. She found that athletes, who rely on the testing system being effective and working well worldwide show greater distrust or dissatisfaction with the current testing system. The different views of the athletes show that the current anti-doping policy is simultaneously met with sport, (dis)trust and frustration (Overbye, 2016). By including the views and experiences of top Danish athletes, this study confirmed that the current testing system faces obstacles and contributed to the knowledge of some of the challenges WADA faces in implementing the policy.

About 90% of all athletes (Tavani et al., 2012) believed that anti-doping testing should be conducted regularly by sports federations, during training and not only during competitions. 72% felt that only a small proportion of athletes who engage in illegal doping practises are detected during anti-doping controls. Researchers (Dunn et al., 2010)also found that the majority of their participants believed that testing for banned substances is an effective way to deter people from using them.

On the other hand, athletes often have negative attitudes toward testing (Judge et al., 2010) about two-thirds of their participants did not believe that testing protocols were fair. More than half of the athletes believed that drug testing is the most effective way to prevent the use of performance-enhancing drugs in sports, but a large majority agreed that drug testing does not catch all athletes who cheat. From this study, we can also see that participants do not believe that drug testing is an invasion of privacy and accept drug testing as part of participation.

Athletes believe (Ćorluka et al., 2011; Rodek et al., 2012) that first offenders should receive a lenient sentence and second offenders should receive a life sentence. Almost half of the participating Croatian athletes (Šajber et al., 2013)believe that a financial penalty is the correct sanction for doping offenders, while one-third of the participants would opt for a life ban and one-fourth for an initially lenient, then life ban. Similarly, Iranian athletes were found to be against the free use of all drugs (Halabachi et al., 2011) and strongly believe in doping controls, the same result was found among Iranian coaches (Seif Barghi et al., 2015). Studies uniformly confirm that the majority of athletes oppose doping and support doping controls - both in terms of attitude and behavioural intention (Judge et al., 2010).

How willing we are to report doping abuse also depends on our level of moral development. Kohlberg defined three stages of moral orientation, each consisting of two stages (Papalia et

al., 2003) - this is a theory related to Piaget's theory of cognitive development, as it uses a person's thinking to determine the level of moral development (Zupančič, 1990). Kohlberg (Kohlberg, 1984) describes three stages of moral development-the pre-conventional, conventional, and post-conventional stages, where a person's sense of morality is defined in terms of more abstract principles and values. Although we would expect people who are at this highest stage to be most ready to "blow the whistle" (Kohlberg, 1984), this stage is rarely reached. Moral development is a difficult construct to measure because what we are willing to say and what we do can differ considerably (Bucik, 1997).

Cognitive theories of moral development understand moral maturity as understanding the society in which we live-the more complex the society, the more complex one's morality must be in order for the person to successfully adapt to it (Marjanovič Umek & Zupančič, 2004). Since doping abuse is a complex issue, the athlete's morality should be at the highest possible level in order to respect the rules and regulations and truly understand the importance of doping to the sport and to each individual athlete.

Moral development, according to Kohlberg, depends on the level of cognitive development, but also on motivation (Thomas, 1992) - a person may be able to act at a higher moral level, but does not show it in a certain environment because it may be "dangerous" for them to do the right thing. It also depends on taking on social roles - a person may take on different roles in different environments, which also means they will make moral decisions at different levels. Finally, moral development also depends on the structure of rights in social groups and institutions - groups that promote decision making and responsibility, where the principles of equality and reciprocity apply, will stimulate moral development far more than rigid groups and institutions based on authority (Kroflič, 1997). This means that we should focus heavily on education and understanding as a means of prevention, rather than punishment, in promoting the moral development of athletes.

Although there are various mechanisms for investigating or detecting illicit drug use in sport, such as oral and written evidence, academic research, and investigative journalism, encouraging individuals to report illicit drug use (in other words, to be a "doping whistleblower") has received increased attention in research (Erickson et al., 2017). Whistleblowers have become increasingly important and impactful in exposing doping in sport. Recent examples include Russian insiders whose allegations led to the country's exclusion from some sports at the 2016

Summer Olympics in Rio de Janeiro and from the entire 2018 Winter Olympics in Pyeongchang.

The increasing prevalence of whistleblowing in sport has led to the need to understand the conditions underlying the intent of whistleblowing. Whistleblowing involves the reporting of an illegal (or unethical) act by an observer who has inside information about the wrongdoing (Goldsmith, 2015). Track and field athletes appeared willing to contribute (Whitaker et al., 2014)to the elimination of doping in athletics by blowing the whistle, while rugby league players revealed a moral dilemma by suggesting that they would all abide by a code of silence and not report a teammate for doping despite disagreeing with the teammate's actions.

Over the past fifteen years, there have been an increasing number of high-profile whistleblowing cases in sports. One of the first cases of whistleblowing in doping was when Trevor Graham, a former track and field coach from the United States, anonymously called the U.S. Anti-Doping Agency and alerted them to undetectable anabolic steroids being distributed to world-class athletes (USADA, 2023). The case, which became known as the BALCO scandal, was at the time the largest doping scandal in the history of athletics, also involving sprinters and baseball stars. Whistleblowing was also a reason for one of the biggest doping scandals in cycling. Landis, a former teammate of Lance Armstrong, blew the whistle on Armstrong after he himself was caught blood doping. The case ended with Armstrong being stripped of his seven Tour de France titles and ordered to pay millions in compensation (The Wall Street Journal, 2015).

The purpose of this study was to examine attitudes toward drug testing and anonymous reporting among male and female athletes, among coaches and athletes, and among athletes in team and individual sports. We will attempt to find a correlation between attitudes toward drug testing and attitudes toward anonymous reporting and attempt to predict intention to report anonymously based on attitudes toward drug testing.

METHODS

Participants

255 top athletes and coaches from Estonia and Slovenia - two small, athletically successful countries -participated in this study (M_{age}= 32.90 ±14.78 years), of whom 176 were men (M_{age}= 34.60 ± 15.43 years) and 79 were women (M_{age}= 29.11 ± 12.49 years); men were older than

women (t =3.01; sig (t)=0.00). 156 of them were athletes (M_{age}= 24.60 ± 9.15 years) and 99 coaches (M_{age}= 45.98 ± 12.28 years), coaches were older than athletes (t =-14.90; sig (t)=0.00). 166 participants in individual sports (M_{age}= 34.14 ± 15.99 years) and 87 participants in team sports (M_{age}= 30.30 ± 11.63 years), participants in individual sports were older (t = 2.26; sig (t)=0.03).

Instruments

Participants were administered an attitudes questionnaire about drug testing (14 questions) and an anonymous report (3 questions), which they answered on a 5-point scale (1 - I strongly disagree, 5 - I strongly agree) (Makuc et al., 2019). The attitudes questionnaire was part of the questionnaire developed by Konrad Kleiner and Lisa Steinmaurer from the Centre for Sport Science and University Sport at the University of Vienna for an international project on doping in sport. The questions on anonymous reporting were also used in this project and were created by Nina Makuc from SLOADO.

Procedure

Participants were contacted by email as part of an international doping project and asked to complete an online questionnaire. Before completing the questionnaire, they all signed an informed consent form to participate in the study, the rules of the Helsinki declaration were fully accounted for. The National Anti-Doping Agency provided the information on actual cases of anonymous reporting. The data were processed using IBM SPSS Statistics 25.0. We used t – test to compare male and female participant, coaches and athletes and athletes of team and individual sports. Homogeneity of variance was tested with Levene's test for equality of differences, when differences were significant on the level of 0.05, we used a rectified value of t. Pearson correlation was used for checking the correlations, and linear regression to look for relations between doping attitudes and willingness to make an anonymous report. The used level of significance was 0.05.

RESULTS

Table 1. Significant differences in attitudes toward doping control and anonymous reporting between male and female participants, athletes and coaches, and individual and team athletes.

	males		females					95% CI for Cohen's d	
	M	*SD*	*M*	*SD*	*t*	*sig (t)*	*Cohen's d*	*Lower*	*Upper*
the use of banned substances should be punished	3.91	1.06	4.19	0.86	-2.03	0.04	0.23	0.01	0.46
readiness to make an anonymous report if someone was using doping	3.88	1.24	3.53	1.3	2.05	0.04	0.40	0.15	0.66
	athletes		coaches					95% CI for Cohen's d	
	M	*SD*	*M*	*SD*	*t*	*sig (t)*	*Cohen's d*	*Lower*	*Upper*
awareness of possible report of mistakes during doping control procedure	3.48	1.3	3.98	1.24	-3.05	0.00	-0.26	-0.48	-0.05
punishments for doping violations should be more severe	3.67	1.14	4.19	1.11	-3.58	0.00	-0.52	-0.72	-0.32
NADO is a trustworthy organization	3.61	1.11	4.04	1.03	-3.16	0.00	-0.07	-0.12	-0.02
our country has stricter rules regarding doping than other countries	2.08	1.02	1.77	1.07	2.37	0.02	0.32	0.11	0.53
doping controls are a necessary part of elite sport	4.45	0.84	4.72	0.64	-2.89	0.00	-0.31	-0.50	-0.12
knowledge how to make an anonymous report	3.15	1.4	3.55	1.38	-2.19	0.03	-0.34	-0.58	-0.10
anonymous report is a tool to fight for clean sport	3.79	1.09	4.11	1.13	-2.27	0.02	-0.36	-0.60	-0.12
	individual sports		team sports					95% CI for Cohen's d	
	M	*SD*	*M*	*SD*	*t*	*sig (t)*	*Cohen's d*	*Lower*	*Upper*
doping controls are an interference in my life	2.08	1.17	1.74	0.98	2.38	0.02	0.11	-0.13	0.36

In Table 1, we can see that several differences were found between the subgroups of our participants. Female participants are more likely to believe that taking banned substances should be punished but are less likely to make an anonymous report if they know that someone is violating the doping rules. Several differences were also found between coaches and athletes - coaches seem to be better informed about the issue of doping than athletes - they are more aware that they can report possible errors during the testing process and know better how to make an anonymous report, also they are more likely than athletes to believe that anonymous reporting is useful in the fight for clean sport. They also believe more than the athletes that the

NADO is trustworthy, are more likely to believe that the penalties for doping rule violations should be harsher and believe that doping controls are a necessary part of elite sport, while the athletes in both participating countries believe more than the coaches that their countries have stricter anti-doping rules than other countries and that this puts them at a disadvantage.

Table 2. Correlations between attitudes to doping testing and readiness to make an anonymous report.

	knowledge how to make an anonymous report	anonymous report is a tool to fight for clean sport	readiness to make an anonymous report if someone was using doping
awareness of possible report of mistakes during doping control procedure	0.40		
NADO's work is highly proficient	0.32		
punishments for doping violations should be more severe		0.32	0.31
NADO is a trustworthy organization	0.43	0.30	

Note: Only significant correlations, higher than 0,30 are shown in the table.

Table 2 shows that knowledge of how to make an anonymous report correlates with awareness that reporting errors in the doping control process is possible and the trustworthiness and competence of the NADO. The belief that an anonymous report is a means to fight for a clean sport correlates with the belief that the punishments for doping offenders are too lenient and with the trustworthiness of the NADO, while the willingness to make an anonymous report correlates with the belief that the punishments for doping offenders should be harsher.

Table 3. Linear regression for readiness to make an anonymous report in male and female participants separately.

		B	Beta	t	sig (t)
men	Constant	0.32		0.45	0.65
	adult athletes should decide on their own regarding doping, external control is redundant	-0.19	-0.22	-2.81	0.01
	our country has stricter rules regarding doping than other countries	0.25	0.22	2.69	0.01
	doping control helps protect clean athletes	0.35	0.31	3.68	0.00
women	Constant	1.11		0.79	0.43
	understanding the procedure before being tested for the first time	0.35	0.39	2.87	0.01
	punishments for doping violations should be more severe	0.27	0.24	1.96	0.05
	doping controls are a necessary part of elite sport	-0.56	-0.30	-1.98	0.05

We ran a regression of attitudes toward doping control on willingness to make an anonymous report when someone uses doping separately for men and women, because we found in Table 1 that men were more willing to make this report. Thus we decided to run a separate regression model for male and female participants. The dependent variable was willingness to make an anonymous report, the predictors were attitudes to doping testing. We found both models were found to be significant (men: R =0.51, R2=0.26; F = 4.05; sig (F) = 0.00; women: R =0.57, R2=0.33; F = 2.25; sig (F) = 0.01). Men are most likely to make an anonymous report if they believe athletes should not make their own decisions about doping, if they believe their country applies doping rules very strictly, and if they believe doping controls help protect clean athletes. Our female participants are most likely to make an anonymous report if they are well acquainted with the testing process, if they believe that penalties for doping violations should be harsher, and if they believe that doping controls are a necessary part of elite sport.

DISCUSSION

Our review of attitudes toward drug testing and willingness to report anonymously confirms some findings of previous studies and sheds new light on this issue. Studies uniformly confirm that athletes believe in strict punishments for doping offenders (Ćorluka et al., 2011; Rodek et al., 2012), but differences between male and female athletes are rarely examined. Our results show that female participants feel more strongly than our male participants that the use of banned substances should be punished, but that they are less willing to report the abuse of banned substances, even through an anonymous channel. This means that men are more forthcoming when it comes to doping rule violations but would act more quickly if they found out someone was doping - so our male participants seem more willing to act.

When looking at differences between coaches and athletes, we found several differences. The coaches in our study show greater knowledge of the rules for doping controls compared to the athletes - for example, they know that you can make a report if you think there has been a mistake during the testing process, they also know how to make an anonymous report, and they see this tool as a useful way to keep doping out of sport. When asked how trustworthy the NADO is, the coaches indicate a more positive attitude than the athletes. Coaches' opinion on doping also seems to be stricter - they say that doping violations should be punished severely, while athletes have a less strict attitude towards it (however, on a 5-point scale, both coaches and athletes score an average of more than 3, which means that they neither agree nor disagree

with the statement). Previous studies have shown that coaches are strongly against doping (Seif Barghi et al., 2015).

Coaches in our study are also more likely than athletes to believe that doping controls should be part of elite sport-so our findings are consistent with those of researchers (Judge et al., 2010) who found negative attitudes toward doping controls among athletes, although this study lacks data from coaches to make a good comparison. It was interesting to find that athletes in both participating countries were more likely than coaches to think that their countries had stricter anti-doping rules than other countries and that this put them at a disadvantage - athletes are likely to be more sensitive when it comes to doping because they are the ones primarily exposed to doping controls and these affect their daily lives much more than coaches'. In the past, national implementation of the code has been found to take different forms (Wagner & Hanstad, 2011). Since athletes share information and frequently communicate with their counterparts from other countries, it is understandable that they have a less positive attitude towards doping controls if they feel that they are treated more strictly than athletes from other countries.

We also compared athletes from team and individual sports and found that athletes from individual sports view doping controls as a greater intrusion into their lives than athletes from team sports - it would be interesting to see if this is just an attitude or reality. That there are differences in perceptions of doping offences and views on doping controls in team and individual sports was also confirmed in interviews, where others noted that track and field athletes seemed willing to report doping, while rugby league players would refrain from reporting a teammate for doping - even though they disagree with the teammate's actions (Whitaker et al., 2014).

Next, we wanted to look for correlations between attitudes toward doping control and views on anonymous reporting and found that people who know more about how doping control is conducted (e.g., that they know they can report irregularities during the control process) and who believe that their NADO is trustworthy and does its job well, i.e., who believe in the NADO's competence, also have more knowledge about how to make an anonymous report. We can assume that people who already know a lot about doping and trust NADO would also be more likely to visit their website, follow their posts, and follow them on social media and thus learn about the whistleblower programme. Following NADO's information and belonging to social groups where knowledge is promoted also promotes moral development (Kroflič, 1997),

and it is easy to understand that people with more knowledge also have more positive attitudes toward the whistleblower programme.

Our results also show that the belief that anonymous reporting is a means to fight for clean sport correlates with the belief that punishments for doping offenders are too lenient and that the NADO is a trustworthy organisation. It is believed that the prevalence of doping is likely much higher (Whitaker et al., 2014) than testing indicates (less than 2% of drug tests performed show positive results). Some studies suggest prevalence rates as high as 35%, calling into question the effectiveness of current doping control systems. Encouraging people to become doping whistleblowers is one of the hopes for the fight for clean sport (Erickson et al., 2017). This is based on the trustworthiness of NADOs and the individual belief of athletes that punishments should be harsher, as well as the belief that testing is not the only solution, as was previously found (Judge et al., 2010). Our results show that willingness to make an anonymous report correlates with the belief that penalties for violations should be harsher. It appears that our participants view anonymous reporting as a tool that can help catch more violators, which would go some way to correcting the fact that violators caught through testing receive a penalty that they view as too lenient. Catching more violators through anonymous reporting could be seen as offsetting lenient penalties.

We also conducted a regression analysis to see what combination of attitudes influences a person's decision to make an anonymous report when they have information about doping abuse. Because we found differences in attitudes toward drug testing between male and female participants, we ran two separate regressions and found that both regression models were significant. We found that men were more likely to report suspected doping abuse if they strongly believed that external doping control was necessary, implying that people should not make their own decisions about doping. External control provides structure, establishes rules, and enables fair play (Kajtna & Jeromen, 2013), i.e., it provides a sense of safety and security, which is a basic human need, and it is understandable that our participants aspire to a sport where the rules are clear. Most athletes believe in the need for drug testing (Dunn et al., 2010; Tavani et al., 2012) - we can speculate that most male athletes are therefore willing to make a report if they suspect it. This conjecture is supported by the other two beliefs that affected men's willingness to make an anonymous report, namely, the belief that their country is very strict about doping rules and the belief that doping controls help protect clean athletes. We have already found that the athletes in our study believe that their countries are very strict about

doping rules, which confirms our conclusion that male athletes will make a report if they suspect abuse.

The regression model for female athletes shows that they are willing to make an anonymous report if they have a good knowledge of the testing procedure, which usually also means that they are aware of and have a great knowledge of the doping rules, and if they believe in stricter penalties for doping violations. Women are also more likely to file a report if they believe that doping controls are a necessary part of sport. This highlights the importance of NADO's educational efforts. The more people know about doping controls, how important they are, and what WADA has accomplished through doping controls, the more likely they are to actively participate in the fight for clean sport. This is important for both men and women, but our research shows that it may be especially important for women. Education contributes to moral development as it depends on cognitive development (Thomas, 1992). Through education, we could help athletes develop a greater awareness of clean sport and get them to join the fight for clean sport. This in turn would contribute to a better sporting environment for all athletes and make elite sport a safer place for all.

CONCLUSION

In our study, we investigated the attitudes of male and female athletes, coaches and athletes, and athletes in team and individual sports toward drug testing and anonymous reporting. We also sought to determine what attitudes increase the likelihood that athletes will make an anonymous report of doping abuse.

We found that female participants felt more strongly than male participants that taking banned substances should be punished, but they were less likely to report banned substance abuse, even through an anonymous channel. The male participants in our study would act more quickly if they found out someone had doped. We also found differences between coaches and athletes. Coaches report knowing more about doping rules and testing procedures, and they also have a more positive attitude toward the NADO and are generally more firmly opposed to doping. Athletes from individual sports view doping controls as an intrusion into their lives, while team athletes are more accepting of them. We also found correlations between attitudes toward doping control and attitudes toward anonymous reporting, and elaborated on this with a regression analysis that found that men are most likely to report suspected doping abuse if they believe doping control is necessary, if they live in a country that strictly enforces WADA rules,

and if they believe doping control helps protect clean athletes. Women, on the other hand, are most likely to report suspected doping rule violations if they are knowledgeable about the testing process, if they believe that penalties for violations should be harsher, and if they believe in the necessity of testing to maintain clean sport. We believe that NADOs play an important role in creating these "conditions," both through education and through rigorous testing that ensures athletes have an environment and knowledge in which they will participate in the fight for clean sport through the whistleblower programme. An education programme needs to be created to support athletes at all levels in their whistleblowing actions to ensure that doping does not occur(Zhang, 2018). The education programme should not only discuss the meaning, mechanisms, responsibilities, and psychological, social, and economic consequences of doping in sport, but also highlight the reporting options available, the potential risks of reporting (e.g., stress, intimidation), and the measures to protect the integrity and identity of whistleblowers.

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki, all participants signed an informed consent form before participating in the study.

Consent to publication

All authors have read the manuscript and agree that it can be submitted for publication in its current form.

Availability of data and material

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the sensistity of the topic.

Competing interests

The authors declare that they have no competing interests.

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HANDSTAND ON PARALLEL BARS: TEMPERATURE DIFFERENCES OF PALMS AFTER STATIC AND DYNAMIC LOAD

STOJA NA ROKAH NA BRADLJI: RAZLIKE V TEMPERATURI DLANI PO STATIČNI IN DINAMIČNI OBREMENITVI

ABSTRACT

The temperature of palms and their differences after different loading have not been well studied. Our research question was how palm temperature differs in human hands after different 30-second loads (handstand and swinging in handstand) on low parallel bars. A high-quality thermal imaging camera was used to measure 38 students from the University of Ljubljana, Faculty of sport. Palm temperatures were measured before the load was applied, immediately after load and every 30 seconds for a period of 5 minutes after the load. Each hand was divided into 9 different Regions of Interest (ROIs). Mean (XA), standard deviation (SD), maximum and minimum, and number of pixels were calculated. According to our results, there was no difference between the left and right hands. The temperature immediately after loading decreased significantly in both loads and then increased above the level as before loading. After static loading, the temperature decrease is smaller and then increases faster than after dynamic loading. For both loads, the temperature is higher 5 minutes after the load than before the load. We need to further investigation how long it takes for the hand temperature to reach the pre-load temperature.

Keywords: palm temperature, thermal imaging, handstand, swing in handstand, parallel bars

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IZVLEČEK

Temperature dlani in njihove razlike po različnih obremenitvah niso dobro raziskane. Naše raziskovalno vprašanje je bilo, kako se razlikuje temperatura dlani v človeških rokah po različnih 30 sekundnih obremenitvah (stoji na rokah in kolebih v stoji na rokah) na nizki bradlji. S kakovostno termovizijsko kamero smo izmerili 38 študentov Fakultete za šport Univerze v Ljubljani. Temperature dlani so bile izmerjene pred obremenitvijo, takoj po obremenitvi in vsakih 30 sekund v obdobju 5 minut po obremenitvi. Vsaka dlan je bila razdeljena na 9 različnih območij zanimanja (ROI). Izračunani so bili povprečje (XA), standardni odklon (SD), maksimum in minimum ter število slikovnih pik. Glede na naše rezultate ni bilo razlike med levo in desno roko. Temperatura takoj po obremenitvi se je pri obeh obremenitvah bistveno znižala in nato narasla nad nivo kot pred obremenitvijo. Po statični obremenitvi je padec temperature manjši in nato narašča hitreje kot po dinamični obremenitvi. Pri obeh obremenitvah je temperatura 5 minut po obremenitvi še vedno višja kot pred obremenitvijo. Nadaljnje raziskave so potrebne, da bi ugotovili, kako dolgo traja, da temperatura dlani doseže temperaturo pred obremenitvijo.

Ključne besede: temperature dlani, slikanje s termokamero, stoja na rokah, koleb v stoji na rokah, bradlja

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INTRODUCTION

The oldest organized sport is gymnastics and handstand is one of the basic and most essential gymnastics skills. It requires extraordinary muscular activity and strength of the upper extremities, the activity of which has an antigravity function. It is included in routines of artistic gymnastics repeatedly, therefore requires an extraordinary level of strength abilities of the upper body. Balancing in this inverted position is a complex process based on physical and physiological principles. Handstands are performed on various apparatuses with larger (e.g. floor) and smaller (e.g. parallel bars) support surfaces, whose stability and mechanical properties influence the difficulty of balance. If the centre of gravity is already out of the support base due to a small deflection, the difficulty of a handstand increases (Gautier et al. 2009; Hedbávný, Sklena, et al. 2013; Hedbávný, Bago, and Kalichová 2013; Kochanowicz et al. 2015, 2019; Omorczyk et al. 2018; Rohleder and Vogt 2018). Such performances require specific muscle activation, which varies according to the gymnast's experience and condition. To improve and develop the handstand, gymnasts must move to apparatus that requires a hand grip, such as the parallel bars. Consequently, the support surface is still stable, while the strategy to maintain the handstand can cause a change in the position of the wrist (Kochanowicz et al. 2019). It is well known that for a well-balanced handstand, the execution of wrist and shoulder moments is essential (Kerwin and Trewartha 2001; Mohammadi 2016; Rohleder and Vogt 2018; Yeadon and Trewartha 2003). Discomfort and subsequent skin injuries may be caused by repetitive loads and friction, which have an effect on the increase in temperature (Zhang and Mak 1999). When injured, thicker skin requires greater friction and longer duration of exposure, while thinner skin is more likely to blister or be injured (Sulzberger M. B. et al. 1966). Skin injuries occur on artistic gymnastics apparatus, where the gymnasts' palms are exposed to frictional forces that, in combination with pressure, can cause shear forces on the skin that affect blood circulation (Pušnik, Čuk, and Hadžič 2017; Zhang and Roberts 1993; Zhang, Turner-Smith, and Roberts 1994), or more accurately, the microcirculation. Anatomical and microstructural differences between the palmar and dorsal sides were found in studies of the microcirculation on both sides (Gulyaev et al. 1995; Sangiorgi et al. 2004).

The movement of the hand consists of two basic patterns called precision grip and power grip. In the field of sports, there is a whole range of activities in which the hands form a power grip, and disciplines in which the body hangs (artistic gymnastics, sport climbing, fitness, crossfit, etc.). Most of these disciplines and activities take place in a room temperature environment, but there is a lack of data on how palm loading directly affects the palm and hand. In power grip,

the main force is applied by the extrinsic muscles, which therefore play a key role in the movement (Napier 1956).

Infrared thermal imaging has become accepted as a non-destructive testing method and is increasingly used in various areas of research and industry (Qu, Jiang, and Zhang 2020). Human health is strongly correlated with body and tissue temperature, which is within a narrowly defined range in healthy individuals under standardised environmental conditions, so deviations may indicate pathological processes, physical abnormalities, or defects (Kesztyüs, Brucher, and Kesztyüs 2022). Especially in sports and exercise science, thermography is used extensively as a tool to promote human health, evaluate athletic performance, examine exercise-induced superficial vascular changes, monitor injuries, and attempt to develop optimal training and results (Gómez-Carmona et al. 2020; Gulyaev et al. 1995; Hildebrandt, Raschner, and Ammer 2010; Kasprzyk-Kucewicz et al. 2020; Kwon et al. 2010; Martínez-Nova et al. 2021; Perpetuini et al. 2021; Sousa et al. 2017; Zontak et al. 1998).

The differences in palm temperature were compared when performing simple elements on uneven bars with and without the use of magnesium carbonate (Pušnik and Čuk 2014). The temperature remained constant without the use of magnesium carbonate, while the temperature of the palm increased with the use of magnesium carbonate. The short-term effects of loading on palm temperature for different forms of gymnastic rings were compared (Pušnik et al. 2017), and depending on the different shapes of the rings, statistical differences were found in the decrease of palm temperature after loading. The differences in palm temperature after static and dynamic loading were studied (Šibanc et al. 2021) and discovered that the temperature decreased significantly immediately after the load was applied for both loads and then increased above the level before the load was applied. After the static load, the temperature reached a consistently higher level after 3 minutes, while temperatures continued to rise after the dynamic load throughout the measurement period.

Few studies were found that focused on hand temperature: when applying pressure or load to the palms or handling objects at room temperature in a given time frame (Bennett, Goubran, and Knoefel 2015), the effect of cooling the hand on fatigue during high-intensity bench press (Kwon et al. 2010), the response of skin temperature to exercise (Zontak et al. 1998) and generally discovered an initial cooling of the hand immediately after loading. resulting to a constant decrease in finger temperature followed by rewarming of the hands, reflecting the dominance and balance of thermoregulatory reflexes and hemodynamics in the later phase of

exercise. To reduce swelling and inflammation, local cooling was used in rehabilitation or between intense exercise sessions.

Under thermoneutral conditions, the temperature dynamics of the surface of the human body at rest is determined mainly by peripheral blood flow. This is controlled by the extent of vasoconstriction, which in turn is almost entirely controlled by the sympathetic nervous system (Hall and Guyton 2016). However during a long swing on rings, blanching of the skin after the application of pressure is a well-known phenomenon (Pušnik et al. 2017), although the associated changes in skin temperature have not been well studied.

The thermograms in recent research (Pušnik et al. 2017; Šibanc et al. 2021) showed a different temperature distribution in the area of the hands, so we focused on more regions of interest (ROI) depending on the load. Healthy skin temperatures should be considered symmetrically distributed (Mercer and De Weerd 2014), also a study measuring palm temperatures after hang (Šibanc et al. 2021) showed no asymmetries between the left and right hands after the load was applied. However, there are proven asymmetries in gymnastics (Čuk and Marinšek 2013; Pajek et al. 2016) and a study that showed a left-right asymmetry of hand temperature after cold stress (Sundqvist 2017). From the above studies (Bouzida, Bendada, and Maldague 2009; Gulyaev et al. 1995; Hildebrandt et al. 2010; Lahiri et al. 2012; Pušnik et al. 2017; Šibanc et al. 2021), it was found that the differences in the temperature of the skin of the palm during the formation of a grip during the execution after the loads and different amplitude of these loads were very different.

The recovery phase of temperature is not well studied. In the research of Gulyaev et al (Gulyaev et al. 1995) temperatures returned to the pre-occlusion level after 2-3 minutes. The time period chosen for our measurement was 5 min, although the study by Bennett et al (Bennett et al. 2015) showed some different patterns after a 10-minute recovery period. The aim of this study was to observe what happens to palm temperature after static (handstand) and dynamic loads (swinging in handstand, referred to as "swing" in the following text) in an inverted position when the whole body is above the grip point. Determined load for measurements was 30 seconds, which is an average for routines on uneven bars, rings, pommel horse, parallel bars and high bar, that usually last between 20 and 50 seconds (Aarkaev and Suchilin 2004).

METHODS

In gymnastics hall at the University of Ljubljana, Faculty of Sport of the 38 healthy subjects (27 women and 11 men; students of Faculty of Sport), who volunteered to participate in the study and all attended classes and lectures of artistic gymnastics at university. They were 22.1 years (±2.9) old, 1.73 m (±0.10) tall, and had a body weight of 72.2 kg (±12.5). Ethical approval was obtained from the Ethics Committee of the Faculty of Sport, University of Ljubljana (12_2018). The Declaration of Helsinki was followed. All included subjects provided written informed consent and were familiar with handstands from previous lectures. They were in the hall for acclimatization 15 minutes before the start of the first measurement. They were asked not to drink alcohol or smoke for 24 h, not to consume caffeine for 12 h, and not to use creams or lotions on their hands for 12 h before the measurements (Fernández-Cuevas et al. 2015). The skin on their hands was not allowed to be visibly damaged.

The measurement protocol was developed and adapted according to our hypotheses:

1. The temperature of the palms decreases after the static load in handstand.
2. The temperature of the palms increases after the dynamic load in swing during the handstand.

We measured the hand temperature of the subjects on the palmar side. Thermal images were taken before loading, immediately after loading, and then for 5 min (indicated as "300 s" in the following tables) at 30-s intervals (12 thermograms per subject per loading). Each load lasted for 30 s. During thermal imaging, the subject was seated with hands resting on the table with fingers at approximately the level of the heart and on an additional insulating surface to prevent heat loss into the table. Subjects performed two tasks on low parallel bars (wooden surface, vertical axis of the profile 5 cm ± 0.1 cm; horizontal axis of the profile 4 cm ± 0.1 cm (Federation Internationale de Gymnastique 2022)). For the first load, students performed a handstand for 30 s while leaning on a wall behind them, as shown in Figure 1a. The support provided by the wall in the handstand allowed subjects to remain still without additional compensatory movements for keeping balance. In the second load, the students swung back and forth in the handstand for 30 seconds while being spotted by two other students (see Figure 1b). The angle of the swing was approximately 15-20°, and subjects required additional force to maintain balance and swing.

Figure 1. (a) Handstand, (b) Swing in Handstand.

(a) *(b)*

Subjects were randomly and equally assigned for task order. The cylindrical power grip was used for both tasks. The measurements took place in the gymnastics hall of the Faculty of Sport of the University of Ljubljana. The temperature in the hall was 23 °C and the relative humidity was 40%. 15 minutes before the start of the first measurement of thermal images, all subjects were in the hall for acclimatization. They were asked not to use creams or lotions on their hands for 12 hours, not to consume caffeine for 12 hours, and not to smoke or drink alcohol for 24 hours prior to the measurements (Fernández-Cuevas et al. 2015). The skin on their hands was not visibly damaged.

A high-quality thermal imaging camera (FLIR T650sc FLIR Systems, Oregon, USA) was used for the study. The camera has a 45° wide-angle lens (f = 13.1 mm) with a field of view (FOV) of 45° × 34°, a continuous zoom (8×), a minimum focus distance of 15 cm, and a spatial resolution of 1.23 mrad (IFOV). The emissivity can be adjusted in steps of 0.01 from 0.10 to 1.00. The camera was calibrated prior to research measurements at the LMK Laboratory for Metrology and Quality at the Faculty of Electrical Engineering, University of Ljubljana (LMK is the holder of the Slovenian National Standard for Thermodynamic Temperature. As a national laboratory for temperature and relative humidity and an accredited calibration laboratory, it has CMCs calibration measurement capabilities that are among the best in Europe and the world in the respective measurement ranges, which confirms its accuracy). The resolution of the camera is 640 × 480 pixels, which corresponds to 307,200 pixels of temperatures in a single thermogram. This high resolution is important for a comprehensive

analysis of the selected ROIs (Perić et al. 2019). The detector type was an uncooled microbolometer with the FPA operating in the spectral range of 7.5 μm to 14 μm, a specified accuracy of ±1% of reading or 1 °C in the temperature range of 5 °C to 120 °C, at ambient temperatures of 10 °C to 35 °C, and a noise-equivalent temperature difference NETD < 30 mK. Measurements were corrected for reflected temperature, optics transmission, atmospheric transmission, and external optics. Image analysis in the associated software environment (ResearchIR Max from (FLIR Systems, Oregon, USA) allowed the analysis of various ROIs, e.g., spots, areas, automatic detection of hot/cold spots, temperature differences, isotherms, line profiles, alarms, temporal temperature dependency, etc.

Each hand was divided into nine ROIs (polygons) using the ResearchIR application, as shown in Figure 2: palm, thumb, index finger proximal phalanx, index finger distal phalanges, middle finger proximal phalanx, middle finger distal phalanges, ring finger proximal phalanx, ring finger distal phalanges and little finger. The boundary of ROI must be at least 7 pixels away from the edge of the observed surface to avoid the influence of the size-of-source effect (Pušnik and Geršak 2021). The ROIs from Figure 2 are also shown in Table 1, again with the abbreviations used in the following text for each ROI. Polygons 1-9 represent the right hand and polygons 11-19 represent the left hand.

Figure 2. ROIs on hands.

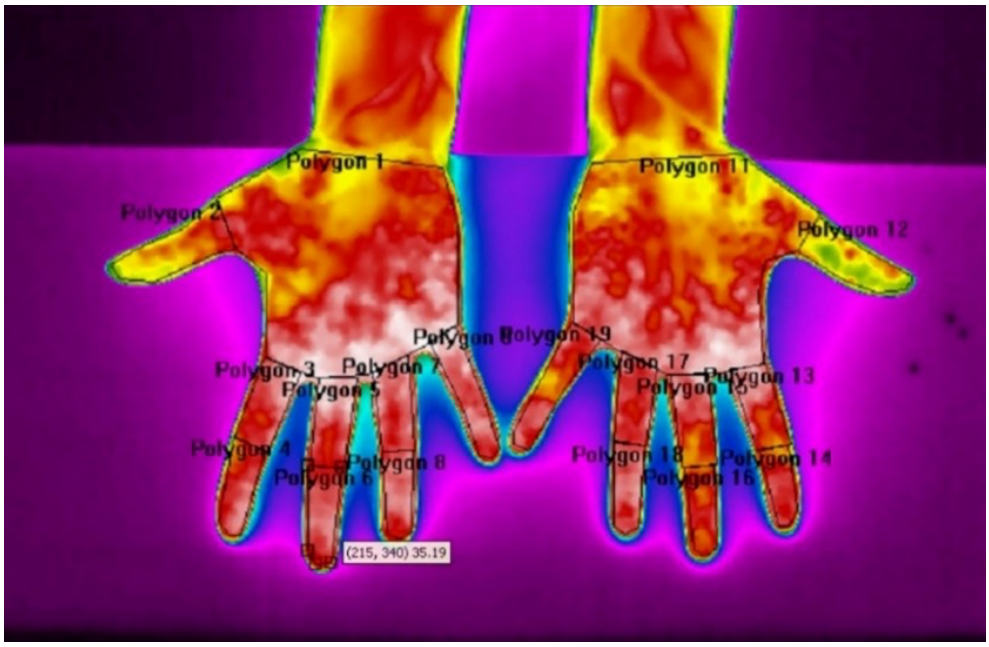

Table 1. ROIs on each hand.

Hand	Polygon	ROI	abbreviation
Right Hand	Polygon 1	Palm	P-R
	Polygon 2	Thumb	T-R
	Polygon 3	Index Finger Proximal Phalanx	IPP-R
	Polygon 4	Index Finger Distal Phalanges	IDP-R
	Polygon 5	Middle Finger Proximal Phalanx	MPP-R
	Polygon 6	Middle Finger Distal Phalanges	MDP-R
	Polygon 7	Ring Finger Proximal Phalanx	RPP-R
	Polygon 8	Ring Finger Distal Phalanges	RDP-R
	Polygon 9	Little Finger	LF-R
Left Hand	Polygon 11	Palm	P-L
	Polygon 12	Thumb	T-L
	Polygon 13	Index Finger Proximal Phalanx	IPP-L
	Polygon 14	Index Finger Distal Phalanges	IDP-L
	Polygon 15	Middle Finger Proximal Phalanx	MPP-L
	Polygon 16	Middle Finger Distal Phalanges	MDP-L
	Polygon 17	Ring Finger Proximal Phalanx	RPP-L
	Polygon 18	Ring Finger Distal Phalanges	RDP-L
	Polygon 19	Little Finger	LF-L

From ResearchIR, data for each ROI were exported to Excel for Windows 10 (Microsoft corp.): Mean (XA), standard deviation (SD), maximum and minimum, number of pixels. We calculated the sum of the temperature differences of the section before the task until the end of the 5th minute using the formula Σ(Tn-Tn+1); and the temperature differences from the first to the last measurement using the formula T1-Tn+1, where n represents the time series.

Statistical analyses were performed in SPSS 25.0 (IBM corp.): Kolmogorov-Smirnov test, means (XA), standard deviations (SD), standard errors (SE), for each sector variable. A paired Student's t-test and Spearman-Brown rank correlation (to determine the reliability of the measurement) were calculated to compare the temperature difference between support and swing, to compare the temperature difference between left and right sectors, and to compare the temperature difference between time series in each task. Excel software was used to generate the figures and graphs.

RESULTS

The Kolmogorov-Smirnov test did not show normal distribution for the variables. As expected and found in other studies, no significant difference was found between men and women. The results in our study are presented for the left hand because there were no significant differences between the left and right hands.

Table 2 shows the temperature difference immediately after load application for handstand and swing and 300 seconds after load application. Immediately after load application, all values decrease for all ROIs, for both loads. For all ROIs, the decrease is greater after swing than after handstand. Immediately after load application, the difference between static and dynamic load is greatest for the little finger, while it is least for the palm. The greatest decrease in temperature after loading was for the little finger after the swing (2.99 °C) and the least decrease was for the proximal phalanx of the middle finger after the handstand (2.04 °C). There were no statistical differences between static and dynamic loading immediately after load application, nor 5 minutes after load application. At 5 minutes after load application, the temperatures increased above the initial value. Except for the palm, where there is no difference between the temperatures after static and dynamic loading, the temperatures after handstand are higher than after swing. The greatest difference between handstand and swing is in the distal phalanges of the middle finger, which (along with the distal phalanges of the index and ring fingers) also have the highest temperature increase at 5 minutes after handstand. The lowest increase after 5 minutes is for the proximal phalanges of the index, middle, and ring fingers after the swing

Table 3 shows the significant differences in temperature by time and region before and after load application for 30 seconds each in a 5-minute period, with $p < 0.05$ indicating a significant difference in temperature by a paired t-test. After the handstand, there is a significant difference for the proximal phalanges of the middle and ring fingers up to 240 s, and for the proximal phalanx of the index finger up to 210 s, while for all other ROIs the significant difference persists up to 150 s after load application. After swinging, the temperatures for the proximal phalanges of the middle and ring fingers are significantly different even after 240 s after load application, while for all other ROIs the temperatures are significantly different after 210 s after dynamic load application.

Table 4 shows the temperature differences between handstand and swing, where the values given indicate a difference by t-test ($p < 0.05$). For the palm, the only significant temperature difference is 30 s after load application. The temperatures of the distal phalanges of the middle finger are significantly different for the longest time, 150 s after the application of the load. The proximal phalanges of the index and middle fingers are significantly different for a shorter time than the distal phalanges of the same fingers. All phalanges of the ring finger differ significantly only 30 and 60 seconds after load application. The palm, distal phalanges of the index finger, and all phalanges of the ring finger do not differ significantly immediately after load application.

Table 2. Temperature difference for handstand and swing immediately after load ($XA0_{HA}$-$XA0_{SW}$) and after 300 seconds ($XA300_{HA}$-$XA300_{SW}$) for left hand by ROI.

Variable	XA0/°C	$XA0_{HA}$-$XA0_{SW}$ /°C	p(ttest) 0/°C	XA300/°C	$XA300_{HA}$-$XA300_{SW}$ /°C	p(ttest) 300/°C
Handstand P[a]-L	-2.07	-0.20	0.491	0.34	0	0.685
Swing P[a]-L	-2.27			0.34		
Handstand T[b]-L	-2.02	-0.30	0.911	0.46	-0.13	0.689
Swing T[b]-L	-2.32			0.33		
Handstand IPP[c]-L	-2.18	-0.31	0.597	0.31	-0.2	0.938
Swing IPP[c]-L	-2.49			0.11		
Handstand IDP[d]-L	-2.36	-0.32	0.715	0.52	-0.26	0.584
Swing IDP[d]-L	-2.68			0.26		
Handstand MPP[e]-L	-2.04	-0.27	0.849	0.33	-0.19	0.981
Swing MPP[e]-L	-2.31			0.14		
Handstand MDP[f]-L	-2.30	-0.36	0.759	0.61	-0.35	0.699
Swing MDP[f]-L	-2.66			0.26		
Handstand RPP[g]-L	-2.09	-0.27	0.653	0.34	-0.13	0.964
Swing RPP[g]-L	-2.36			0.21		
Handstand RDP[h]-L	-2.68	-0.27	0.990	0.54	-0.17	0.770
Swing RDP[h]-L	-2.95			0.37		
Handstand LF[i]-L	-2.58	-0.41	0.704	0.43	-0.13	0.672
Swing LF[i]-L	-2.99			0.30		

Note: [a] P = Palm; [b] T = Thumb; [c] IPP = Index finger proximal phalanx; [d] IDP = Index finger distal phalanges; [e] MPP = Medial finger proximal phalanx; [f] MDP = Medial finger distal phalanges; [g] RPP = Ring finger proximal phalanx; [h] RDP = Ring finger distal phalanges; [i] LF = Little finger. XA0= sum temperature difference right after applying load, XA300 = sum temperature 300 seconds after applying load.

Table 3**.** Differences based on t-test in temperature by time and region for support and swing for the left hand.

Variable	−30 / s	0 / s	30 / s	60 / s	90 / s	120 / s	150 / s	180 / s	210 / s	240 / s	270 / s	300 / s
Handstand P[a]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.129	0.164	0.157	0.391	0.401
Swing P[a]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.294	0.465	0.255
Handstand T[b]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.005**	0.073	0.182	0.094	0.146	0.335
Swing T[b]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.036**	**0.001**	0.781	0.131	0.092
Handstand IPP[c]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**	**0.008**	0.120	0.044	0.491
Swing IPP[c]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	0.208	0.151	0.094
Handstand IDP[d]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	0.193	0.107	0.167	0.034	0.064
Swing IDP[d]-L		**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.009**	**0.012**	0.782	0.232	0.320
Handstand MPP[e]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.012**	**0.008**	0.139	0.386
Swing MPP[e]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.030**	0.026	0.102
Handstand MDP[f]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	0.096	0.110	0.119	0.089	0.224
Swing MDP[f]-L		**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**	**0.014**	0.852	0.098	0.371
Handstand RPP[g]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.007**	**0.013**	0.636	0.140
Swing RPP[g]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.018**	0.019	0.574
Handstand RDP[h]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.015**	0.312	0.103	0.347	0.150	0.391
Swing RDP[h]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.013**	**0.003**	0.470	0.446	0.434
Handstand LF[i]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.010**	0.623	0.100	0.276	0.249	0.237
Swing LF[i]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.083	**0.000**	0.583	0.685	0.367

Note: [a] P = Palm; [b] T = Thumb; [c] IPP = Index finger proximal phalanx; [d] IDP = Index finger distal phalanges; [e] MPP = Medial finger proximal phalanx; [f] MDP = Medial finger distal phalanges; [g] RPP = Ring finger proximal phalanx; [h] RDP = Ring finger distal phalanges; [i] LF = Little finger.

Table 4. Differences based on ttest between the handstand and swing time series (where stated values indicates difference by t-test ($p < 0.05$)) for left hand.

Variables	−30 / s	0 / s	30 / s	60 / s	90 / s	120 / s	150 / s	180 / s	210 / s	240 / s	270 / s	300 / s
P[a]-L		0.128	**0.008**	0.064	0.172	0.124	0.196	0.426	0.807	0.760	0.706	0.934
T[b]-L		**0.026**	**0.003**	**0.004**	**0.046**	**0.044**	0.142	0.221	0.527	0.329	0.290	0.653
IPP[c]-L		**0.025**	**0.006**	**0.004**	**0.035**	0.058	0.112	0.180	0.312	0.254	0.122	0.382
IDP[d]-L		0.070	**0.007**	**0.003**	**0.032**	**0.031**	0.074	0.146	0.228	0.167	0.126	0.397
MPP[e]-L		**0.049**	**0.001**	**0.002**	**0.044**	**0.040**	0.061	0.099	0.183	0.175	0.242	0.264
MDP[f]-L		**0.044**	**0.003**	**0.003**	**0.026**	**0.019**	**0.033**	0.075	0.149	0.091	0.074	0.249
RPP[g]-L		0.060	**0.003**	**0.007**	0.076	0.074	0.087	0.200	0.336	0.400	0.693	0.510
RDP[h]-L		0.167	**0.021**	**0.017**	0.089	0.048	0.122	0.234	0.409	0.453	0.378	0.618
LF[i]-L		**0.030**	**0.003**	**0.003**	**0.041**	**0.034**	0.116	0.183	0.471	0.459	0.419	0.705

Note: [a] P = Palm; [b] T = Thumb; [c] IPP = Index finger proximal phalanx; [d] IDP = Index finger distal phalanges; [e] MPP = Medial finger proximal phalanx; [f] MDP = Medial finger distal phalanges; [g] RPP = Ring finger proximal phalanx; [h] RDP = Ring finger distal phalanges; [i] LF = Little finger.

Figure 3 shows the mean temperature differences of all measured subjects for handstand and swing for the left and right hands for all measured ROIs in the hands. The two graphs on the left side of the figure show the temperature differences for support and the graphs on the right side of the figure show the temperature differences for swings. The top two diagrams show the left hand, while the bottom two diagrams show the right hand. There were only slight differences between the left and right hands for both loads, while the significant difference between the loads can be seen in Figures 3 and 4, although Table 2 showed no significant differences immediately after the load and 5 minutes later. For all ROIs, the temperature was higher 300 seconds after loading than before loading. The palm temperature begins to rise faster than the other ROIs for both loads, although this is much more evident after swinging. As can be seen in Table 2, temperatures in the distal phalanges of the little finger and ring finger decrease the most immediately after loading, and the temperature decrease after swinging is greater than after handstand. For all ROIs, the temperature increases to the initial value faster after the handstand than after the swing, and at 300 s after the handstand, the values are higher than after the swing.

Figure 3. Temperature difference for right and left hand during support and swings.

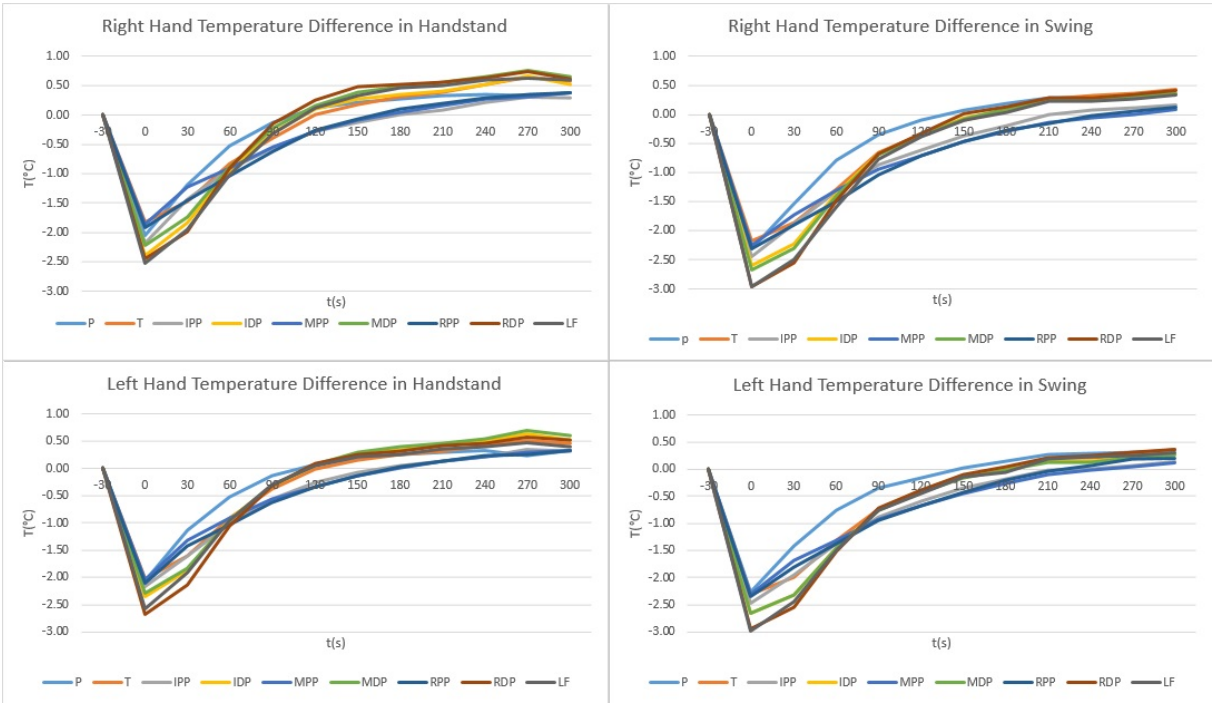

Figure 4 shows the temperature difference between support and swing for each DOI separately. The graphs on the left side of the figure show the temperature values for the palm and all three proximal phalanges; the graphs on the right side show the values for the thumb, all three distal phalanges, and the little finger. The values for the index, middle and ring fingers are in the same row for each finger. For the palm, there was no significant difference between support and swing except at 30 s (see also Table 3), and the difference is also small and short for all phalanges of the ring finger. For the distal phalanges of the middle and ring fingers, the temperature difference between supports and swings was larger than for the proximal phalanges, and similar differences exist for the little finger. As can be seen from the curves, the thumb, distal phalanges and little finger respond similarly, while the palm and proximal phalanges of the index, middle and ring fingers respond similarly according to the temperature distribution 5 minutes after applying different loads.

Figure 4. Temperature difference of the left hand in support and swing for different ROIs.

DISCUSSION

The temperature distribution and difference between the left and right hands before and after exercise appeared to be symmetrical in our study. This was also evident in a study in which temperatures were measured after hanging, and in a study in which healthy subjects were measured in a static position, hand temperature was symmetrical (Pauk, Wasilewska, and Ihnatouski 2019). There were studies in artistic gymnastics that showed asymmetries (Čuk and Marinšek 2013; Dallas et al. 2022; Pajek et al. 2016), but the loads considered in this study were symmetrical (e.g., no rotations about the longitudinal or transverse axis, standing on one hand, etc.). Studies of hand temperatures after hanging on the high bar (Šibanc et al. 2021) showed similar results - after loading, possible body asymmetries did not affect temperature differences on the hands.

Table 2, Figures 3 and 4 show significant temperature decrease immediately after both load applications, similar to a research after hang (Šibanc et al. 2021). Immediately after loading, the temperature decrease after dynamic loading is greater than after static loading, while after 5 minutes the temperatures after static loading are higher than after dynamic loading. The largest temperature decrease after loading for the little finger after the swing makes sense – it was shown (Kochanowicz et al. 2019) that during the handstand on the parallel bar, the torque is generated during abduction and adduction movements around the sagittal axis, the parallel bar forces a specific handgrip that shows a more balanced EMG signal of the wrist flexors and extensors. When swinging in the handstand, the centre of gravity moves backward and forward, and in the author's personal experience, the forward movement places the most stress on the little finger to maintain balance. The smallest temperature difference between the loads is at the palm, where the compressive force is similar for static and dynamic loading (see also Table 4). According to Table 3, the proximal phalanges of the middle and ring fingers play an important role in maintaining balance during both loads, more clearly after the handstand than during the other ROIs. After the handstand, the temperature differences are significant for a shorter time than after the swing (except for the proximal phalanges of the middle and ring fingers), whereas after the swing, all ROIs show a significant temperature difference from 210 to 240 seconds after the application of the load.

According to Table 4, the smallest difference between static and dynamic loading is in the palm and ring finger, and in the other fingers the significant differences last longer. It is known that the angles in the shoulder, elbow, hip, and knee joints to maintain a straight body shape are

essentially required for a quality handstand (Hedbávný, Sklena, et al. 2013; Rohleder and Vogt 2018; Uzunov 2008). Consequently, the body's centre of gravity must be stable over the hands and head, and without gaps between the shoulders and ears, axial alignment at the spine is required (Rohleder and Vogt 2018; Uzunov 2008). Gymnasts with better strength abilities may dare to perform the corrective movements to a greater extent, but they usually choose a three-part balancing strategy. Gymnasts who have less strength abilities use the three-segment balancing strategy exceptionally and for a shorter time. Their corrective movements are performed on the basis of the four-segment strategy, which results in a poorer quality of execution of the handstand (Hedbávný, Bago, et al. 2013). In this study, the grip in the handstand did not have to be firm, and maintaining balance was easier if you had the wall at your back. In swinging, it was also easier to maintain balance when supported on both sides, although changing the position of the wrist in the extreme positions of forward and backward swinging required a different strategy for maintaining the handstand (Kochanowicz et al. 2019).

Comparison of the results of this study with the study in which the load was in hang (Šibanc et al. 2021). The measurement protocol was similar, the position of the hands is now parallel, while during hanging they are behind each other and the momentum in the handstand is relatively small, so there is practically no friction between hands and bars. The temperature differences after hanging are much higher. The temperature decrease immediately after the load is applied is greater after hanging because the grip must be stronger during hanging. The load on the hands in handstand is less than in hanging, which allows faster regeneration of the hands and faster return to the initial state. Also the temperatures are higher after 5 minutes in hanging and swinging in hanging than after supporting and swinging in supporting. The difference between static and dynamic load is interesting and almost opposite - after hanging the biggest differences are after 150 seconds, while after handstand most differences are up to 120 seconds.

Strength and limitations

Because of the large database, Tables with all values were not included.

With this study, we continued to question the dynamics of temperature distribution after loads. According to our results, further investigations should be conducted to obtain more information about the time for skin temperature to reach its value before the load, to be determine when skin is ready for the next load without the risk of potential skin damage.

The values for the thumb are correct for this angle of measurement, but since the main contact with apparatus is on the inner side of the thumb, measuring separately and from a different

angle would give different temperatures. To get more precise data, the thumb should be measured from a different angle.

The use of an accurate (calibrated) non-contact temperature device is necessary when we observe low temperature differences (in the order of a tenth of a degree Celsius). It is not enough to rely on any non-contact temperature device because low-cost radiation thermometers and thermal imagers are not capable of accurate or consistent measurement of temperature differences.

CONCLUSION

In this study, we examined a fundamental gymnastic skill – the handstand. The handstand is a complex posture, and adding another task to this posture, such as the swing, severely restricts the system and affects the hands differently (Gautier et al. 2009). According to our study and a previous study on hanging (Šibanc et al. 2021), the principle of temperature changes is the same whether the heart is below or above the grip. In any exercise with the grip (handstand, hanging...) there is always a decrease in blood flow, which means that the palm and fingers cool down immediately after the load and then try to return to the initial state. While this knowledge comes from students of various sports, it could also be used by gymnasts, acrobats, physical education teachers, and many others who practice this skill to improve handstand performance. Handstand can also be used for conditioning exercises for the anterior part of the deltoid muscle and the rectus femoris (these 2 muscles showed increased activity during handgrip on parallel bars). It appears that both muscles are heavily used to control the balance of the body over the shoulder and hip joints when a handstand is held.

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Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethical Commission of the University of Ljubljana’s Faculty of Sport (13. 9. 2018; 12_2018).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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DIFFERENCES IN PERCEIVED PHYSICAL ACTIVITY CONSTRAINTS BETWEEN TURKISH AND 4TH GENERATION TURKISH-GERMAN YOUNG ADULTS

RAZLIKE V ZAZNANIH OMEJITVAH TELESNE DEJAVNOSTI MED TURŠKO IN TURŠKO-NEMŠKO MLADINO ČETRTE GENERACIJE

ABSTRACT

The aim of this study was to examine perceived leisure-time physical activity constraints between Turkish young people living in Germany and Turkey. The current study was conducted with a causal-comparative model to examine the differences in perceived physical activity constraints between Turkish youth living in Turkey and fourth-generation Turkish-German youth who grew up and lived in Germany. 196 young adults from Germany and 201 young adults from Turkey participated in this study. A 2-way Multivariate Analysis of Variance test was used to assess the effects of country of residence and gender background on perceived physical activity constraints. Analysis revealed that there was a statistically significant interaction effect between the country of residence and gender on perceived physical activity constraints of Body Perception, Facilities, Income, Family, Skill Perception, Time, Willpower, and Society. There was also a statistically significant simple main effect of country of residence on all subscales except the skill perception, and the significant simple main effect of gender on facilities, income, time, willpower, and society subscales. Young adults living in Turkey and female precipitants reported higher physical activity constraints compared to participants living in Germany and males. These differences might be associated with the differences in economic development and physical activity norms in Turkish and German societies. These factors are vital for the number of environmental and organizational opportunities to increase leisure-time physical activity participation.

Keywords: physical activity, migrant, physical activity barriers

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IZVLEČEK

Namen te študije je bil preučiti zaznane omejitve telesne dejavnosti v prostem času med turško mladino, ki živi v Nemčiji in Turčiji. Pričujoča študija je bila izvedena z vzročno-posledičnim primerjalnim modelom, da bi preučili razlike v zaznanih omejitvah telesne dejavnosti med turško mladino, ki živi v Turčiji, in turško-nemško mladino četrte generacije, ki je odraščala in živela v Nemčiji. V tej študiji je sodelovalo 196 mladih odraslih iz Nemčije in 201 mladi odrasli iz Turčije. Za oceno vpliva države prebivališča in spolnega ozadja na zaznane omejitve telesne dejavnosti je bil uporabljen dvosmerni test multivariatne analize variance (MANOVA). Analiza je pokazala, da obstaja statistično pomemben interakcijski učinek med državo prebivališča in spolom na zaznane omejitve telesne dejavnosti na področjih zaznavanja telesa, objektov, dohodka, družine, zaznavanja spretnosti, časa, volje in družbe. Prav tako je bil statistično pomemben učinek države prebivališča na vse pod lestvice, razen na pod lestvico zaznavanja spretnosti, in statistično pomemben glavni učinek spola na pod lestvice objektov, dohodka, časa, moči volje in družbe. Mladi odrasli, ki živijo v Turčiji, in prekarci ženskega spola so poročali o večjih omejitvah telesne dejavnosti v primerjavi z udeleženci, ki živijo v Nemčiji, in moškimi. Te razlike so lahko povezane z razlikami v gospodarski razvitosti in normah telesne dejavnosti v turški in nemški družbi. Ti dejavniki so ključnega pomena za število okolijskih in organizacijskih priložnosti za povečanje udeležbe pri telesni dejavnosti v prostem času.

Ključne besede: telesna dejavnost, migranti, ovire pri telesni dejavnosti

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INTRODUCTION

In the face of vast and expanding numbers of migrants and their culturally adapted descendants in host countries, knowledge of the influence of factors related to health-related behavior raises a substantial issue for the field of public health, as migrants seem to be a population at risk for health outcomes (WHO, 2017). Epidemiologic studies indicated that migrants and their descendants are at a higher risk of non-communicable diseases and poor mental health than natives of the host country (Belhadj Kouider et al., 2014; Solé-Auró & Crimmins, 2008; Ujcic-Voortman et al., 2012). Physical inactivity is a key risk factor for many adverse health conditions, including major non-communicable diseases, in highly developed countries with high migration rates (Ding et al., 2016). To illustrate, a lack of participation in physical activity is associated with obesity (Kobel et al., 2019; Murphy et al., 2017; Sarkar et al., 2017), poor mental health (Kim et al., 2016), and metabolic diseases (Dhillon et al., 2016; Piao et al., 2020) among migrant populations. To illustrate, Spaas et al. (2022) highlighted that migrants in Europe experience stress from a young age. Rosenthal, Touyz, and Oparil (2022) indicated that cardiovascular diseases and metabolic syndrome are prominent factors contributing to poorer physical health conditions among migrants. Given the extensive benefits of PA participation in mitigating the negative health outcomes associated with the aforementioned conditions, it is imperative to enhance our understanding of PA behavior and the factors influencing it within this population.

Although the widely acknowledged positive outcomes of PA are evident, studies indicate that non-western migrants living in the United States and Europe tend to be physically inactive, and therefore more vulnerable to potential health problems (Banna et al., 2012; Hosper, Klazinga, et al., 2007; Kandula & Lauderdale, 2005). The constraints of PA participation among these non-western migrant populations are crucial for assessing their needs and planning culture-specific interventions. Many studies and reviews of the constraints of PA in migrants have been conducted (Bradbury, 2011; Doherty & Taylor, 2007; Holdsworth et al., 2017; Kay, 2006; Langøien et al., 2017; Patel et al., 2012); such reports present a diverse range of social, psychological, behavioral, environmental constraints of PA. A recent review (Smith et al., 2019) particularly indicated that many of these constraints are directly linked to migrants' pre-existing cultural capital. Accordingly, the PA environment is one of the sites where migrant-specific culture is reproduced, and where cultural traits are negotiated concerning the host culture. Hence, negative pre-existed cultural attitudes towards PA can limit the participation among migrants (Dagkas & Benn, 2006).

Latter generation migrants are a special group as they have grown up in the host culture. For example, European Commission has addressed the importance of including EU citizens with a migration background in the 2021-2027 integration action plan, as 10% of young (15-34 years old) EU citizens born in the EU have at least one foreign-born migrant parent (European Commission, 2020). Studies indicate differences between first and second-generation migrants in terms of various health outcomes and behaviors in European countries and the United States (Hosper, Nierkens, et al., 2007). Greater social and cultural adaptation is associated with higher PA participation among migrants in European countries (Afable-Munsuz et al., 2010; Hosper, Klazinga, et al., 2007). Social and cultural adaptation processes might be easier for second and third-generation migrants who are also a citizen of the host country, as they are born and enrolled in the education system of the host country. In this way, second and third-generation migrants would be more likely to adopt the health norms of the society in the host country. To illustrate, latter-generation migrants' PA behavior seemed to approach the level of individuals from the host ethnicity in the Netherlands (Hosper, Nierkens, et al., 2007). This adaptation process might engender alteration of PA behavior and perceptions towards PA including constraints between migrants and non-migrants from the same ethnicity and culture.

Although individuals from different countries share the same ethnicity and culture, perceived constraints may differ with respect to the type of leisure time constraints. According to Crawford and Godbey (1987), who distinguished between three categories of constraints: structural, intrapersonal, and interpersonal, the entire process of leisure desire and involvement is impacted by constraints. External obstacles, such as a lack of resources like time, money, or transportation, that are present before involvement but before leisure preferences have been established are referred to as structural constraints. The development of interests and preferences is limited and shaped by intrapersonal and interpersonal constraints, on the other hand, which are known as "antecedent constraints". Interpersonal constraints are social factors, such as friends or family who prefer different leisure activities, whereas intrapersonal constraints are psychological characteristics of the individual that influence the formation of leisure preferences, such as anxiety or perceived lack of skill. Participation in physical activity among individuals may also be significantly hampered by intrapersonal restrictions, which are personal psychological concerns (Mulligan et al., 2012; El Masri, Kolt & George, 2021). Moreover, Marconnot et al. (2019) highlighted the importance of the sense of fear and insecurity among immigrant children as possible PA participation constraints. Interpersonal constraints refer to social factors, such as the influence of family, friends, or community

members on PA participation. For immigrants, interpersonal constraints may include pressure to conform to cultural norms around PA or a lack of social support for engaging in PA To illustrate, the duration of settlement, and the influence of key persons and community groups were providers of necessary conditions and opportunities for Chinese immigrants to interact with locals and experience local culture in sport and leisure activities (Li, Sotiriadou, & Auld, 2015). Finally, structural constraints refer to external factors such as lack of time, money, and transportation. For immigrants, these factors can be particularly challenging, as they may face language barriers, limited access to resources, and discrimination, which can all impact their ability to engage in PA (Marconnot et al., 2019). Furthermore, in more developed countries, people may have more opportunities for leisure time physical activity due to better infrastructure, access to recreational facilities, and more flexible working hours (Cameron et al., 2013). Therefore, it is important to understand the perceived PA constraints by migrant populations, especially in different countries with different development levels.

Factors influencing leisure time PA behaviors may differ for ethnic groups concerning their culture and level of adaptation to the host culture (Crespo et al., 2000; Whitt-Glover et al., 2009). Moreover, the perceived PA constraints might be specific to the culture of migrants and the host country. Therefore, focusing on specific migrant populations from the same indigenous culture and living in the same alternative culture and comparing them with non-migrant individuals from their country of origin would pave the way for a better understanding effect of culture on perceived PA constraints. In this sense, Turkish immigrants in Europe and specifically in Germany represent a special population as third and fourth-generation youths were born, raised, and get educated in the host country. Turkish-origin migrants and their descendants constitute the biggest ethnic minorities in European Union countries. Turkish migration to Europe started in the early 1960s, due to the seeking for foreign labour caused by the economic boom in Western Europe, and continued with family reunification. According to the European Commission (2011), Turkish citizens make up the biggest group of non-nationals in 2009 and comprise 2.4 million people accounting for 7.5% of all foreigners living in European Union countries. In Germany, 25.5% of the population has a migration background, either having ancestors who immigrated or having personally moved and 2.8 million Turkish-origin individuals constitute the largest ethnic group in this country (Federal Statistical Office, 2019). Considering, the history of Turkish migration, young Turkish-origin populations living in Europe culturally adapted to host countries based on their length of residency and language proficiency (Koca & Lapa, 2014).

Haase et al. (2004) indicated that international comparisons are important for defining variations in PA in different cultures from the perspective of global public health. In this manner, comparing physical activity constraints between individuals with a migrant background and their counterparts in the country of origin would point to common and different perceived leisure time PA constraints, and suggest the areas in most need of amendment for physical activity promotion across different countries and highlight the important points of good practice for both migrants and non-migrant populations. To date, current migrant literature investigating the PA constraints is limited to differences between host and indigenous cultures. Therefore, examining how Turkish young fourth-generation migrants perceive constraints in German society and comparing them with natives of their origin country would enhance our understanding of perceived PA constraints in migrants from and in specific host and indigenous cultures. Due to the lack of comparison analyses with individuals from the same origin but various cultures, the aim of this study was to compare the perceived constraints related to physical activity among fourth-generation Turkish origin youth living in Germany who speak both German and Turkish as their mother tongue to their Turkish counterparts residing in Turkey.

METHODS

Research Model

The current study is a prospective causal-comparative study that examines the perceived PA constraints differences between Turkish youth living in Turkey and fourth-generation Turkish-German youths who grew up and have lived in Germany. A prospective causal-comparative study is a type of research design where the researcher aims to identify the cause-effect relationship between two or more variables. The cause-effect relationship of country of residence and perceived PA constraints were examined in this study. The ethical approval of the research was obtained by the decision of Anadolu University Health Sciences Scientific Research and Publication Ethics Board No:42615.

Sample design and data collection

The variables in this research are the participants' year of birth, i.e. their chronological age, years of service in profession, and level of education which is differentiated as undergraduate, graduate university, high school and, primary school.

Statistical data processing

A total of 196 young adults from Germany and 201 young adults from Turkey participated in this study with a convenience sampling method. This method involves selecting participants based on their accessibility and willingness to participate, rather than randomly selecting them. Before the data collection, participants were introduced to the study and the data collection tool. Individuals who reported a struggle of understanding at least a single item on the data collection tool were excluded from the study to ensure accuracy and reliability of the data. A total of 11 participants were excluded due to a misunderstanding of items in the data collection tool. The study includes two groups of participants: those who were born in Germany and currently reside there, aged between 18 and 29, and those living in Turkey, aged between 18 and 27. 4th generation Turkish-German participants constituted 104 female (Age: 22.38±2.23) and 81 male (Age: 21.76±1.88) young adults, born and living in Germany. Data was collected from Turkish young adults composed of 89 females (Age: 21.11±1.28) and 112 males (Age: 21.90±1.97) living in Turkey. The German data set was collected in the 2019 annual camp of the Turkish Ministry of Youth and Sports for young Turks living abroad. The inclusion criteria for the study were born and being university students in Germany, speaking German and Turkish fluently for participants from Germany. Participants of the Turkish data set were randomly selected with the stratified random selection method from the universities located in Ankara, the capital of Turkey. Each government university was accepted as strata, then 2 universities randomly selected out of four government universities. All participants were unmarried.

Measurement Instruments

In order to measure the research model constituted; Demographic Information form and "Leisure Time Perceived Physical Activity Constraints Scale" are used (Öcal, 2012).

Demographic Information

Participants self-reported their gender, age, and country of residence.

Data analysis

2-way Multivariate Analysis of Variance (2-way MANOVA) test was used to assess the effects of country of residence and gender background on perceived physical activity constraints between participants. The distribution of all dependent variables was homogenous according to Levene's test of homogeneity. Kolmogorov-Smirnov test indicated that data were normally distributed. Results of the descriptive statistics were presented as mean and standard deviation

(M±SD). As there were only two levels for both independent variables, none of the post-hoc tests were run following the 2-way MANOVA. Post-Hoc power was also reported. However, follow-up ANOVAs were examined for single main effects. All analyses were conducted by using SPSS 25.0.

RESULTS

Descriptive statistics indicate that generally, Turkish females living in both countries perceive higher constraints in all subscales compared to Turkish males. Similarly, participants living in Turkey perceive higher physical activity constraints compared to participants living in Germany. Descriptive statistics are shown in Table 1.

Table 1. Mean and standard deviations of the perceived barrier according to country of residence and gender.

	Country of Residence					
	Germany			Turkey		
	Female	Male	Total	Female	Male	Total
Body Perception	9.55±4.73	10.61±4.20	10.02±4.52	12.19±5.31	11.18±4.94	11.63±5.12
Facilities	18.80±7.90	15.46±6.64	17.34±7.54	24.26±8.60	23.96±8.67	24.09±8.62
Income	14.93±8.26	11.48±6.63	13.42±7.76	16.98±6.35	16.50±6.17	16.71±6.24
Family	7.08±5.20	6.08±3.07	6.64±4.41	9.52±4.22	9.68±4.47	6.43±4.35
Skill Perception	8.33±4.18	7.43±3.99	7.94±4.11	7.38±3.84	7.05±3.49	7.19±3.64
Time	9.50±4.16	7.98±4.42	8.84±4.33	8.06±3.40	7.69±3.15	7.86±3.26
Willpower	8.26±4.05	6.92±3.28	7.68±3.78	11.46±4.54	10.79±4.01	11.08±4.25
Society	12.04±5.45	8.88±4.36	10.66±5.23	14.49±4.85	11.53±4.18	11.96±4.50

A two-way MANOVA was run with two independent variables – country of residence and gender - and eight dependent variables – mean values of subscales of the Leisure-Time Physical Activity Constraints scale. There was statistically significant interaction effect between country of residence and gender on subscales, F $F_{(8,375)}$= 2.037, p= 0.041, Wilks' Λ= 0.958, partial η2= 0.42. Follow-up univariate two-way ANOVAs were run. These tests indicated a statistically significant interaction between the country of residence and gender for perceived physical activity constraints in body perception, income, and society subscales (shown in Table 2).

As such, a simple main effect analysis was also run. There was statistically significant simple main effect of country of residence, F $F_{(8,375)}$= 31.361, p= 0.000, Wilks' Λ= 0.599, partial η2= 0.401 (shown in Table 2). Follow-up ANOVAs indicated a statistically significant main effect of the country of residence on all subscales except skill perception. Turkish participants reported higher constraint scores on body perception, income, facilities, willpower, and society subscales, while Turkish-German participants reported higher scores on family and time subscales. Similarly, the simple main effect of gender was statistically significant on facility, income, time, willpower, and society subscales, $F_{(8,375)}$= = 2.813, p= 0.005, Wilks' Λ= 0.943, partial η2= 0.057. Follow-up analysis indicated that these simple main effects were in favor of males, which indicates female participants reported higher constraints scores.

Table 2. MANOVA Results of interaction and simple effects of country of residence and gender.

Independent variables	Dependent Variables	df	Mean Square	F	p	η^2	1-β
Country of residence	**Body Perception**	1	243.620	10.427	.001	.027	.896
	Facilities	1	4624.296	71.121	.000	.157	1.000
	Income	1	1188.110	24.742	.000	.061	.999
	Family	1	866.775	45.093	.000	.106	1.000
	Skill Perception	1	42.183	2.807	.095	.007	.387
	Time	1	71.329	4.981	.026	.013	.705
	Willpower	1	1183.268	73.373	.000	.161	1.000
	Society	1	227.117	10.073	.002	.026	.886
Gender	**Body Perception**	1	.075	.003	.955	.000	.050
	Facilities	1	315.206	4.848	.028	.013	.693
	Income	1	368.503	7.674	.006	.020	.789
	Family	1	16.778	.873	.351	.002	.154
	Skill Perception	1	36.083	2.401	.122	.006	.340
	Time	1	85.061	5.940	.015	.015	.781
	Willpower	1	95.843	5.943	.015	.015	.681
	Society	1	402.528	17.853	.000	.045	.998
Country of residence x Gender	**Body Perception**	1	101.041	4.324	.038	.011	.646
	Facilities	1	218.399	3.359	.068	.009	.448
	Income	1	208.332	4.338	.038	.011	.647
	Family	1	31.917	1.660	.198	.004	.251
	Skill Perception	1	7.876	.524	.470	.001	.112
	Time	1	31.447	2.196	.139	.006	.315
	Willpower	1	10.889	.675	.412	.002	.130
	Society	1	114.949	5.098	.025	.013	.715

DISCUSSION

The current study's objectives were to analyze the perceived constraints to PA among Turkish youth who reside in Turkey and fourth-generation Turkish-German youth who were raised and now live in Germany, as well as the potential effects of gender and country of residence on these constraints. The study aimed to determine whether there were any significant differences in perceived constraints related to Body Perception, Facilities, Income, Family, Skill Perception, Time, Willpower, and Society between the two groups using a causal-comparative model and multivariate analysis of variance. The study's ultimate goal was to offer information on the variables that affect the disparities in participation and levels of PA between various populations, particularly with regard to the effects of economic development and social standards. Country context is an important determinant of PA behavior among young people with its' unique health communications, political environments, social and cultural environments, institutional environments, physical environments, and accessibility to PA facilities (Langøien et al., 2017). The findings of this study revealed that young Turkish people living in Germany reported significantly fewer constraints in body perception, facilities, income, family, willpower, and society subscales compared to participants from Turkey. These results demonstrate the importance of economic, cultural, and institutional factors in the host country in terms of perceived leisure time PA constraints among acculturated migrants.

In this study, fourth-generation Turkish-German participants reported significantly less leisure time PA constraints in facility and income subscales, which are associated with the economic development of the country. The economic environment of the country is one of the most significant factors in the health-related behavior of residents (Lakerveld et al., 2014; Spinney & Millward, 2010), and it is also one of the main determinants of PA among migrants. The economic growth in developed countries is associated with a corresponding PA change in trends among the residents (Bauman et al. 2012). Bauman et al. (2011) indicated that associations of leisure and occupational PA with socioeconomic indicators are likely to reflect the economic development of six Asia-Pacific countries. Developed countries' investment in infrastructures such as traffic and recreational areas that enable people to be physical activity is higher than developing countries (Cameron et al., 2013). Moreover, Haase et al., (2004) also found that national economic development played a significant role in the relationship between leisure time PA and health beliefs, with the association being stronger in higher-income countries. Haase et al., (2004) also indicated that the rate of physical inactivity during leisure time differed based on cultural and economic development factors, with an average of 23% in North-Western

Europe and the United States, 30% in Central and Eastern Europe, 39% in Mediterranean countries, 42% in Pacific Asian countries, and 44% in developing countries. Thus, the economic growth is associated with the leisure time PA participation. The economic growth difference between Turkey and Germany is significant according to World Bank. Germany is a high-income country, whereas Turkey is classified as an upper-middle-income country (World Bank, 2019). In this manner, opportunities for PA are highly developed in Germany, and those opportunities have been steadily increased by local authorities since (Filippidis & Laverty, 2016), while environmental factors including lack of parks and heavy traffic prevent jogging and cycling in big cities, are not organized for promoting physically active lifestyles in Turkey (Hacisoftaoğlu & Pfister, 2012).

Haase et al. (2004) indicated that geographical, political, and cultural criteria are important in physical activity behavior. These factors are important for creating social norms related to physical activity, besides facilitating environmental opportunities for leisure-time PA. Given the fact that social support for physical activity is relatively insufficient among migrant communities (Marquez & Mcauley, 2006), social norms related to leisure-time PA in the host society become even more important for affecting PA behavior. Berry (1998) explained that the duration of residence in a new country increases the number of social interactions and contacts, which in turn increases the PA opportunities for migrants. Moreover, birthplace and duration of residence are important indicators of adopting healthy behavior in the host culture (Rotermann, 2011). Thus, because the PA participation level is higher in German society compared to Turkish (World Health Organization, 2014), it can be concluded that German social norms related to leisure time PA is more sophisticated, and this might be the main reason why German participants perceived significantly less leisure time constraints in society subscale.

Cultural traits of migrant origin citizens and the host country are also an important aspect of perceived PA constraints in society, as the holistic definition of PA strongly emphasizes the cultural spaces and contexts in that people move, act, and perform (Piggin, 2020). To illustrate, social adaptation in Dutch culture was strongly associated with sports participation for only first and second-generation Turkish migrant women, but not for Moroccan women (Hosper et al., 2008). Higher participation was accounted for by the culturally specific beliefs and lesser extent by self-efficacy and perceived disadvantages among Turkish-origin migrants (Hosper et al., 2008). Similar to this explanation, the qualitative study reported that the lifestyle choices of Turkish migrants in Denmark transition from a sedentary lifestyle to physically active health

choices, as their Danish contemporaries (Hacisoftaoğlu & Pfister, 2012). Participants of this qualitative study also said that "sport is always on the agenda in Denmark; it is part of Danish people's lives. You always hear, read about it, and are influenced by that discourse", whereas sports for all is not rooted in Turkish culture as another participant emphasized, "People in Turkey believe that sport is just for losing weight." As it was previously explained by Hacisoftaoğlu and Pfister (2012), encounters in socio-ecological environments such as peers, and with the aid of formal education in schools, which can be seen as more significant for fourth-generation Turkish in Germany, individuals acquire the rules, expectations, and norms that is pertinent in the host culture.

Results of this study also indicated that Turkish participants reported significantly higher perceived constraints in the family subscale. A study focused on the parent-child contact differences between Turkish migrant background families and native German families indicated that contact is more frequent in Turkish families (Steinbach, 2013). Although this finding indicates the power of family ties to direct youth generations to health-related behavior, the PA participation rates are low in first and second-generation Turkish migrants in Germany (Krist et al., 2020) similar to Turkish society (World Health Organization, 2014). However, Turkish origin young Germans attribute more power to themselves in the decision-making process (Schönpflug, 2001), which in turn might be effective on PA choices independent of family ties.

Perceived differences in PA constraints between Turkish and fourth-generation Turkish-origin young people living in Germany also can be attributed to generations included in this study. As this study only includes fourth-generation Turkish-origin German citizens, their adaptation level to German culture is expected to be higher than earlier generations, which in turn affects the level of interiorizing the culture-specific health norms. Given that fourth-generation individuals of Turkish descent in Germany have already undergone a process of acculturation into German society, it is expected that their perceptions of PA constraints would differ from those of individuals living in Turkey. Previous studies examining the effect of acculturation on PA behavior among Turkish migrants in England have reported no effect, and researchers explained that their results might be affected by the composition of participants which only included first-generation migrants (Koca & Lapa, 2014). On the other hand, their participant group from Germany which included second and third generations were more physically active compared to participants from England. To illustrate, compared to Turkish migrants who were born in Turkey, PA behavior of migrant background latter generation individuals who were

born in host culture seemed to approach the level of individuals from the host ethnicity in the Netherlands (Hosper, Nierkens, et al., 2007).

CONCLUSION

In conclusion, this study sheds light on the perceived constraints of leisure-time PA among Turkish young adults living in Turkey and Germany. The findings indicate that the country of residence and gender background have significant effects on PA constraints, with young adults in Turkey and females reporting higher levels of constraints. This study highlights the significant effects of country of residence and gender background on leisure-time PA constraints among Turkish young adults living in Turkey and Germany. Specifically, young adults in Turkey and females reported higher levels of PA constraints, emphasizing the need for targeted interventions and policies to increase PA participation in different cultural and economic contexts. The findings suggest that economic development level and PA norms play a crucial role in shaping attitudes and perceptions towards leisure-time PA (World Bank, 2019; World Health Organization, 2014). As previous research has shown, the availability and accessibility of environmental and organizational opportunities for PA in developed countries influence migrant-origin citizens' behavior toward PA (Hacisoftaoğlu & Pfister, 2012; Hosper, Nierkens, et al., 2007). Therefore, transferring effective policy practices from developed countries that promote PA among migrants should be carefully examined and implemented in sending countries to improve leisure-time PA opportunities for their citizens. Further research is needed to identify underlying factors that contribute to differences in PA constraints and to develop effective strategies to address them.

There were some limitations to this study, firstly the small sample size of both migrant-origin participants and local Turkish participants is not sufficient to represent young people in Germany and Turkey. Secondly, interpreting perceived leisure PA constraints with actual PA levels would improve the data analysis and results. However, data of participants living in Germany collected during their visit to Turkey and 7-day accelerometry-based PA levels would be different than their actual in Germany. Moreover, participants from Germany reported that they understand and speak Turkish clearly, but reaching larger sample and checking the validity of the questionnaire would be necessary to determine the generalizability of these findings to the wider population and ensure the validity of the instrument. Even though the data collection tool does not include any specific item related to country of residency nor culture, it is also

important to note that participants from the Germany were in the annual camp of the Turkish Ministry of Youth and Sports for young Turks living abroad while collecting data. Since they were asked to answer questions by considering their daily routines in Germany, collecting data in Germany would also potentially differ the results. Lastly, collecting data from various European countries with high numbers of Turkish origin people would be able to provide new insights into the research question that investigates geographical, climatic, economic, and sociocultural factors on PA constraints.

Declaration of Conflicting Interests

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

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SCROLLING FOR SWEAT: UNPACKING THE DYNAMICS OF SOCIAL MEDIA, MOTIVATION, TRUST, AND REPURCHASING IN THE FITNESS WORLD

POVEZANOST DRUŽBENIH OMREŽIJ, MOTIVACIJE ZA VADBO, ZAUPANJA IN PONOVNEGA NAKUPA V INDUSTRIJI FITNESA

ABSTRACT

Our goal in this study was to examine the structural relationships between social media fun, social media informativeness, exercise motivation, trust, and repurchase intention. Participants, all of whom were members of fitness center, completed surveys to assess these relationships. Results showed that both social media fun and social media informativeness had a positive impact on trust, but not on repurchase intention. Social media fun has a significantly positive influence on exercise motivation, but we could not confirm this for social media informativeness. Moreover, our results show that only social media fun has a positive influence on exercise motivation. We could not confirm the influence of motivation on trust. Finally, we confirmed that trust predicts repurchase intention for fitness center members.

Keywords: Exercise motivation, social media, trust, repurchase intention, fitness centers

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IZVLEČEK

Naš cilj v tej raziskavi je bil preučiti strukturne odnose med zabavnostjo družbenih medijev, informativnostjo družbenih medijev, motivacijo za vadbo, zaupanjem in namero ponovnega nakupa. Udeleženci, ki so bili vsi člani fitnes centrov, so izpolnili ankete za oceno teh odnosov. Rezultati so pokazali, da ima tako zabavnost družbenih medijev kot tudi informativnost družbenih medijev pozitiven vpliv na zaupanje, vendar ne na namero ponovnega nakupa. Zabavnost družbenih medijev pozitivno vpliva na motivacijo za vadbo, medtem ko tega nismo mogli potrditi za informativnost družbenih medijev. Poleg tega naši rezultati kažejo, da ima le zabavnost družbenih medijev pozitiven vpliv na motivacijo za vadbo. Vpliva motivacije na zaupanje nismo mogli potrditi. Nazadnje smo potrdili, da zaupanje napoveduje namero ponovnega nakupa med člani fitnes centrov.

Ključne besede: motivacija za vadbo, družbena omrežja, zaupanje, namera za nakup, fitnes centri

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INTRODUCTION

The health and fitness industry are growing every year, and they have almost tripled in some EU countries in the last decade (Trening, 2019; Storm & Hansen, 2021). In 2021 there were more than 56 million fitness members in Europe alone (Europe Active, 2022). For gyms, their communication with their customers is extremely important because it impacts the number of customers and revenue (García-Fernández et al., 2017).

However, the impact of marketing communication tools, such as social media on training center performance, and number of users has not been adequately researched (García-Fernández et al., 2017). When looking at fitness center users' decisions, it has been shown that their motivational structure is important (Tsitskari et al., 2017). Some authors have claimed that exercise motivation is lower for females who spend more than 1 hour on social media daily (Graff & Czarnomska, 2019). The growing number of fitness communities on social media has also raised the question of whether users can be motivated to exercise or even purchase through social media or other marketing communication channels?

Some studies have demonstrated that motivation to exercise can also be positively influenced by marketing communication channels, such as social media, who send framed messages daily (Gilbert et al., 2021). The extent to which persuasive communication about physical activity motivates people to exercise and improve their health is an extremely important area for future research (Bergeron et al., 2019). A recent scoping review on physical activity messages showed that although there is evidence of the influence of message content on physical activity and exercise, there are still gaps in the literature, for instance in terms of media or mode of delivery (Williamson et al., 2020). In this article, we therefore explore and focus on the research gap regarding the relationship between different types of social media marketing communications, exercise motivation, trust, and repurchase intention in fitness centers. In this way, we make an important contribution to the literature on exercise motivation. To date, no attempt has been made to establish an empirical relationship between exercise motivation, marketing channels, trust and repurchase intention in fitness environments, so such a study would be of great conceptual as well as practical value. Some researches have been conducted on sub-models, but there is none that encompasses all of the above constructs. This study would be of interest to gym owners and managers, as well as to their customers who want to get or stay active. It would also be very beneficial for public health on a national level, as active citizens are more

productive and less likely to get ill (Jimenez et al. 2020; Nieman, 2019; Nieman & Wentz, 2019).

Communication channels that gyms use include social media and e-mail (Mulchrone, 2021; Vučković & Majerič, 2021). Social media, such as Facebook, can be used to build a fitness center brand (García Fernández et al., 2015) and indirectly improve decision making to purchase a ticket (Wright et al., 2017). For this reason, many authors believe that fitness centers should integrate social media as an important part of their marketing communication (García-Fernández, et al., 2017; Middelkamp & Rutgers, 2020, Vučković & Majerič, 2021). In study which was done in Ireland, up to 37% of fitness participants first learned about the current fitness class they were attending through social media. And a quarter of survey participants reported that a post shared by a health and fitness influencer motivated them to try a fitness class online (Mulchrone, 2021). A study of a Slovenian sample also showed an increasing trend of social media and Internet marketing being a member's first contact with a gym – from 8.4% in 2016 to 31.8% in 2020 (Vučković et al., 2023). Some authors have demonstrated that athletes' posts on social media increase their followers' motivation for physical activity, especially when they include images (Johnston & Davis, 2019; Ehrlén & Villi, 2020). In addition, Tricás-Vidal et al. (2022) confirmed that residents of the United States, who felt encouraged to be physically active by fitness influencers on Instagram, were more physically active. Baranow (2019) and Haemers (2016) have shown that marketing communication via Instagram influencers has a positive impact on brand perceptions of fitness activity and even influences purchase decisions (Schiefer, 2018), but they didn’t further divide perceptions of different social media content.

According to Morgan and Hunt (1994), trust in relationships is characterized by qualities such as consistency, competence, honesty, responsibility, good faith, and integrity of the partner. Several authors have recognized trust as a critical factor in fostering successful relationships between companies and customers (Morgan & Hunt, 1994). It is well known that user satisfaction and trust in the fitness center brand have a positive influence on the decision to repurchase (Hurley, 2004; Musskopf et al., 2021). Istanbulluoglu & Sakman (2022) believe that communicating with customers through social media channels may be associated with stronger repurchase intentions by instilling greater trust in the company. Many more studies have found connections between marketing communication channels and purchase decisions in other areas, outside fitness industry (Dabbous & Barakat, 2020; Ramesh and Vidhya, 2019).

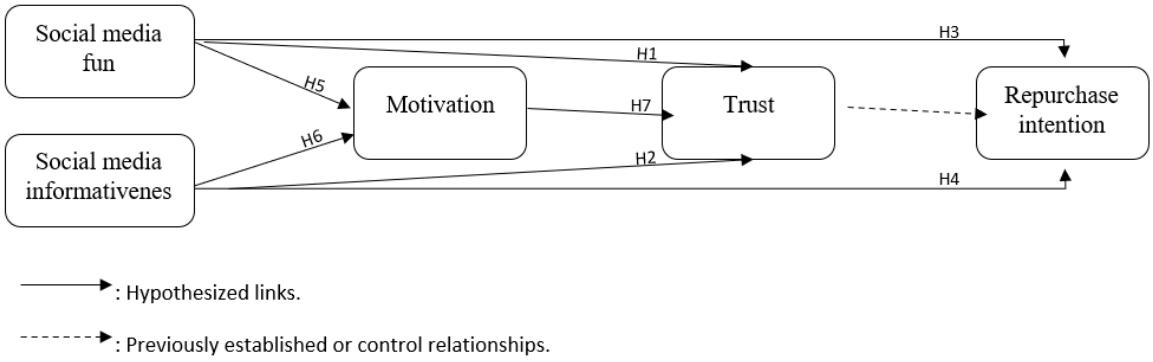
In the fitness industry, it has been shown that with posts on social media and the use of influencers, it is possible to influence consumer trust (Barranow, 2019) and purchase (Schiefer, 2018) or even exercise intent (Durau et al., 2022). Tsitskari et al. (2017) segmented gym participants based on their motivation. Their study showed a statistically significant difference between groups with exercise motivation for both service quality and psychological commitment to the fitness center. A recent study conducted in Indonesia also shows that marketing content on social media can have a positive effect on customer engagement, which in turn affects intention to use the service (Miryam & Antonio, 2022). But contradictory, Zhou and Krishnan (2019) could not confirm a direct effect of social media content on exercise maintenance. Furthermore, contradictory empirical findings in this area is one more reason to conduct research.

A study conducted in Korea showed that customer trust in fitness centers had a significant impact on customer satisfaction, and customer satisfaction had a significant impact on revisit intention (Kim & Lee, 2018). In addition, content quality had significant positive effects on the perceived value of fitness platforms on social media, and perceived value was positively correlated with revisit intention in China (Gao et al., 2021). Trust also had a direct and positive impact on repurchase intention in fitness centers in Brazil (Musskopf, 2021), so we expect the same results in our research.

The aim of our study is to investigate the relationships between marketing channels, exercise motivation, trust, and repurchase intention. First, we will collect information from users of Slovenian gyms. Following factorial analysis, which has been shown to be a good method for Exercise Motivations Inventory – 2 (EMI-2) in the Slovenian population (Vučković et al., 2022), we will use the first factor in Structura Equation Modelling (SEM).

Specifically, we propose that social media informativeness and social media fun should both have positive effect on consumer trust (H1, H2). Social media informativeness will also have a positive effect on consumers' repurchase intention (H4), because it is expected that informing customers about the positive effects of exercise can increase interest in exercise and trust in the center as a reliable source of information. There is not much evidence that posting fun posts on social media can attract customers, but we expect there a visible connection. There will be a positive effect of perception of social media fun on repurchase intentions (H3). As aforementioned, social media can have different effects on exercise motivation (Vaterlaus, 2015; Carrotte et al., 2015). However, we hypothesize that both social media fun (H5) and

social media informativeness (H6) will have positive effects on motivation. Finally, we will investigate the relationship between motivational structure and trust in fitness center (H7).



METHODS

Participants

The purpose of the present study was to determine the trust and repurchase intentions of fitness centers users in relation to marketing channel use and exercise motives of fitness users. We collected data from fitness center members from 18 fitness centers from 9 major Slovenian cities (4 from the eastern region and 5 from the western region). A total of 1696 questionnaires were distributed, 764 of which were completed and eventually used, representing a response rate of 39.36%.

Table 1. Sample characteristics.

	(%)
Gender	
Male	50.5
Female	49.5
Age	
Mean age	27.4
Status	
Single	49.7
In relationship	50.3
Education	
Elementary school degree	1.8
Secondary school degree	47.4
High school degree	18.5
College degree	25.8
Master's or doctoral degree	6.4
Occupation	
Student	47.9
Unemployed	2.0
Corporate employee	39.0
Self-employee	9.9
Retiree	1.0

In the Table 1, we can see the demographic characteristics of the samples.

Instruments

Exercise Motivation

The EMI-2 scale consists of 51 items and each item is measured on a 6-point Likert scale ranging from zero (does not apply to me at all) to five (applies to me very much), with higher scores indicating higher motivation to exercise. These items form 14 subscales, including: Affiliation, Appearance, Challenge, Competition, Enjoyment, Health Pressure, Disease Prevention, Agility, Positive Health, Revitalization, Social Recognition, Strength and Endurance, Stress Management, and Weight Management. Each subscale is determined by calculating the average of 3 to 4 appropriate items based on the EMI-2 scale scoring key. The EMI-2 is a factorially valid mean of assessing a wide range of motives for participation in sporting activities in adult men and women and is suitable for both athletes and non-athletes (Markland & Ingledew, 1997). EMI-2 was already used on Slovenian population, with Cronbach's alpha ranging from 0.70 to 0.94 (Vučković et al., 2022). There are several other instruments that are similar in nature and can be used to measure exercise motivations for instance the Behavioral Regulation in Exercise Questionnaire-2 (BREQ-2), whos Cronbach's alpha coefficients for the different subscales range from 0.60 to 0.88 (Mahony et al., 2019).

Social Media Informativeness and Social Media Fun

Consistent with studies of traditional advertising, the two main benefits of advertising are expected to be informativeness and entertainment (Edwards et al., 2002). Perceptions of informativeness of social media were assessed using a four-point scale (helpful, unimportant, uninformative, useless; the last three items were reverse coded), as were perceptions of social media fun (attractive, enjoyable, entertaining, fun). We adopted scales to our context from original, where instead of social media, more generalized, advertising informativeness and fun/entertainment (Edwards et al., 2002; Noguti & Waller, 2020). The scale was never used in Slovenian speaking area, so we translated it back-forth.

Trust

A scale previously used by Morgan & Hunt (1994) was adapted by Walsh & Beatty (2007) to measure trust. The scale consists of 6 five-item Likert-type items. The original scale has acceptable reliability with a Cronbach's alpha of 0.74 to 0.83. The scale was never used in Slovenian speaking area, so we translated it back-forth.

Repurchase Intention

Four five-point Likert-type items measure a customer's attitude toward his current and future purchases of the brand. The original scale has acceptable reliability with a Cronbach's alpha of 0.66 to 0.77 (Kumar & Pansari, 2016). The scale was never used in Slovenian speaking area, so we translated it back-forth.

Research Design

Members were approached with iPad when they were leaving fitness center after their workout. To encourage participation, members were offered a protein bar and kindly asked to complete a questionnaire. They sat down on a chair and completed the questionnaire in peace. All questionnaires were distributed from Monday to Sunday in the morning, afternoon, and evening. Although the sample was convenient rather that a randomly selected one, all fitness centers in the country have similar characteristics in terms of facilities, equipment, programs offered, and membership conditions. This study was conducted in accordance with the Declaration of Helsinki and the British Psychological Society's Code of Ethics and Q4 Conduct. All participants provided written informed consent before participating in the study, and the Ethics Committee of the Faculty of Sport at the College of Ljubljana granted ethical approval for data collection (No. 2021-19).

In a pilot study for Slovenian population (Vučković et al., 2022), it was demonstrated that we extract 8 factors when factorizing 52 EMI-2 items and that the first component accounts for 36.2% of the explained variance. Consequently, we took the items from this first component.

We first conducted a confirmatory factor analysis (CFA) for the model constructs.

RESULTS

With factor analysis, we got 8 factors. Most of the questions are in the first component, which accounts for 36.2% of the explained variance. According to original scoring key, questions from first component fit into 3 motivations: Stress management, Revitalization and Enjoyment. Those 3 dimensions of motivation were used in Structural model equation.

Below, we can see the results of confirmatory analysis, composite reliability and average variance extracted of used constructs.

Table 2. Construct measure and psychometric properties.

Construct	λ	CR	AVE
Stress management		0.85	0.65
EMI20	0.77		
EMI34	0.78		
EMI46	0.88		
Revitalization		0.8	0.58
EMI3	0.66		
EMI17	0.85		
EMI31	0.76		
Enjoyment		0.84	0.57
EMI9	0.63		
EMI23	0.80		
EMI37	0.82		
EMI48	0.76		
Social media informativeness		0.92	0.78
INFDO2	0.83		
INFDO3	0.91		
INFDO4	0.92		
Social media fun		0.88	0.65
ZABDO5	0.80		
ZABDO6	0.86		
ZABDO7	0.87		
ZABDO8	0.68		
Trust		0.97	0.78
TRUST1	0.85		
TRUST2	0.89		
TRUST3	0.91		
TRUST4	0.88		
TRUST5	0.89		
TRUST6	0.89		
Repurchase intention		0.89	0.72
RINT1	0.85		
RINT2	0.85		
RINT4	0.85		
Model fit			
χ^2		1087	
df		278	
RMSEA		0.06	
NNFI		0.97	
CFI		0.98	

Notes: λ – standardized loading, CR = composite reliability, AVE = average variance extracted

As we can see in Table 2, psychometric properties of our constructs are acceptable. The CFA model resulted in a good overall fit (χ2=1087, df=278, RMSEA=0.06, NNFI=0.97; CFI=0.98) and high construct reliability (ranging from 0.8 for revitalization to 0.97 for trust). In addition,

convergent validity of the measures was supported, as all indicators significantly load on their respective latent variables.

Table 3. Discriminant validity assessment.

# construct	1	2	3	4	5	6	7
Informativeness	**0.81**						
social media fun	0.19**	**0.76**					
stress management	0.08*	0.26**	**0.75**				
Revitalization	0.12**	0.27**	0.71**	**0.88**			
Enjoyment	0.08*	0.27**	0.63**	0.73**	**0.81**		
Trust	0.31**	0.46**	0.24**	0.30**	0.28**	**0.88**	
repurchase intention	0.25**	0.32**	0.17**	0.22**	0.20**	0.73**	**0.85**

Notes: correlations are shown below the diagonal; square root AVEs are shown on the diagonal in bold.
** . Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

As we can see in Table 3, average variance extracted (AVE) ranged from 0.57 to 0.78 and all square roots of AVEs were much larger than any of the corresponding correlations (Fornell & Larcker, 1981) thus establishing discriminant validity.

Table 4. Structural model estimation results.

Estimated paths	β (t-value)	R^2
Stress management → trust	-0.08 (-1.19)	0.35
Revitalization → trust	0.46 (1.66)	
Enjoyment → trust	-0.03 (-0.24)	
Social media informativeness → trust	0.17 (5.65)	
Social media fun → trust	0.39 (10.69)	
Trust → repurchase intention	0.80 (19.41)	0.62
Social media informativeness → repurchase intention	0.02 (0.83)	
Social media fun → repurchase intention	-0.05 (-1.62)	
Social media informativeness → stress management	0.01 (0.24)	0.09
Social media fun → stress management	0.36 (6.88)	
Social media informativeness → revitalization	0.03 (1.31)	0.10
Social media fun → revitalization	0.18 (6.57)	
Social media informativeness → enjoyment	0.03 (0.67)	0.10
Social media fun → enjoyment	0.34 (6.98)	
Model fit	$\chi2$ = 1087.58, df = 281, RMSEA = 0.06, NNFI = 0.97; CFI = 0.98	

Notes: β = standardized coefficient

As shown in Table 4, SEM resulted in an acceptable model fit ($\chi2$ = 1087.58, df = 281, RMSEA = 0.06, NNFI = 0.97; CFI = 0.98) and was valid.

DISCUSSION

In the age of digitalization, marketing channels, such as social media, can greatly influence consumer trust (Baranow, 2019) and purchase intention (Schiefer, 2018) in the fitness market. While previous studies have shown that social media content can positively influence exercise intention (Durau et al., 2022) and service usage intention (Miryam & Antonio, 2022) in fitness centers, our study contributes to this knowledge by examining the influence of different types of social media content on motivation, trust, and repurchase intention.

Our results suggest that both informativeness and social media fun have a significant positive impact on gym members' trust. Thus, we confirmed H1 and H2. By providing informative content on social media, companies can establish themselves as experts in their field and build credibility (Fog & Indra, 2022). They can help customers better understand the value of their services and increase their commitment to their health and fitness goals, creating a relationship that can lead to greater trust in brand. On the other hand, social media fun can help create a sense of community among fitness center members. By offering their members the opportunity to interact on social media, fitness centers can create a positive and supportive environment that fosters trust. It is well known that the use of humor by salespeople positively influences customer trust (Lussier, Grégoire & Vachon, 2017). Our research has shown that by providing fun and creative content on social media, fitness centers can show their members that they are not just a faceless business, but a group of people with a sense of humor and a passion for fitness; this can help increase members' trust in the brand.

Some studies have demonstrated that people can be motivated to exercise through social media (Li et al., 2023). Conversely, other studies have attempted to confirm that social media can influence exercise maintenance, but the results were not significant (Zhou & Krishnan, 2019). To further the body of knowledge, we examined the effects of different types of content on social media channels on membership repurchase intention in fitness centers.

Our results show that the impact of social media fun on the intention to repurchase membership is not significant, so we reject H3. There may be several reasons for this. If individuals perceive the fitness brand's social media posts as frivolous or unrelated to their fitness goals, they may begin to question the credibility and relevance of the fitness center, which could negatively impact their intention to repurchase membership. On the other hand, entertaining content looks fun and interesting, and members enjoy watching it. However, after some time, the fitness brand posting such content may appear less professional and competent, which may cause members

not to renew their membership. Also, the impact of social media fun on repurchase intention may also depend on how the fitness center uses its social media presence to drive engagement and encourage customers to return. For example, if the fitness center uses social media to offer exclusive deals or provide personalized recommendations, customers may be more likely to repurchase their membership (Vučković & Majerič, 2021). However, if the fitness center does not actively use social media to engage or provide value to customers, the impact of social media fun on repurchase intention may be minimal.

In addition, we found that the perception of social media informativeness on intention to repurchase ticked in attended fitness center is not significant, so we rejected H4. We expected, as posting informative content about exercise could position fitness club as credible and competent, making customers want to stay and renew their membership. However, our results show that while informative content may increase brand trust, it may not necessarily lead to purchase behavior. Even if customers perceive the fitness center as informative on social media, they may not necessarily feel compelled to renew their membership if they have concerns or priorities that outweigh their appreciation for the informative content. This is not consistent with previous literature suggesting that informative and high-quality content on social media can influence customers' intentions, such as exercise intention (Li et al., 2023). However, it is very important to have in mind that the decision to repurchase a fitness center membership is influenced by several factors, such as perceived quality (Musskopf et al., 2021) and service quality (Choi, 2001), customer commitment and frequency of weekly visits, and perceived price (Ferrand et al., 2010). In addition, other factors such as variety of classes or convenience of location (Plummer, 2003; Plummer, 2007), or even type of membership (DellaVigna & Malmendier, 2006) could also influence the decision to repurchase membership at a fitness center visited.

Social media fun positively and significantly impacts all three types of motivation, so we could confirm H5. Laughter and humor can trigger positive emotions such as joy and happiness, which can lead to increased motivation for physical activity (Ekkekakis et al., 2008). When people see a funny post, it can help them associate exercise with positive emotions, which can increase the likelihood of wanting to engage in physical activity. In addition, seeing a funny post on social media can provide a brief distraction and help people forget about negative thoughts, making it easier to stay motivated and focused on fitness goals. When people find exercise enjoyable and fun, they are more likely to continue doing it consistently. Fun posts on

social media can help exercise feel less like a chore and more like a fun activity, which can increase willingness to exercise.

We found no significant effect of social media informativeness on exercise motivation types, so we rejected H6. One possible explanation could be that the type of information provided on social media may not be directly related to exercise motivation. While informative content may increase trust in the fitness center brand, it may not necessarily address the specific needs and motivations of individual customers. Exercise motivation is a complex construct that is influenced by a variety of internal and external factors (Markland & Ingledew, 1997). Therefore, even if customers perceive the fitness center as informative on social media, it may not necessarily impact their exercise motivation. Furthermore, the impact of social media informativeness on exercise motivation may depend on how the information is presented and the engagement it elicits from customers. For example, if the informative content is presented in a motivational way that excites and encourages customers to exercise, it may have a more significant impact on exercise motivation. However, if the informative content is presented in a passive or uninspiring manner, customers may not engage with it and the impact on motivation to exercise may be limited. In addition, there is a difference between reading or knowing information about exercise and being motivated for exercise. Some people just want to know about something but are not motivated to exercise.

We also examined the relationship between exercise motivation and trust in a fitness center, but could not find significant connection, so we rejected H7. A more fine-grained approach showed that Revitalization as a part of motivation positively influenced trust, but we could not conclude so for Enjoyment and Stress management. Members who exercise for stress management or enjoyment reasons do not trust fitness center brand - connection was negative but not significant. Perhaps it is due to the fact that people who exercise for pleasure like it so much that they do not care which gym they work out at. They are intrinsically motivated to exercise no matter which club they are training. Even more, they enjoy exercise, but they may hate the "Fitness club community", because there is a lot of noise, talking and socializing. They do not want that; they just want to enjoy in exercise. Similarly, people who exercise because exercise helps them relieve stress. They also do not care in which fitness center they work out at; they are just happy to get away from stress. And it's likely that the "fitness club community" and all the measures that fitness clubs make to engage members and build brand trust have an opposite effect on such motivated members. Our results also show a positive but not significant relationship between revitalization motive and trust. It is known that members who exercise for

revitalization reasons are mostly older members (Vučković & Kajtna, 2023), who exhibit more consistent exercise behavior (Rahman et al., 2018) and change clubs less frequently, so we expected them to trust their fitness center brand; but our results could not confirm this. Sandach (2022) empirically examined whether specific self-efficacy for a particular health behavior (in his case, habitual meditation, and mindfulness for stress reduction) had a moderating effect on the influence of social media, but again the results were inconclusive.

Lastly, we confirmed the previously researched fact that user trust in a fitness center strongly predicts repurchase intention, similar to Kim & Lee (2018) and Musskopf (2021).

Overall, social media can play a critical role in success of fitness centers by providing a platform for informative content that builds trust, educates customers, keeps them engaged, and influences their behavior for future purchases.

Limitations

The results of this study are of some theoretical value and practical importance, but also have some limitations. First, this study was cross-sectional, data were collected at one time, and no effective follow-up study was conducted. Second, the sample size was 18 gyms; since Slovenia is a small country and 18 large gyms from 9 major cities were included in the study, the conclusions can only be generalized to a certain extent. Third, due to the cultural and sociological characteristics of Slovenia, this study cannot be generalized worldwide. Fourth, participants were asked about their perception of social media content and that can also be subjective – future studies could use more objective measures or qualitative approaches to capture specific content characteristics. Lastly, we surveyed participants of fitness centers, who already train and are already (highly) motivated to participate in fitness training. It would be interesting to observe the interaction of factors in a general population.

CONCLUSION

Our research contributes to the international kinesiology literature by seeking to better understand the relationships between exercise motivation, marketing channels, trust, and repurchase intention in the fitness sector. To the best of our knowledge, our study is the first to examine the relationships between these constructs.

We found that both social media informativeness and social media fun had a significant positive impact on the trust of fitness center members, but neither had a direct significant impact on

repurchase intention. In addition, we found that social media fun positively influenced all three types of motivation, while social media informativeness had no significant influence on exercise motivation.

Managerial implications

From a practical perspective, the study's findings provide some guidance on how fitness managers and owners should communicate with their members on social media to build trust in their brand and thus increase the likelihood of repurchase intention. It is important for fitness centers to invest in market research to better understand the motivational structure of their target audience and use this information to develop effective marketing strategies.

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All authors declare that they are not aware of any competing financial interests or personal relationships that could have influenced the work in this article.

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COOPERATIVE LEARNING VS. DIRECT INSTRUCTION IN YOUTH SPORT: EFFECTS ON CHILDREN'S MOTOR LEARNING

PRIMERJAVA SODELOVALNEGA UČENJA IN DIREKTNEGA POUČEVANJA V ŠPORTU MLADIH: UČINKI NA GIBALNO UČENJE OTROK

ABSTRACT

Cooperative Learning promotes peer teaching that fosters active learner engagement and better retention and usefulness of knowledge. Research has shown that Cooperative Learning has a positive impact on motor learning in PE students. The aim of this study was to investigate whether Cooperative Learning is a more appropriate teaching approach for use in youth competitive athletics to improve children's motor learning, compared to the Direct Instruction used so far. Using cluster random assignment, twelve Slovenian track and field groups (140 young athletes) were divided into an experimental group that completed three Cooperative Learning units (30 training sessions) and a control group. The children's performances in four track and field skills were recorded and rated by three qualified assessors. A pretest-posttest research design was used. Nested analyses of covariance were conducted to examine whether the model (Cooperative Learning vs. Direct Instruction) affected posttest scores, adjusting for the average age of children and their track and field proficiency at baseline. Significant differences in favour of Cooperative Learning were found for three variables: track and field skills, low skipping, and crouch start. We found that Cooperative Learning is very effective in improving motor learning in youth competitive athletics and even more effective than Direct Instruction. The cooperative nature of the studied pedagogical model promotes peer teaching, giving feedback and taking responsibility, which has a more positive effect on the young athletes' sports skills than the traditional teaching method.

Keywords: teaching method, pedagogical model, young athletes, athletic skills

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IZVLEČEK

Sodelovalno učenje spodbuja medvrstniško poučevanje, ki omogoča aktivno učenje in boljšo zapomnitev ter večjo uporabnost znanja. Raziskave so pokazale, da ima sodelovalno učenje pozitivne učinke na gibalno znanje učencev pri športni vzgoji. Namen naše študije je bil preučiti, če je sodelovalno učenje bolj primerna metoda poučevanja za uporabo v športu mladih z namenom izboljšanja gibalnega učenja, v primerjavi z direktnim poučevanjem, ki se je uporabljalo do sedaj. Dvanajst slovenskih atletskih skupin (140 mladih atletov) smo naključno razdelili v eksperimentalno skupino (ta je opravila tri enote sodelovalnega učenja na 30 treningih) in kontrolno skupino. Otroke smo posneli pri izvajanju štirih atletskih spretnosti. Posnetke so nato ocenili trije usposobljeni ocenjevalci. Uporabili smo raziskovalni načrt s pred- in post-testiranjem. Da bi ugotovili učinke modela (sodelovalno učenje proti direktnemu poučevanju) na končne rezultate in pri tem kontrolirali povprečno starost otrok pred eksperimentom in začetno atletsko znanje, smo uporabili grajeno analizo kovariance. Pomembne razlike v prid sodelovalnemu učenju so se pokazale pri treh spremenljivkah: atletske spretnosti, nizki skiping in nizki štart. Ugotovili smo, da je sodelovalno učenje zelo učinkovito za izboljšanje gibalnega znanja v tekmovalni atletiki mladih in da je učinkovitejše od direktnega poučevanja. Sodelovalna narava preučevanega pedagoškega modela spodbuja medvrstniško poučevanje, dajanje povratnih informacij ter prevzemanje odgovornosti in ima zato bolj pozitiven vpliv na športne spretnosti mladih atletov kot tradicionalna metoda poučevanja.

Ključne besede: metoda poučevanja, pedagoški model, mladi atleti, atletske spretnosti

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INTRODUCTION

According to Fitts and Posner's model, learning a motor skill involves three stages (Magill & Anderson, 2017). In the cognitive stage, learning success relies heavily on demonstration and verbal instruction. In the second, associative stage, a person refines their performance and acquires the ability to recognise and identify performance errors. Continuous improvement of a motor skill and eventual movement automatism are made possible by frequent training, a large number of repetitions, feedback, etc. However, the success of motor learning is influenced by many other factors, such as the personal characteristics of the individual, their motor and intellectual abilities, and also the approach to teaching and learning (Škof, 2016).

Traditional teaching methods are blamed for passive knowledge and poor understanding of the subject matter among learners (Rutar Ilc, 2004). On the other hand, active knowledge acquisition is characteristic of the constructivist paradigm. Learners construct their knowledge independently by using higher-order thinking processes to incorporate new information into existing experiences. Active learning improves retention, understanding, usefulness, and transferability of knowledge (Casey et al., 2009). The basic assumption of constructivism is that each person should create knowledge through their own thinking activity in a productive interaction process or dialogue with others (Marentič Požarnik, 2004). Thus, the teacher cannot inculcate knowledge into the learners, but it is up to them to acquire it themselves.

Cooperative learning (CL) is a pedagogical model in which children work as active learners in small, heterogeneous groups (Casey & Quennerstedt, 2020; Metzler & Colquitt, 2021). The main idea of CL is that children are responsible for learning in the group and that they depend on their classmates (Casey et al., 2015; Johnson & Johnson, 2009). To pursue group goals, children learn how to teach their peers, which enables them to improve their knowledge as well (Cecchini Estrada et al., 2019; Johnson & Johnson, 2009). Interactions between group members and mutual support encourage learners to critically analyse each other's performance and actively receive feedback from peers (Huang et al., 2017). Feedback is one of the four common instructional strategies that promote active student engagement (Moon, 2022).

Since CL corresponds to the processes of motor learning and control in a way that promotes active learning through peer teaching and feedback, it is not surprising that it improves motor learning in PE students (Darnis & Lafont, 2013; Dyson, 2002; Huang et al., 2017). Physical activity in pre-adolescence needs to focus on learning new sports skills, regardless of the sport context – physical education (PE) or competitive sport (Way et al., 2016). If the main objective

of a lesson/session is based on learning, competitive activities are less appropriate as competition limits learning opportunities in some areas (Grineski, 1996; Johnson & Johnson, 2009). Moreover, competition motivates only those children who have the potential to succeed and does not promote the development of social skills. Although psychosocial and cognitive goals are becoming increasingly important in youth sport, physical goals remain the main effects of the learning process (Bailey et al., 2009). However, the quality of children's physical activity depends on the number of children achieving as many different learning goals as possible (Grineski, 1996). Through cooperation, children can develop multiple psychological and social skills that cannot be fostered by the other goal structures – competitive or individual (Hortigüela Alcalá et al., 2019). CL proved to be more suitable than DI for improving peer relationships, motivational climate and emotional self-concept in young athletes (Železnik Mežan et al., in press). Therefore, it could help reduce high dropout rates among promising athletes (Sheehan et al., 2018). Among other things, CL also enables children to develop critical thinking skills, which are positively associated with motor learning (Chou et al., 2015; Dyson et al., 2010). The aim of our study was to find out whether CL is also suitable for motor learning in youth competitive athletics. Two pedagogical models, namely CL and direct instruction (DI – classical teaching method most commonly used for training young athletes), were empirically investigated to compare their effects on young athletes ' track and field skills.

METHODS

Design

The effects of CL intervention on the track and field skills of young athletes were compared with the effects of the control programme (DI). A cluster random assignment and a pretest-posttest research design were used.

Participants

The Republic of Slovenia is a small country in central-southeast Europe with a population of 2.052 million people. In order to obtain the largest possible sample, we contacted all potential athletics clubs in Slovenia. Twelve of them met certain conditions, the fulfilment of which made it possible to carry out the experiment: at least one group of 8-to 11-year-olds; at least twelve children who train regularly; possibility of using indoor sports facilities in winter; training accessories; trainer with appropriate education (university degree, pedagogy) or qualification

(at least first level and at least seven years of professional experience); trainer is willing to participate in the study; training takes place two or three times a week with the same trainer. All twelve clubs were thus included in the study.

By recruiting twelve trainers for the experiment, all their athletes aged 8-11 years were invited to participate in the study. The twelve track and field groups were randomly divided into an experimental group (EG) (six clubs) and a control group (CG) (six clubs). 140 children participated in both measurements and in at least 70% of the training sessions. EG with CL consisted of 52 girls and 26 boys (mean age: 9.22 ± 0.68 years). CG with the traditional DI consisted of 37 girls and 25 boys (mean age: 9.86 ± 0.76 years). Further demographic data can be found in Appendix A.

Procedure

Table 1 shows the timeline of the experiment.

Table 1. Timeline.

February 2021	March-October 2021	May 2021	October 2021	November 2021 – first two weeks	November 2021-March 2022	April 2022
- approval by the Ethics Committee* - introductory session for trainers and parents	- coach training for CL	- trainers signed a consent form - trainers received the entire intervention programme	- parents and children signed a consent form	- pretest: Recording of children performing track and field skills → assessment (first time point)	- 30 consecutive training sessions with CL/DI (immediately after pretest) - recording of randomly selected sessions – model fidelity	- posttest: Recording children performing the same skills as pretest → assessment (second time point)

Note. *Committee on Ethical Issues in Sport (University of Ljubljana, Faculty of Sport, Ljubljana, Slovenia).

Model Fidelity

The next subsections determine the model fidelity of the intervention. Although each pedagogical model has its own idea and set of specific characteristics, each model is flexible and allows practitioners to design units that are adapted to the specific circumstances of their context (Hastie & Casey, 2014). To ensure appropriate interpretation of the findings, we have described the context of the study in detail in the three elements of model fidelity that should be considered when researching educational approaches (Casey et al., 2015; Hastie & Casey, 2014).

A Rich Description of the Curricular Elements of the Unit

The intervention programme consisted of 30 training sessions divided into three CL units. The first unit (Introduction to CL) started with cooperation games (icebreakers) that did not yet contain all the key elements of CL (see Appendix B). The trainers added them gradually as they first had to get used to the new teaching and learning method (Casey et al., 2015). In the second and third units, the content focused on athletics. Different track and field skills were taught, although the children only had to perform four of them during the measurements. The trainers had to form fixed, heterogeneous groups of four (±1), taking into account gender, abilities, knowledge, psychosocial characteristics, friendships, etc. The children were presented with different cooperative structures that determined how they worked together and what their learning objectives were (Appendix B). Pairs-Check-Perform (Grineski, 1996; based on Kagan (1992)) was introduced first because peer teaching in pairs is much easier than working in larger groups. Peer teaching was also promoted through Learning Teams (Johnson & Johnson, 1994). Trainers had to assign specific roles to children (e.g. performer, trainer, timekeeper, referee, etc.) so that they learned to take responsibility for part of a group task. Jigsaw (Grineski, 1996) was also widely used for learning basic track and field skills that were broken down into parts (subtasks). With PACER (Kane & Kane Jr, 2004) we focused on improving running technique. Student Teams-Achievement Divisions (STAD; Slavin, 1995) was the most complicated of all the structures used. Learners tried to make the most progress as a group, so they taught the other group members the correct technique. Collective Score (Orlick, 1982) was mainly used to develop movement skills for learning sports skills (Kane and Kane Jr 2004). Most of the cooperative structures were chosen because they enable children to learn sports skills independently. This should be the main learning objective of training plans for young athletes (Way et al., 2016). The criterion for selecting the cooperative structures was also the achievement of affective goals. Each structure was adapted to the 8-11 year olds and used several times with different track and field skills. Only six different structures were used because the learners had to get to know each of them well before a new one was added (Grineski, 1996).

The cooperative structures promoted peer teaching and all five CL non-negotiables. The children were provided with learning materials, e.g. special flashcards with coordination exercises (PACER), so that face-to-face promotive interaction was encouraged. Positive interdependence and individual accountability were promoted by giving each member of a jigsaw group only one piece of information needed to complete a group task. PACER also

emphasised positive interdependence, by requiring all members to reach a certain level of competence in coordination exercises before the group (consisting of two pairs) could play a game. Individual accountability was also promoted by publicly presenting both the group's progress and individual results (posters). As part of the affective goals, the interpersonal and small group skills were defined separately for each training session (Appendix B). The trainers presented each skill to the children and they wrote it together on a special poster that accompanied them throughout the experiment. Group processing took place at the end of each session. It evolved from a whole group discussion led by the trainer to an independent debate in fixed groups.

The control programme corresponded to the intervention programme in terms of content. Regardless of the model used, the children worked on the same physical goals. However, there were differences in psycho-social learning, while DI does not allow for all types of goal achievement, as is typical for CL. In the CG, the trainers continued to use DI. They were the only ones who set tasks, determined the course and pace of learning, assessed goal achievement and monitored the group's interactions (Metzler & Colquitt, 2021). The work was organised frontally so that the children had the same tasks at the same time. The goal structure was either individual or competitive.

A Detailed Validation of Model Implementation

To determine model fidelity, i.e. whether reported learning outcomes could be attributed to the pedagogical model, we recorded four randomly selected training sessions from each athletics group in EG (Zach et al., 2020). Data were collected through systematic event coding of the 17 categories of the Cooperative Learning Validation Tool (CLVT) (see Appendix D). It was developed by Dyson (2010) and tested and modified by Casey and colleagues (2015). Observations were conducted by the first author. Average percentages for each coded category were calculated. The Post Lesson Teacher Analysis Tool (PLTA) was used to report on children's learning and the actions of the trainers from the trainers' perspective (Bodsworth & Goodyear, 2017). They were asked to write structured reflections after each training session.

The CLVT results showed that we achieved a satisfactory degree of CL model fidelity (Appendix D). All critical elements of CL were used in 75% of the sessions, but group processing was done in all sessions. Other key concepts beyond the five non-negotiables (categories 2-6 in Appendix D) were also observed in about three-quarters of the recorded

training sessions. We found that the percentage of observed CL key elements would be even higher if the structures and non-negotiables were not added gradually (Appendix B).

Student learning was assessed in each session and improvements were made in 92% of the sessions, indicating high student engagement (Appendix D). The number of learning assessments and observed improvements were highest in the social or emotional domain. The CLVT revealed that physical goals were observed in every training session, while cognitive goals were observed in three-quarters of the recorded sessions (Appendix D). Consistent with the CLVT results, trainers reported improvements primarily in the areas of social/emotional and sports skills (PLTA). Trainers noted that the children showed an understanding of the track and field technical elements and that they learned to recognise major mistakes that they and their peers were making.

We cannot say that full fidelity was achieved in every session. However, this moderate to high degree of model fidelity allows us to assume that the children's response to the units was the result of CL (Bjørke & Mordal Moen, 2020; Casey et al., 2015).

A Detailed Description of the Programme Context that Includes the Previous Experiences of the Trainer and Children with the Model

All the trainers (except me – the first author) had only the traditional approach (DI) before the study. CL caught my attention a year before the study, so I first did a literature review and then started using it in practice, as I work as an athletic trainer for children. The impact of CL on children's learning is also the topic of my PhD (in progress). I have conducted a coach training for CL for the trainers in EG. We met five times from March to October and conducted two lectures and three workshops, which lasted a total of 20 hours (Table 1). In the lectures, the trainers were theoretically introduced to CL with its non-negotiables and structures. In the workshops, the trainers were given a first insight into the intervention programme. The cooperative structures with athletic content were presented in practise. To check whether learning had taken place, the trainers tried their hand at teaching according to CL. During the experiment, we were in constant contact with the trainers. We met regularly remotely and communicated by phone and email to solve various dilemmas, deepen the trainers' knowledge of CL and adapt the plan according to the circumstances.

Details of the participating children can be found in the subchapter Participants and in Appendix A. They had no previous experience with CL.

Data Collection

The children were recorded on camera during pre- and posttest as they performed the same four track and field skills that represent sets of basic athletic disciplines: low skipping and bounding (running), crouch start (sprinting), and vortex throw (throwing). Each task was first demonstrated by the principal investigator. The children's performances were observed and evaluated by three qualified assessors who teach athletics at the Faculty of Sports, University of Ljubljana. In order to evaluate the children's progress in athletics, the assessors evaluated the recordings at two points in time – first the baseline condition (of the children's athletics practical knowledge) and also the final condition after the experiment (see Table 1). The children's performances were scored from 1 to 5, based on the descriptive criteria for each task. The average scores were then calculated and compared between the models (CL vs. DI). A protocol based on the integral rating model was followed (Majerič, 2004). Validation of the rating scales was conducted by Železnik Mežan and Škof (2022) and confirmed the variability of the scores as well as external and internal consistency. Factor analysis confirmed that the selected tests represent the same concept or single construct. To obtain a composite score (track and field skills), we estimated the coefficients of the factor scores using the Anderson-Rubin method. For the purposes of this study, we calculated test-retest reliability by having assessors rate the performance of 30 randomly selected children after some time (see Results section).

Data Analysis

The data were analysed using IBM SPSS Statistics for Windows, version 26. Descriptive statistics were first compiled and pretest differences between groups were tested the independent samples T-test or its nonparametric alternative (Mann-Whitney U-test) (see Table 2). In order to apply the analysis of covariance (ANCOVA), the data had to meet certain assumptions. We conducted exploratory analyses to confirm that there were no significant outliers; our residuals were approximately normally distributed for each category of the independent variable; Levene's test confirmed homogeneity of variances; the covariate (initial knowledge) was linearly related to the dependent variables at each level of the independent variable; Scatter plots representing the standardised residuals and the predicted values (Z-scores) of each dependent variable confirmed homoscedasticity; no interaction was found between the covariate (initial knowledge) and the independent variable (i.e. the homogeneity of the regression slopes). Nested ANCOVAs were used to examine whether the posttest results of the dependent variables differed between the models (CL vs. DI) when controlling for pretest

results and the average age of the children at baseline. Athletics clubs were nested within the EG and the CG. At the end, we reported the effect sizes. Reliability was calculated using the Pearson correlation coefficient. For all statistical analyses, the significance level was set at $p \leq 0.05$.

Table 2. Descriptive Statistics and Pretest Differences Between Groups.

Variable	Pretest					Posttest	
	M ± SD EG	CG	Test statistic	p	Cohen's d	M ± SD EG	CG
Low skipping	2.46 ± 0.90	2.57 ± 0.77	-0.73	0.47	-0.12	2.58 ± 0.70	2.38 ± 0.73
Bounding	2.15 ± 1.06	2.33 ± 1.02	2768*	0.19	*-0.18*	2.47 ± 1.03	2.47 ± 0.92
Crouch start	2.09 ± 0.66	2.23 ± 0.70	2780.50*	0.23	*-0.20*	2.60 ± 0.88	2.22 ± 0.63
Vortex throw	2.54 ± 0.79	2.60 ± 0.87	-0.45	0.66	-0.08	2.60 ± 0.57	2.57 ± 0.78
Track and field skills	-0.07 ± 1.01	0.11 ± 0.97	-1.10	0.27	-0.19	0.14 ± 1.05	-0.17 ± 0.91

Note. To analyse pretest differences between the groups, the independent samples T-test was used for dependent variables that met the normality assumption. *For other variables, the Mann-Whitney U-test was used.

RESULTS

Descriptive statistics and pretest differences between the two groups are presented in Table 2. Non-significant differences and small effect sizes (which can be considered trivial) were found for all dependent variables.

Nested ANCOVAs revealed significant differences between EG and CG at posttest in the areas of general track and field skills, low skipping, and crouch start (Table 3). We proved that CL was more effective than DI in improving low skipping, crouch start, and track and field skills of young athletes. In fact, the children of CG performed worse on the posttest than on the pretest in all tests except bounding (Table 2). We found no statistically significant differences between EG and CG at posttest in bounding and vortex throw. The effect sizes showed large effects in track and field skills, crouch start, and low skipping.

Table 3. Nested ANCOVA for Posttest Differences between Experimental and Control Group.

Variable	Estimated marginal mean		Nested ANCOVA		Partial eta squared	Observed power
	EG	CG	F	*p*		
Low skipping	2.67	2.34	5.58	0,03*	0.27	0.60
Bounding	2.56	2.37	0.79	0.39	0.06	0.13
Crouch start	2.65	2.13	7.87	0.01*	0.36	0.74
Vortex throw	2.64	2.53	0.93	0.35	0.05	0.15
Track and field skills	0.25	-0.28	13.37	0.00*	0.44	0.93

*$p < 0.05$.

Using Person Correlation Coefficient and Intraclass Correlation Coefficients we found that the test-retest reliability was good in vortex throw and excellent in all other dependent variables (see Table 4).

Table 4. Test-Retest Reliability.

Variable	Pearson correlation coefficient	ICC (consistency)	ICC (absolute agreement)
Low skipping	0.91	0.95	0.94
Bounding	0.94	0.97	0.96
Crouch start	0.96	0.98	0.98
Vortex throw	0.81	0.89	0.89
Track and field skills	0.88	0.94	0.94

Note. ICC = Intraclass correlation coefficient.

DISCUSSION

The results of the present study support the hypothesis that CL produces greater improvement in the track and field skills of young athletes compared to DI. The results are consistent with those of previous studies showing that PE students improve more in motor learning when they work collaboratively than when traditional teaching methods are used (Altınkök, 2017; Velazquez-Callado, 2012; Casey et al., 2009; Darnis & Lafont, 2013; Dyson, 2002; Guzmán & Payá, 2020; Huang et al., 2017). Several studies have already confirmed the effectiveness of CL for teaching PE, but none of them has yet tested it under competitive conditions. The novelty and significance of our study is also related to data collection and analysis. Altınkök (2017) did not control for baseline condition and other potential confounding variables. Velazquez-Callado (2012) did not describe the data collection and quantitative analysis in detail, so the replicability

of the experiment is not possible. Casey and colleagues (2009) conducted only a qualitative analysis of interviews, reflective journal, reflections, non-standardised questionnaires, observations, etc., which do not allow for an objective assessment of the relationships between variables.

The main goal of our study was to objectively compare the effects of CL and DI on motor learning in youth competitive athletics. The results showed significant differences in the areas of general track and field skills, low skipping, and crouch start between EG and CG. The results may suggest that CL is an effective pedagogical model for developing athletic skills in youth competitive sports. The improvement in track and field skills in EG could be due to the children's active engagement in learning. Children were encouraged to give verbal instructions, demonstrate, observe peers and analyse their partner's movement. In the cognitive motor learning stage, learning success is highly dependent on verbal instructions and demonstrations (Magill & Anderson, 2017). Although the theoretical background and empirical evidence suggest that it is better for beginners to observe skilled demonstrators, there is evidence that beginners can also gain learning benefits by observing unskilled demonstrators (peers). It is unlikely that a particular way of performing a skill (by a teacher/trainer) will suit every learner. It is also beneficial to demonstrate a skill not only before the learner starts to practise it, but also while practising – as often as possible. In CL, giving instructions, feedback, and encouragement is not just the domain of the teacher/trainer, as is characteristic of DI. CL therefore allows for more frequent feedback and encouragement, leading to greater improvements in motor skills (Dyson et al., 2010). The results of previous studies have shown that verbal discussions between peers about technical characteristics, learning objectives, and playing strategies enable the development of technical and tactical skills (Darnis & Lafont, 2013).

The trainers in EG noted that the children learned to recognise major mistakes made by their peers and showed an understanding of the track and field technical elements (PLTA). This is consistent with the findings of previous (qualitative) research (Casey et al., 2009; Dyson, 2002; Dyson et al., 2010). Some research has even shown that beginners who observe peers perform better than performers (observed beginners) (Magill & Anderson, 2017). When providing feedback to peers, children in EG relied on learning cues – sentences of three or four words describing the basic characteristics of a sports skill (Dyson, 2002). Instructions and learning cues were readily available to them in the learning materials (see Appendix C). Because they allow children to provide qualitative corrective feedback (Casey et al., 2009; Dyson et al.,

2010), learning cues have been shown to be a key factor in improving motor learning (Wisniewski et al., 2020).

Our findings confirm the study by Huang and colleagues (2017), who found that CL has greater effects on children's sports skills than DI. They also found that the impact of CL on critical thinking was greater than that of DI. Several other studies confirmed that working together can improve children's critical thinking (Brennan et al., 2012; Dyson, 2002; Dyson et al., 2010; Gorucu, 2016; Lodewyk, 2009). While problem-solving abilities such as organising and analysing problems, planning and adjusting work progress, and sensitivity in making observations are essential for the development of critical thinking skills, the latter can help children correct misconceptions about motor skills (Lodewyk, 2009). Three important factors for the development of critical thinking skills and progress in motor performance are group processing, decision making, and cooperative problem solving, all of which should be present (Brennan et al., 2012; Huang et al., 2017) and were present in our CL intervention (see Appendix D). To improve problem solving, children should use interpersonal and small group skills and spend a lot of time in face-to-face promotive interaction (Chen, 2001). Appendix D shows that the above categories were coded as being observed very frequently in our study. Social interactions among peers enable them to look at problems from different perspectives and develop critical thinking skills (Dyson, 2002). The learner is also more active in problem solving while pursuing a physical goal when he/she observes and learns from peers (Magill & Anderson, 2017), which our participants did most of the time (Appendix D). When trainers create a cooperative learning environment, young athletes develop psychosocial skills to a greater extent and are thus more successful in motor performance (Chou et al., 2015; Dyson et al., 2010). Our study supports these conclusions. Results reported by Železnik Mežan and colleagues (in press) on the same sample of young track and field athletes confirmed that CL promotes better peer relationships, higher levels of mastery motivational climate, lower levels of performance climate, and better emotional self-concept in young track and field athletes compared to DI. According to the current literature (Brennan et al., 2012; Dyson, 2002; Huang et al., 2017), improving these social and affective variables has an impact on the improvement of learners' sports skills and could also reduce dropout rates in young athletes (Sheehan et al., 2018; Železnik Mežan et al., in press).

CONCLUSION

Given the child's biological development, physical activity in prepuberty needs to focus on learning sports skills (Way et al., 2016). We examined two pedagogical models to determine, which had a greater positive impact on young athletes' track and field skills. We found that CL is more effective than the traditional DI for improving motor learning in youth competitive sport. The positive impact of CL on young athletes' track and field skills is likely to be due to its key features of ensuring children's active involvement in learning and problem solving. The use of interpersonal and small group skills enables young athletes to develop critical thinking skills that are positively associated with the improvement of motor learning (Chou et al., 2015). Peer teaching allows for more verbal instruction, demonstration, more frequent feedback and encouragement, which has a more positive impact on young athletes' sports skills than the traditional teaching method.

First limitation of our study could be its duration. Since the intervention programme was only 30 sessions, not all children reached the second stage of motor learning, although most of the skills were not completely new to them. We assume that retention would not be satisfactory unless the duration of the experiment was longer. For future studies on improving sports skills, we therefore recommend extending the duration of the intervention. It would also be useful to record the children on the same tests some time after the end of the experiment to check retention and compare it between the two models.

In terms of the level of motor learning achieved, we found that the motor tests were not equally demanding for the children. At the pretest, the young athletes had the most difficulty with bounding and crouch start. At the posttest, the EG improved the crouch start significantly, but the mean score of bounding was still much worse than in the other tests. Too high a difficulty level for children of this age could therefore be the reason for the statistically non-significant differences between the groups in bounding. In contrast, the vortex throw seemed to be the easiest of the selected motor tests, so that neither the children in the EG nor the participants from the CG were able to make significant progress. We also found poorer test-retest reliability (Table 4) and interobserver reliability for the vortex throw (Železnik Mežan & Škof, 2022). The descriptors for this test should have been improved when used for future research in this area.

A limitation could also be too small a sample, as shown by the observed power for some of the dependent variables (see Table 3). Small samples could compromise the extrapolation of

research findings to the population as a whole. Generalisation might also be limited as only track and field athletes aged 8-11 years were included in the study. To generalise the results to other sports, future studies should include different groups of participants from different sports in one sample. In our opinion, generalisation to different age groups would not be very useful, as sports training in children and adolescents should differ not only in terms of teaching and learning approach, but also in terms of content. We selected children before the onset of puberty, while the main goal of training at this age should be learning sports skills. Future studies of CL in other age groups are certainly welcome, but we do not support this kind of generalisation of results.

Because of the small number of young track and field athletes in Slovenia, we also had to randomise by natural groups. Due to the specific context, we could not use the matched groups technique. In addition, the clubs had very different training conditions (see Appendix A), although the selection process was based on certain selection criteria. Another limitation arose from the coronavirus pandemic. The closures resulted in a lower average attendance of children, so the standard for exclusion from the study had to be adjusted (it is normally 80%). There were two limitations in determining model fidelity. If we were to study CL another time, we would record all the training sessions to get a more realistic picture of the model implementation. If there was another CL expert in Slovenia, we would ask him to assess model fidelity using the CLVT so that we could calculate the reliability of the first author's observations.

According to the CLVT results and the trainer's reports of improvements in the cognitive domain (PLTA), future research should focus on the cognitive development of young athletes as an effect of CL.

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Conflicts of Interest

The authors report there are no competing interests to declare.

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Appendix A

Table A1. Demographic Information of the Clubs, Coaches and Youth Participants in Experimental Group.

Club	E	F	G	I	J	N
Facilities	Good	Good	Poor	Very good	Good	Very good
Number of sessions per week	2	2	3	3	2	2
Length of a session [min.]	90	60	60	90	90	75
Coach's gender	F	F	F	F	F	F
Coach's age	39	44	29	49	36	27
Coach's education/ qualification	PE teacher[a]	2. level	Sports coaching graduate[a]	2. level	1. level	PE teacher[a]
Coach – professional/amateur	A	P	A	A	A	A
Coach's experience coaching athletics	13	18	7	13	10	9
Male athletes	7	5	3	7	1	3
Female athletes	11	3	9	7	10	12
Athletes' age [M]	9.44	8.38	9.17	9.29	9.40	9.29
Athletes – years in sport	1.5	0.7	1.2	2.0	1.4	2.1

Note. Facilities: Poor – little gymnasium, track and field stadium (200-400m); Good – gymnasium, track and field stadium (300/400m); Very good – track and field hall and stadium.

[a] Educated personnel (PE teachers, sports coaches) does not need a qualification to coach.

Table A2. Demographic Information of the Clubs, Coaches and Youth Participants in Control Group.

Club	A	B	C	K	L	M
Facilities	Good	Good	Good	Poor	Poor	Very good
Number of sessions per week	2	2	2	3	2	3
Length of a session [min.]	60	90	90	75	90	60
Coach's gender	M	F	M	F	F	M
Coach's age	23	27	30	24	36	28
Coach's education/ qualification	Student, Sports coaching; 1. level	Preschool teacher; 2. level	PE Student[a]	PE Student[a]	1. level	2. level
Coach – professional/amateur	A	A	A	A	A	A
Coach's experience coaching athletics	1	7	5	4	15	7
Male athletes	3	4	7	6	1	4
Female athletes	5	3	8	4	9	8
Athletes' age [M]	9.75	10.43	9.17	9.50	10.22	10.36
Athletes – years in sport	1.4	2.1	1.3	1.7	2.0	1.9

Note. Facilities: Poor – little gymnasium, track and field stadium (200-400m); Good – gymnasium, track and field stadium (300/400m); Very good – track and field hall and stadium.

[a] Educated personnel (PE teachers, sports coaches) does not need a qualification to coach.

Appendix B - Description of Cooperative Learning Units

Unit	Session	Structures	Non-negotiables	Learning goals
1. – Introduction to CL	1.	/	Cooperative skills	Physical: - coordination, reaction speed Affective: - active cooperation of all - proper communication
1. – Introduction to CL	2.	/	Cooperative skills	Physical: - natural human movement - running technique - precision Affective: - active cooperation of all
1. – Introduction to CL	3.	/	Cooperative skills, group processing	Physical: - natural human movement - endurance, speed, precision Affective: - proper communication
1. – Introduction to CL	4.	/	Cooperative skills, group processing	Physical: - running technique - coordination Affective: - active cooperation of all
1. – Introduction to CL	5.	/	Cooperative skills, group processing	Physical: - speed, agility, precision Affective: - everyone included - cooperation – communication, help
1. – Introduction to CL	6.	Pairs-check-perform	Cooperative skills, group processing, face-to-face promotive interaction (worksheet)	Physical: - running technique - dynamic balance Affective: - mutual help - giving feedback
1. – Introduction to CL	7.	Collective Score	Cooperative skills, group processing, positive interdependence	Physical: - repetitive strength Affective: - listening to others carefully
1. – Introduction to CL	8.	/	Cooperative skills, group processing, face-to-face promotive interaction	Physical: - running technique - speed, agility Affective: - sharing ideas - giving feedback
1. – Introduction to CL	9.	Jigsaw	Cooperative skills, group processing, face-to-face promotive interaction, individual accountability	Physical: - endurance, coordination - precision Affective: - cooperation – communication, help
1. – Introduction to CL	10.	/	all five	Physical: - natural human movement - endurance Affective: - everyone included - proper communication
2. – Jumping and throwing	11.	Jigsaw, Collective score	all five	Physical: - place vortex throw - standing long jump - explosive strength Affective: - mutual respect and help
2. – Jumping and throwing	12.	STAD	all five	Physical: - running technique - place vortex throw - precision, strength Affective: - encouraging others - giving praise
2. – Jumping and throwing	13.	Jigsaw	all five	Physical: - long jump - explosive strength (legs) Affective: - focus on task - mutual help
2. – Jumping and throwing	14.	Jigsaw, Learning Teams	all five	Physical: - long jump - strength (technique) Affective: - listening to others carefully - encouraging active involvement

Unit	Session	Structures	Non-negotiables	Learning goals
2. – Jumping and throwing	15.	Collective Score	all five	Physical: - medicine ball throw - explosive strength (upper extremities), endurance Affective: - mutual trust - asking for help
2. – Jumping and throwing	16.	/	Cooperative skills, group processing	Physical: - long jump - explosive strength, endurance Affective: - sharing ideas - listening to others carefully - encouraging others
2. – Jumping and throwing	17.	Pairs-Check-Perform, Jigsaw	all five	Physical: - high jump (scissors) - running technique (scissors) Affective: - proper communication - mutual help, giving feedback
2. – Jumping and throwing	18.	STAD	all five	Physical: - medicine ball throw - explosive strength, speed Affective: - giving praise (when deserved)
2. – Jumping and throwing	19.	Pairs-Check-Perform	all five	Physical: - place vortex throw - relays (rules) - speed, agility Affective: - giving feedback - focus on task
2. – Jumping and throwing	20.	PACER	all five	Physical: - running technique - coordination Affective: - insistence, supporting others - giving feedback
3. – Sprinting and running	21.	Pairs-Check-Perform, Learning Teams	all five	Physical: - standing start - running technique - endurance Affective: - proper communication - encouraging others
3. – Sprinting and running	22.	Jigsaw	all five	Physical: - block start - speed (frequency, start acceleration) Affective: - sharing ideas - criticizing ideas, not individuals
3. – Sprinting and running	23.	/	Cooperative skills, group processing, face-to-face promotive interaction (worksheet)	Physical: - block start - explosive strength, stabilization Affective: - active cooperation - solving problems together
3. – Sprinting and running	24.	Collective Score	all five	Physical: - relays - speed endurance Affective: - insistence, encouraging others
3. – Sprinting and running	25.	PACER	all five	Physical: - running technique - coordination Affective: - insistence, supporting others - active cooperation
3. – Sprinting and running	26.	Learning Teams	all five	Physical: - block start - stride frequency, explosive strength (legs), precision Affective: - focus on task - giving feedback
3. – Sprinting and running	27.	STAD, Collective Score	all five	Physical: - block start - acceleration speed, stabilization Affective: - encouraging others - giving feedback and praise

Unit	Session	Structures	Non-negotiables	Learning goals
3. – Sprinting and running	28.	Jigsaw	all five	Physical: - balance, coordination, agility, strength Affective: - proper communication - sharing ideas - criticizing ideas, not individuals
3. – Sprinting and running	29.	Learning Teams	all five	Physical: - place vortex throw, block start, long jump (refreshing) - explosive strength Affective: - independent individuals - active cooperation - mutual help and support
3. – Sprinting and running	30.	/	all five	Physical: - place vortex throw, block start, long jump (refreshing) - explosive strength, speed Affective: - mutual support - giving praise

Appendix C - Results of the Systematic Event Coding on Cooperative Learning Validation Tool

Category number	Description of category	Percentage of sessions category coded as observed		
1a	Social/emotional goals	75		
1b	Physical/skill goals	100		
1c	Cognitive goals	75		
2	Equitable heterogeneous groups	92		
3	Student centered instruction	75		
4	Teacher facilitator	75		
5	Cooperative learning structure	75		
6	Students have shared ownership	67		
7	Face-to-face promotive interaction	92		
8	Positive interdependence	75		
9	Small group and interpersonal skills	83		
10	Individual accountability	75		
11a	Physical assessment	75		
11b	Cognitive assessment	67		
11c	Social or emotional assessment	100		
12a	Physical improvement	92		
12b	Cognitive improvement	75		
12c	Social or emotional improvement	92		
13	Self, group or peer assessment	100		
14	Students encouraging one another	42		
15a	Group processing – what happened?	100		
15b	Group processing – so what?	100		
15c	Group processing – now what?	100		
		Low	Moderate	High
16	High academically focused time	17	42	42
17	High level of student attention/interest/engagement	0	25	75

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CAREER DEVELOPMENT IN WOMEN'S HANDBALL ELITE PLAYERS – MIDDLE RANKING COUNTRIES SPECIFICS

RAZVOJ KARIERE V ŽENSKEM VRHUINSKEM ROKOMETU – NEKATERE POSEBNOSTI SREDNJE RANGIRANIH REPREZENTANC

ABSTRACT

This qualitative research aimed to study the career development outcomes of women's handball players. The purpose was to identify the socio-cultural factors and personal characteristics that enabled athletes from geographically small countries with middle-ranking national handball teams to fulfil their sporting career goals. Data collection via semi-structured interviews and systematic observation of the athlete's career development commenced in 2012 and lasted one decade. Career development was one part of the questions; the other parts concerned migration and dual careers. Altogether sixteen semi-structured interviews were conducted – with players ranked in the top ten players in their national teams, and all had played more than 50 international matches; after the observation phase, the eight players still actively playing at the elite handball level were re-interviewed; all were sports migrants. In the final stage of the study, two additional interviews were done – with two athletes who were among the players with the most successful careers in Europe at that time but not having migration experience. The study concluded that parents and coaches are the most important social support in career development in the first career phase. In the second phase, access to dual career prospects is vital to successful career development, parallel with elite handball sports conditions in a club and national teams. A successful migration path seems to be one of the significant factors in evaluating success in sports career development.

Keywords: career planning, dual career, female handball, career development, migration

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IZVLEČEK

Osnovni namen kvalitativne raziskave je bil preučiti razvoj kariernih poti rokometaši, identificirati sociokulturne dejavnike in osebnostne lastnosti, ki so športnicam iz geografsko majhnih držav s srednje rangiranimi rokometnimi reprezentancami omogočale uresničevanje ciljev v športni karieri. Zbiranje podatkov s pol-strukturiranimi intervjuji in preko sistematičnega opazovanja kariere se je začelo leta 2012 in je trajalo desetletje. Razvoj kariere je bil en del vprašanj; drugi deli so zadevali migracije in dvojne kariere. Opravljenih je bilo skupaj šestnajst pol-strukturiranih intervjujev – z deseti vodilnimi igralkami; ki so odigrale več kot 50 tekem v svojih reprezentancah. V zaključni fazi smo ponovno anketirali osem še aktivnih igralk, ki so imele vse status športne migrantke. V zaključni fazi študije sta bila opravljena še dva dodatna intervjuja – z dvema igralkama, ki sta bila med igralkami z najuspešnejšimi karierami v takratni Evropi, a nista imeli migracijskih izkušenj. Študija ugotavlja, da so starši in trenerji najpomembnejša socialna opora pri razvoju kariere v prvi karierni fazi. V drugi fazi je bila dvojna kariere bistvenega pomena za uspešen razvoj kariere, vzporedno z vrhunskimi športnimi pogoji v klubu in reprezentancah. Uspešna migracijski vzorec se zdi eden od pomembnih dejavnikov pri vrednotenju uspešnosti razvoja športne kariere vrhunskih rokometašic.

Ključne besede: načrtovanje kariere, dvojna kariera, ženski rokomet, karierni razvoj, migracije

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INTRODUCTION

Career planning is part of human resource management also in sport as a profession. Havran (2017) lists the main tasks of human resource management in professional sport (case football), underlining the importance of activities related to individual development and career support. There are to answer the questions such as who is responsible for successful career management, who should finance its costs, and who produces direct (tangible) results in player development (Havran, 2017; Ekengreen et al.,2019)). Some valuable research has been conducted on sports economics on the international level, too, relating to human resource management (Byers et al., 2012; Weerakoon, 2016; Lekavičius, 2020) and career research (Stambulova, Ryba, 2014; Ekengren et al. 2018; 2019; Li et al., 2022).

In career planning in modern elite sport the decision for migrations is nearly always part of career planning Questions concerning broader issues such as globalisation, national identity, and intercultural communication, as well as those relating to more specific matters, for example, 'talent pipelines,' stereotyping, and the ascribing of qualities to athletes from different countries, racial, ethnic, and gender groups, are also part of the migration process (Agergaard, 2008) and part of career development of athletes. Researchers have started to identify specific stressors and challenges for elite athletes, such as cultural, linguistic, and structural barriers to acculturation in migration(Oghene, Schinke, Middleton, & Ryba, 2017; Schinke, Blodgett, Ryba, Kao, & Middleton, 2016) and other challenges in career development (Weerakoon, 2016, Lekavičius 2020): which concern transitions of athletes through the developmental processes of career stages and the establishment of dual careers (Ryba, Stambulova, Ronkainen, Bundgaard & Selänne, 2015; Ryba, Stambulova, Selänne, Aunola & Nurmi, 2017; Stambulova & Wylleman, 2019; Agergarad & Ronglain, 2015; Stambulova, Ryba, & Henriksen, 2020).

Athletes in modern sports are nowadays influenced by different challenges (f.e. globalisation, professionalism) and new possibilities. For athletes from small countries seems to be even more important to plan their career in sports to reach higher standards in their chosen sport. Handball is one of the most developed sports in Europe, but also many differences in handball career development conditions between countries. For our study, female hardball players from middle-ranking countries were selected from Slovenia (SLO) and Switzerland (SUI). The countries exhibit some similarities for elite female handball players; both countries are geographically small, with middle-ranking national teams and a comparatively small number of elite female handball players, with limited possibilities for regular participation in high-level handball

competition. In the last decade, SLO ranked between 10th and 15th place and SUI between 20th and 30th in Europe, according to the 2020 EHF women's national team ranking.

The research question of our research is to find out the characteristics of a successful career development in women's handball players from geographically small countries with middle-ranking national handball teams

Career planning and career transition

In career transitions literature, an athletic career is viewed as a developmental process, which includes career stages and transitions, underpinned by the modernist logic of competitive sports (Stambulova, Alfermann, Statler, & Côté, 2009; Wylleman, Alfermann, & Lavallee, 2004, Bon et al, 2022). As athletes progress along the athletic developmental continuum, aspects such as the multiple demands of individual and team training, competitions, travel and rest periods, for example, become more intensive and time-consuming. Life as an elite athlete presents many conflicting and competing demands, such as dual career obligations, possible transnational migration, communication in a new language and a new culture, as well as different models of career progression.

Geographic mobility is essential to the development of a professional or semi-professional playing career in many sports, including handball and can be crucial for an athlete's career trajectory. The closely intertwined relationship between migration and career development is particularly relevant for the highly skilled labour force (Meyer, 2001), including some elite athletes. Athletes, coaches, and sports administrative personnel are increasingly migrating across national and continental borders for work (Maguire & Falcous, 2010).

Figurational sociological perspectives on sports labour migration have been employed to understand how global networks of power influence the flow of sports labour migration (Elliott & Maguire, 2008; Falcous & Maguire, 2005; Maguire, 1999). The main focus in micro-sociological analyses has been directed toward developing typologies for athletes' motives and reasons for migration (Magee & Sugden, 2002; Maguire, 2004, 2013; Agergaard & Ryba, 2014; Bon et al, 2016; (Schinke, Yukelson, Bartolacci, Battochio & Johnstone, 2011). Some studies highlight that motivating and demotivating experiences of migrant athletes interweave with their adaptation processes, state interventions, and (implicit) integration strategies in sports clubs (Agergaard, 2008; Botelho & Agergaard, 2011).

Research at the individual analysis level of sports careers takes into consideration the extent to which athletes' development involves their athletic and post-athletic careers, including transitions occurring in sports, as well as in other domains of athletes' lives (Wylleman & Lavallee, 2004). Moreover, intercultural and intracultural variations in athletes' career pathways call for increased contextual sensitivity in career research (Ryba & Stambulova, 2013; Stambulova et al., 2009; Stambulova & Ryba, 2013). Sociological research on sports labour migration and psychological research on athletes' career transitions have generated some overlapping research themes (e.g. motives for migration and adaptation, push and pull factors, identity, social support and networks). Researchers in both fields have identified that social and individual factors play an important role in shaping athletes' experiences (Agaard & Ryba, 2014).

In a collaborative effort to develop an interdisciplinary understanding of a transnational athletic career, Agergaard and Ryba (2014) focused on discerning female athletes' crucial career transitions and adaptation processes, which could be defined as normative (i.e. predictable) and non-normative (i.e. more idiosyncratic and less predictable) turning phases in athletes' career development, triggered by a set of demands with which athletes have to cope to continue successfully in their sport or adjust to their post-sports careers (Stambulova, et al., 2009; Bon et all, 2022).

Individual coping is emphasised as a key factor in determining the career transition outcome - either a positive experience or a crisis during transition. Other studies advocated for the need to open up the athletic career framework to a multiplicity of meanings, underpinning career pathways in various socio-cultural contexts, which influence how athletes make sense of themselves and their careers, and to consider the decisions they make (Ryba 2011; Ryba & Stambulova, 2013; Stambulova & Ryba, 2013).

Sport-related challenges of fitting into the training routines and the playing style of a new team proved to be central to players' experience and feelings about migration (e.g. Meisterjahn & Wrisberg, 2013; Schinke et al., 2016), developing a sense of belonging (Ronkainen, Ryba, & Selänne, 2019; Ryba et al., 2015; Schinke, Bonhomme, McGannon, & Cummings, 2012). Some researchers pointed out the essential role of the family, friends and supporters (Light, Evans, & Lavallee, 2017; Ronkainen, Khomutova, & Ryba, 2019; Ryba, Haapanen, Mosek, & Ng, 2012). Ryba et al. (2015) describe three migrations phases (pre-transition, acute cultural adaptation, and socio-cultural adaptation) of the cultural transition model. The pre-transition

refers to the activation of psychological mobility, which typically involves various ways of planning for future relocation and psychological disengagement from the athletes' current origin (Ryba, et al., 2015).

Dual career considerations

Dual career (DC) is becoming one of the crucial topics in the career development for many elite athletes. Stambulova & Wylleman (2019) synthesised the empirical findings into two major categories: DC in sport and education and DC in sport and work. While both DC types were addressed in the European DC Guidelines (2012), DC in sport and education has been, until recently, the central focus of the European DC discourse. For example, athletes find combining sport and work more difficult than combining sport and studies because very little support is provided to employee-athletes, for example, a flexible work schedule (Stambulova & Wylleman, 2019). Female athletes also choose additional work to support themselves financially more often than male athletes (Stambulova & Wylleman, 2019; Stambulova, Engström, Franck, Linnér & Lindahl, 2015; Bon et al., 2022; Fuchs et al., 2021).

The specific aim of our study was to develop a contextualised understanding of the ways in which elite female handball players from small countries constructed and developed their careers and life trajectories through migrations and dual career.

METHODS

Research Design

Qualitative thematic analysis was employed and combined with a small amount of descriptive data to develop a contextualised understanding of the ways in which elite female handball players from small countries constructed and developed their careers and life trajectories through migrations and developing and sustaining sport careers. Responding to the call by Savickas et al. (2009) to explicate the nuanced cultural context underlying career construction, the responses of sixteen female handball players from SUI and SLO were collected. The countries exhibit some similarities for elite female handball players; both countries are geographically small, with middle-ranking national teams and a comparatively small number of elite female handball players, with limited possibilities for regular participation in high-level handball competition. To enhance the transparency and generalizability of the research, we put effort into getting data on all national team players in the 2012 season so that they were

considered representatives of elite female handball players from Slovenia and Switzerland because all were more then five years, with more than 50 playing maths and all having migration experience. Migration experience was the main focus of the first part of the over-investigation of this sample (Bon et al., 2022).

It is to underline that the athletes were very motivated to cooperate, which meant that rich data was collected and could be utilised to build the research and support the conclusions. The players were from the beginning informed about the purposes of the study, besides the scientific also of practical approaches. The authors are still in contact with nearly all athletes who are becoming handball experts and bussines partners.

A semi-structured interview guide was developed to provide a framework for interviews: the participants were asked to recall childhood experiences, memories of family, friends and school, their career development in (and outside of) sport, memorable achievements, challenging transitions and adaptation experiences in different cultural settings. Participants were encouraged to develop their own preferred order in telling their stories.

The data collected from the initial interviews was accompanied by seven years of systematic observation, which was introduced as an objective, well-ordered method for close examination of the aspects of women's national handball team players' career development, especially the characteristics of migration, which helped to obtain reliable data, unbiased by observer interpretation. Systematic observation typically involves specification of the exact actions (national team matches) and attributes (changes in the national team squads), as well as some other available variables about the women's national handball teams in SUI (Handball Suisse, 2020) and SLO (Rokometna Zveza Slovenije, 2020). The data was also collected from media channels and handball federation platforms, then checked with the athletes at the beginning of each interview.

Ethics and protocols of data collection

Ethical approval was received from the regional ethical board. The first author contacted the athletes either face to face or by phone, explaining the aim of the study, ethical issues, and logistics of the interviews. Ethical guidelines were followed by using ID numbers. Furthermore, the athletes were guaranteed that their anonymity would be maintained in relation to any personal or critical data that has not yet been published. It is noted that four of the athletes were prominent current or former players who specifically agreed to their names being used in this

paper. They are public figures whose data is published on different websites such as eurohandball.com and handball club websites.

The interviews were arranged at a time and in a place convenient to the athletes. All main interviews were conducted in person by the first author. At the beginning of each interview, the athletes were informed that the information they provided would remain confidential and that they could terminate the interviews at any time. The face-to-face, semi-structured interviews, with one exception, were conducted at the national team preparation camps in 2012. In the second series the re-interviews with the players were conducted as three face-to-face and the other online in the season 2019/2020. The interviews with two non-migration athletes (SLO) were done at the end of the season 2020 after finishing their career. Each interview lasted from 50 to 105 minutes. The first author was in contact with all athletes throughout the seven-year-plus period of data collection. For players who stopped their careers, we were informed, that they are all employees; two of them are in the frame of SIU handball.

The athletes

The sample was the most successful female handball player in both countries - all national team players with more than 50 national team matches.

In the main phase of the study, two groups of athletes were included. The first group, in the first phase ('Interview 1'), in the year 2012, consisted of six Swiss players (aged 24.9 ± 4.2) and eight Slovenian players (aged 23.2 ± 6.5). In the second phase ('Interview 2'), after seven years, 8 players who were still playing abroad (seven Slovenes and one Swiss) were interviewed again, with some socio-demographic data being collected (Table 1). At the end of the study also two players (SLO (aged 38, 6) were interviewed.

Table 1. Socio-demographic data of the players in 2012 and data about two additional interviewed players.

Women's handball national team players data				
National Team Players	Age at the time of 'Interview 1'	Age at the time of the first migration	Migration / to the Countries	Years abroad by 2012
SUI (n-6)	26.3 ±3.08 (20-27)	25.3 ±7.6 (19-27)	2 (Germany, France)	2.1 (± 0.23) (2- 4)
SLO – Migrant- (n-8)	24.7 ± 2.59 (21- 26)	23.6 ± 3.08 (19- 27)	4 (France, Hungary, Spain, Montenegro)	3.9 (± 0.51)
2 SLO – 2 Non-migration experience players	Interviews after the results of Interview 1 and interview 2			

Data collection – the interviews

The main data collection occurred in three phases of semi-structured interviews, which were recorded for further analysis. A semi-structured interview guide was developed to provide a framework for the interviews. Participants were asked to describe their whole career development from the childhood to the elite level - following by specific focusing questions: 1) whole career development; starting phase, decision, social support, coping with different career challenges, and identifying barriers and resources 2) migration - reasons for, manner of, and organisation of migration; 3) dual career experiences; 4) adaptation strategies and changes in the social environment; 5) general career development and the role of migrations and dual career in career development; 6) career assessment, including their development in the national team; 7) plans about next steps in their careers and the desired future place of residence.

In 'Interview 1', athletes were asked to recall their career development both in sport and outside of sport, including memorable achievements, challenging transitions, especially during different periods and adaptation experiences in different cultural settings. In the second interview, each athlete was given a chronological timeline that was drawn up based on the responses given during the first interview and also based on data collected during the systematic observation and recording of each participant's career by the first author. This information was

used as a support to invite further reflection on the major career events and themes and to check any inconsistencies that emerged during the first interview.

'Interview 2' focused on exploring the shifting discourses of culture surrounding the meanings attached to an athletic career, identity, mobility and migration, performance, kinship and family. 'Interview 2' started with a cross-check of answers from 'Interview 1' seven years prior. All data from the systematic observation (career development, migration in new clubs, playing performance, scoring results, national team performance) was also verified. The athletes were then asked for an overall description of their career thus far and were then asked to address the following three questions; 1) What benefits did your sports career derive from migration? 2) what experiences did you gain to develop your handball and which for your post-sports career, 3) which experiences would not have been possible had you stayed in your home country? The initial interview questions about the background and characteristics of athletes' sporting careers were followed by open-ended questions encouraging athletes' descriptions of the conditions for their talent development. The interview ended with more direct questions about dual careers and how transnational migration had influenced their professional handball career development, their opinions about what they learnt about succeeding as sporting migrants, and how they were able to integrate the benefits of their transnational experiences into their performances for their respective national teams.

Interview 3 was done in 2022 with two players with an extremely successful career, but without migration experience. Interviews were focused on checking the findings of the first part of the study (Bon et al., 2022) that all successful players are of the opinion that migration in women's handball players from geographically small countries with middle-ranking national handball teams is the main factor for having a successful career. They were asked about their experience and feelings compering with players who are (or were) sports migrants. 'Interview 3' started with a cross-check of the results of interviews 1 and 2; the athletes were then asked for an overall description of their career thus far and were then asked to address the following three questions; 1) Did you have an opportunity to go abroad, and why you didn't decide for it?; The opinion about the benefits and disadvantages which your sports career derives from non-migration, 2) what experiences did you gain to develop your handball and which for your post-sports career, and 3) Which experiences would not have been possible had you would be sport-migrate?

The initial interview questions about the background and characteristics of athletes' sporting careers were followed by open-ended questions encouraging athletes' descriptions of the conditions for their career development.

Interviews with SLO athletes were done in the Slovenian language and with SIU athletes in the German language. The analysis of the interview data was completed in Slovenian by the first author. The quotations selected from the data were translated into English directly, and the language revision for the article was made by an English speaker (second author).

Systematic observation

In the systematic observation phase, descriptive statistics about female handball in SLO and SUI were collected, with comments being added by the authors during this phase. The authors then asked all interviewed athletes to check the information and evaluate the authenticity based on their own experiences. Also, during the systematic observation, many notes, photos, video material, and artefacts were collected by the first author. For descriptive statistics, relevant data for particular players was collected, such as socio-demographical data, the number of transfers between clubs and countries and the general situation in both national handball federations and national teams. The descriptive data from the systematic observation was cross-checked for validity through comparison with the official records of the SUI and SLO handball federation websites s and through the European Handball Federation (Eurohandball.com) website.

Data analysis

The final assemblage of data included: audio recordings and transcripts from the semi-structured interviews; structured interview questionnaires containing open comments, including a substantial number of responses to open comment items; audio recordings and transcripts from some focus group sessions; field notes taken while national team matches were being studied; video recordings of matches, preparations and camps); case study notes; documents (reports, minutes of meetings, e-mail communications); diaries, video diaries, observation notes; press clippings and photographs.

Question-focused analysis was used as a starting point when organising the raw data, and the responses that had similar themes and represented the same points were grouped together. All interviews were transcribed verbatim and read through several times by the first and third authors. The first author then conducted a thematic analysis as outlined by Braun and Clarke

(2006), where initial comments, codes and memos were developed systematically into broader themes and concise phrases.

RESULTS

The basic information about each nation is presented in Table 1 to frame some of the differences and similarities in the results of athlete career development.

Table 2. Data about Switzerland and Slovenia and career characteristics of elite handball players in each country (prior to migration).

Data about handball ranking and specifics about HB career of elite players		
Data	**SUI**	**SLO**
Member State	EFTA	EU
Surface	20.7 km2	41.3 km2
Population	8.6 m	2.1 m
GDP (2019)	703,165 m	53,743 m
Women's National Handball Team Ranking 2019	24 (68 points)	14 (148 points)
Age at initiation into Handball	Approximately 8 years of age	Approximately 6 years of age
Who motivated and participation in the home country?	Parents/Friends	Elementary school teacher, coach, parents
Number of migrations in home country	Only 2 players - once	From 1 to 5 clubs
Status	Amateur (no payment)	Half - professional (from 100 to 1500 euro)
Playing at The Senior Level In Domestic Clubs (Years)	4.7 (from -2 to 7)	5.4. (from -2 to 8)
Evaluation of their sporting career to date	Successful to very successful	Very successful

SLO and SUI have different handball traditions. According to the EHF women's national team ranking (eurohandball.com), which includes 49 countries, SLO ranked higher than 20th in all the years between 2012 and 2019, and SUI never better than around 20th. While in 2019, SLO ranked 12th in the national team and 10th in the club ranking, SUI was placed 24th in the national team and 22nd in the club ranking (European Handball Federation, 2019).

Membership information from clubs and national teams indicates that handball is one of the most popular and successful team sports in SLO, and both the women's and men's national teams are internationally renowned. Having a club at the highest handball competition level - Champions League, is one of the biggest differences between SLO and SUI women's handball.

All of the other clubs in SLO and in SUI are at an amateur or semi-professional level. There are approximately 1700 female and more than 7500 male registered players (http://www.rokometna-zveza.si) actively participating in one of the leagues in the Handball Federation of Slovenia (SLO HF).

Following the career transition of all athletes in the sample (Table 2), it is typical that parents have an essential role in the decisions for handball and in the organisational part. In Slovenia, where the teachers of physical education are involved in the school system from the beginning (in children' aged from 6 to 10 years), girls started playing in elementary school earlier than in SUI. In the study period at SUI, it was not very common to change clubs in the home country mainly because they were at similar levels of organisation and standards of play. In Slovenia, it is common, before progressing to transnational migration between clubs a few times. HC Krim is particularly popular because it has been involved in the European Champions League for more than 20 years. As a result of this status, the Club is more financially secure, and the organisation is more professional and business-like when compared to other clubs in SLO and in SUI.

Transnational migrant characteristics

At the time of the initial interviews, none of the Swiss women's national team players had long migration experiences, on average less than 2 years (1.67). They then migrated to five different countries (Germany, Norway, Denmark, France, SLO), made eleven transfers and spent on average 9.6 years (2 -11) abroad until the season 2019/2020. Only one Swiss national team player is still playing in Germany, and one in SUI, having returned from Germany. All others finished their careers (on average at the age of 30.5). Two of these former athletes are involved in a special SUI Handball Federation (SUI HF) project. One is responsible for women's handball development, and the other is a project manager at the SUI HF. The other athletes have different occupations; three have children, and all are employees, but in post-handball vocational careers, their work is not connected to handball.

In 2012 eight migrant Slovenian players played in five different countries (Hungary, Germany, Macedonia, France, and Poland). In the next seven years, the migration dynamic intensified. By 2019, they had spent on average 9.1 (+'1.6 years) years (6-12) abroad, had been playing in eleven different counties (Germany, Hungary, Denmark, France, Macedonia, Montenegro, Croatia, Spain, Switzerland, Romania, Austria) and had made 20 transfers between countries and 28 between clubs (especially in Germany). In 2019, two of the athletes were top

professional players (one in France and one in Montenegro) in the top handball clubs in the Champions League and among the top scorers. The others were semi-professionals. Interestingly, in 2019, four Slovenes were playing together in the same German Club in specific semi-professional conditions – all having different part-time jobs organised with the support of club management.

The results indicate that Slovenes had good experiences with clubs in France and are enthusiastic about the lifestyle in France. The dynamic migration path of one Slovenian player especially stands out. Before her first international migration to France in 2010, she had managed to graduate at the Faculty of Sport in Ljubljana. After 6 years of playing handball in France, she returned to SLO because she wanted to play in the Champions League. During her career in Slovenia, she married a French national, had a child and finished her playing career. A year later (in 2018), however, she returned to France and is still playing there. After seven years of professional handball, she started a dual career as a key account manager.

Table 3. Some characteristics of career development from 2012 until season 2019/20.

Data about players and results								
GENERAL BENEFITS FOR ALL ATHLETES				**Better career development – compering with those who is remaining playing in the home country only** **More successful career because of migration** **Not having tried (to migrate= is the biggest mistake** **Significant improvement in personal and work competencies** **Better salary than in the home country** **Identifying Personal Strengths and Weaknesses** **Social net**			
	2012				**2019/20**			
	Reasons for migration	**Goals wanted to achieve**	**Countries**	**Competition level**	**2nd interview (age)**	**Migration experience**	**Achievements**	**Conclusion**
SUI	Not appropriate conditions for handball improvement in home country	Handball improvement; Improvement in Personal and Work Competences	GER, DEN	First or second national league; only one had played in Champions League (one year)	Age 35 /only one player	9 years (GER)	Decision making; Time management; Results Orientation Teamwork; Organisational Skills	A successful career, Handball, life experience; After sport career - return to the SUI:
SLO	Find better organisation, better salary, better/different conditions for dual career	Better quality of life; handball improvement; dual career, learn new language/s	FRA; MNE; ROU; POL; HUN	Six of them played Champion League	31.5 ± 2.19 (27- 36) / 7 players	9.8 ± 1.57 years (FRA; MNE; ROU; POL; HUN, TUR, GER, MKD, POL; SPA, SUI) (8 - 14)	Competencies: Responsibility; Results Orientation; Decision Making; Communication (foreign languages);	Successful career; Dual Career "I have everything here: handball, job, love/partnership ."

Coping with transnational career transitions

All players tried to prepare for their move physically and mentally. They paid more attention to prevention and treatment of injuries and other health problems. Fear of injury was even more obvious in the migration period than in domestic clubs. Their daily life was described as uneasy because of the number of demands they faced. The athletes mentioned perceived social support from family members during the whole migration period. Their partners, on the other hand, were mostly unwilling to adjust their lives to the athletes' careers.

Having moved abroad, some athletes reported mixed feelings - big expectations and many doubts at the same time. Some remember chaotic feelings and a wish to go home, primarily because of homesickness but also because the conditions and values in foreign clubs were different from expected. Individual coping is emphasised as a key factor in determining the career transition outcome, along with perceived social support from the family, team-mates and also team officials.

By moving to German clubs, Swiss athletes avoided or minimised language difficulties; however, SLO players mentioned that learning German or French was quite a big language challenge.

Dual career during career transitions

Most of the thirteen athletes had dual careers in 2012, combining handball training obligations with studying during the migration periods. Their dual career goals were obligatory for nearly all of them. *SUI: Switzerland was not 'big enough' for my sport career dreams. I liked knowing that sport would also be my profession. I hoped to discover how the other European countries are organising sport. I decided to study sport in Denmark, the 'heart of women's handball'. I was ambitious in sport and in my other career."*

Handball players enrolled in distance education courses. The majority of the athletes showed interest in working in either sports management or some other sport-related business after finishing their handball career. All athletes also mentioned their families' demands that they finish their education.

In 2019, of the 14 athletes, six graduated in sport-related studies, one in social studies, two in economics and three became teachers. Six Slovenes had dual careers, playing handball and working. One Slovenian finished her education before her first migration, and the others during the migration. All said that they consider a dual career essential and that it had been part of their

plans from the beginning. One Slovenian player mentioned that migration gave her dual career a special push: *"When I was at home, I expected my mother to remind me about school. Now I know that I somehow considered my school as my mother's business and not mine. When I moved abroad, I finally realised that everything in my life is my responsibility, including my education*."

Career evaluation

The fact that they got the possibility/invitation to play in foreign clubs was a big success for them. The athletes from 2019 also saw migration as an opportunity to evaluate and reflect upon their whole life, not just their handball career. SLO: "*At the beginning of my career, I decided I would do everything to succeed, to show all friends and relatives – that I will be "The player" SUI: "I'm proud of myself. I felt that migration made me a stronger person. I improved my self-esteem and became many important life competencies."*

Of the eight Slovene athletes, only one returned home and finished her handball career in Slovenia. The remaining seven were still sports migrants in the 2019/2020 season and were at the same time either studying or working. Two had children and were combining elite sports and studies with family life. All athletes were happy about their decision to become sports migrants. An important piece of data is that many of them had objective reasons not to play for their national team anymore, such as the risk of injury and the demands of their Club. The athletes regretted not playing for the national team anymore but indicated there were several problems in trying to do so. It is worth mentioning that Slovenes were more reserved when asked about their national team than in all other questions. Only one player is still playing for the national team. She is one of the best athletes in the French league and the European Champions League, playing right back.

Only one player from SUI in 2022 was still an active migrant with a dual career. One Swiss player, who migrated at the very young age of 19, returned home after two years and then prolonged her career by playing in SUI. The other players from SUI mostly finished their careers abroad, returned to home country around the age of 30, starting different professions and having children. They are all happy about choosing a sports migration experience, but they are satisfied with their life in SUI. Their biggest disappointment and regret is the low ranking of their national team, though they underlined their better performances for the national team having international experience in their foreign clubs.

Two players were interviewed after the results of the first part of the study confirmed that in Slovenia that there are important factors in different phases:

The study concluded that in women's handball players from geographically small countries with middle-ranking national handball teams, parents and coaches are the most crucial part of social support in the very first phases of career development. However, doubt was also presented about the right decision about chosen sport, handball: "*My dear daughter, wouldn't you rather handball play something at the home garden grass*....? Such opinion was at the very beginning of the career, but similar to nearly all other stories, parents were very closely connected with athletes in the first phase. *"At the beginning of the second phase of my career, when I entered as a very young girl in the first team, my father was my first supporter.* In many cases, it was even so that really talented players were changing the lifestyle of all families.*" It was not only that the entire family was coming to watch over handball matches; all weekends we spent around handball, discussing matches and players."*

In the second career phase, access to dual career prospects represents key points of successful career development. "*To finish the education that was in our society always the most important.*

Both interviewed players absolutely agree that the model of successful female athletes from geographically small countries with middle-ranking national handball teams identified several key factors for a successful career in the competition phase of the career; These factors included excellent handball skills for top-level sport; adequate level of education and a realisation of their quality of life aspirations and trajectories as significant factors in evaluating their success, both as athletes and on a personal level external to the sport. And migration is one of the most important factors and an important value and sort of proof of dedicated athletes. "*I must admit that I do regret not going abroad. I had a call from one of the leading clubs in Europe, but I was not bold enough to move there: I'm happy with my career, but this sport migration experience is missing somehow. "*

Also, second interviewed player agrees with concussion about key factors in career development. She was not planning to migrate to other clubs because, at the time of her active career, she was a member of a leading Slovenian club, also one of the leading in Europe, and she was sure about having everything she needed for a successful career. Her lifestyle changed; she became a famous and recognisable person in society and earned a lot of money. Nowadays, she understands that migration means something else, means life experience. "*Although I'm*

happy with my career, I am somehow envious of players nowadays who can gain experience to migrate and change more clubs and countries."

DISCUSSION

In the last decade, nearly synonymous has become a statement that for a successful sports career in elite female handball is to play at the highest level internationally and to be a sport migrant in prominent sports clubs. Sports migrations have intensified worldwide (Magee & Suden, 2002; Maguire & Falcous, 2010; Magee & Sugden, 2002), very intensively also in women's handball (Agregard, 2008, Bon et al., 2016; Bon et al. l 2022). This research study focused on the career development of elite handball players from countries with comparatively small populations and handball federations (SLO, SUI) and on the identification of specific stressors and challenges for athletes, such as dual career challenges, as well as cultural, linguistic, and structural barriers of acculturation, as presented in Schinke et al., (2019) by Ronkainen, Ryba, & Selänne (2019) and Bon et al. l, 2022.

Career development in sports consists of several phases. In the first phase, the social support from family and friends is the most important; in the second phase is the significant role of coaches and clubs' management. In the elite level phase, the most significant findings of this research study are that all participants are convinced that their sporting career has been successful, and even more successful than the careers of those who are also national team athletes but chose not to migrate. Also, two not migrating players agree with this finding. The findings of this research reveal that the most potent reasons for the transnational migration of elite athletes from small countries, such as SLO and SUI, are handball development, dual career possibilities and better quality of life and career prospects. While for Swiss athletes, the prime reason for migration was the development of their handball skills; they were also interested in trying new and different life experiences. Slovenes, on the other hand, wanted to advance their sports careers together with many different benefits, including gaining new life experiences in a different country, trying something new, and leading a more modern life independent of their parents. It is possible to compare the results with the studies on migrant athletes in the Nordic region (Ryba, Ronkainen, & Selänne, 2015; Ryba, Stambulova, Ronkainen, Bundgaard, & Selänne, 2015), which revealed that athletes' career trajectories, lived experiences and psychosocial functioning were closely linked to career discourse practices, professional

opportunities, and to social policy about migrants in their countries of origin and temporal settlement.

The results confirm other authors' conclusions, for example, Ryba et al., 2018; Schinke et al. 2016; Ryba et al., 2015; and Meisterjahn & Wrisberg, 2013, that the sport-related challenges of fitting into the training routines and playing style of a new team proved to be central to athletes' experiences and feelings about migrations. Athletes from countries with a smaller population and small national handball federations who migrate to strong handball clubs in bigger national federations believe that overall club support and being valued by the coach and team-mates are essential factors in an athlete's career. The athletes were often skeptical and doubtful of their own qualities and talents, coming from a small country. This feeling was more typical for athletes coming from SUI. In 2012, some athletes reported difficulties in developing a sense of belonging. With the help of different coping strategies and the support of other club members, they nonetheless mainly managed to adapt to the new environment quickly. As described in similar studies, where some athletes complained about the complexity of their acculturation experiences, inequality of opportunities and the difficulty of developing a sense of belonging (Ronkainen, Ryba, & Selänne, 2019; Ryba et al., 2018; Blodgett & Schinke, 2015; Ryba et al., 2015; Bon et all, 2022). The athletes also reported having similar feelings at the beginning of the transnational migration experience. The athletes with nearly a decade of migration experience also explained that with hard and dedicated work, they had attained a good position in the Club, felt valued, formed treasured friendships, built a network of friends, and found good business opportunities.

Apart from handball-related issues, migrant athletes from SUI and SLO described some other challenges in the migration process, such as learning a new language (especially Slovenes) or adjusting to different cultural norms, as already reported in migrations studies (Agergaard & Ryba, 2014; Kontos & Arguello, 2010; Ryba et al., 2015). The athletes in this study mentioned the benefits of acquiring some specific occupational skills (e.g. psychotherapy, coaching, and beauty therapy), expanding their social network, learning some essential life skills such as cooking and housekeeping, becoming familiar with the new lifestyle and different socio-cultural perspectives.

The findings of the present study confirm those of other researchers about the essential role of family, friends, and other supporters, coaches, and mentors in the migration process (Light, Evans, & Lavallee, 2017; Ronkainen, Khomutova & Ryba, 2019; Ryba, Haapanen, Mosek, &

Ng, 2012). The athletes also pointed out the crucial role of team-mates. Former team-mates or national team team-mates provided support in the first phase of the migration process and, in some cases, were the key factor or enabled and organised the whole migration process, recommending the athletes to coaches or clubs by presenting their competencies, providing contact information, etc. Although very competitive at training sessions and matches, the new team-mates often turned out to be pleasant, amiable, and supportive in their free time away from the court.

The possibility of having dual careers is noted as an essential consideration for all athletes, although it was not such a frequent and well-known consideration at the beginning of the research period. For the Slovenes, in particular, education seemed to have taken priority even over handball development. Six Slovenes finished their education during migration and one beforehand. The one Slovenian player without dual career experience, who by 2019 had not finished her education, proved to be a unique case. She had been playing in the highest-ranking professional women's handball clubs in the EU for more than a decade and had, in her own words, a special 'dual career' with her 10-year-old son. The athletes who decide to stay in a foreign country for a longer period (as is the case with nearly all Slovenes) have to deal with all three phases (*pre-transition, acute cultural adaptation*, and *socio-cultural adaptation)* of the cultural transition model (Ryba et al., 2015).

The pre-transition refers to the activation of psychological mobility, which typically involves various ways of planning for future relocation and psychological disengagement from the athletes' current origin (Ryba et al., 2016). Slovenian athletes interviewed in the season 2019/20 with 8-12 years of migration experience intended to stay in the new countries (Germany, France). All athletes worked through each of the three phases, also acute cultural adaptation and socio-cultural adaptation. All underlined the demands and the need for investing a substantial amount of time and energy, but no one found the adaptation phases problematic - quite the opposite. They highlighted the benefits of knowing different cultures, gaining excellent life experience, and developing skills and competencies. These benefits were acknowledged also by Swiss players, who primarily migrated to improve their handball skills.

All athletes considered their careers successful, and not one of the elite players mentioned regretting going abroad. They admitted having some difficulties in the pre-transition and acute cultural adaptation phases. After adapting to the new environment, they compared their careers with those who had not migrated and felt like they had got more out of their handball careers.

As one Slovene concluded her story: *"In Slovenia, in my Club, everything was at the highest level. The club management organised everything for us players; They were ready to help me with study and with apartment. But I decide to go abroad. Going abroad was one of the best decisions in my life."*

In the recent history of women's handball, we have witnessed a phenomenon in which many of the best athletes in national handball teams are migrants, including SLO and SUI. The aim of this study was to contribute to the scientific part of handball and to find a contemporary model for a successful sporting career for female handball players from small national handball federations. In the career development, both Slovenes and Swiss believed that migration was a key point in their career development, but Slovenian athletes' main reasons for migration went beyond handball as they pursued better life prospects, including better possibilities for dual careers and acquisition of different life competencies, including having better communication and personal relationships in their Club and receiving a more substantial and more regular salary.

The migrations of Slovenian athletes were more frequent, with many more transfers between clubs and countries (11 countries, 26 migrations), with the migration period lasting longer. Slovenes described their first migration as a big, difficult and stressful step in their career, but also as the best decision of their life and career. Five of the SUI handball athletes returned to Switzerland, only one prolonged her career, being dedicated to her dual career (working in a Rehabilitation Centre) but expressed no doubt about returning to Switzerland in the future. *"I knew from the beginning of my migration experience that my future would be in Switzerland. Occupational and opportunities in life are too excellent in Switzerland to stay elsewhere."*

It is quite a different situation with Slovene athletes. Seven Slovenian athletes prolonged their career playing abroad and were still active in the season 2020/2021. They were also ready to remain in the new country with their families and organise their post-handball carer there (in Germany, Switzerland, Montenegro, and France). This represents a new trend in Slovenian handball migration because, in the past, nearly all Slovenian women's handball migrants returned home in the post-handball career phase (Bon et al., 2016; Bon et al., 2022).

CONCLUSION

The research in this study provides some suggestions for more structured career development in women's handball for elite athletes coming from geographically small countries with similar characteristics, such as SUI and SLO. The present study aimed to explore the career development, especially migration (characteristics, reasons, goals, dual career strategies, coping with barriers, competences development) and considerations for success. All athletes stated that they have more successful careers because of migration, more than if they would stay playing in their home country, and more than their national team-mates who are staying to play in their home country; they stated the significant improvement in personal and work competencies; also important is the identification of personal strengths and weaknesses, what is the ground for further personal development.

Our research on the sample of Swiss and Slovene elite handball players was longitudinal, long-lasting, very complex and brought significant results, but the study also has some limitations. Although our participants were all national team handball players and all public persons, being present in different and they agreed to cooperate in the study non-anonymous, the reviewers in general research on this sample (Bon et al., 2022) clearly demanded to cover the identity of the players for the scientific work. The limitation is probably also that we have not followed players who stopped playing during the one-decade data-collection phase of the study. Also, a post-handball career would need to be followed, especially regarding occupational and lifestyle patterns. Now it seems that all Swish athletes have returned to Switzerland, but nearly half of the Slovene remain to stay abroad. Nearly half of all have businesses or professions connected with handball in both countries.

On the basis of the research findings we can conclude that the career pattern of a successful women's handball player from a geographically small country with a middle-ranking national handball team includes: a) excellent handball skills and migration experience; b) an adequate level of education; c) dual career goals from the beginning of the career; and e) high personal ambition and emotional connection to handball. Furthermore, many former migrant athletes use their international experience to contribute to women's handball development as managers or team officials within national handball federations. Analysing the significant number of former elite national team athletes and migrants employed at the top of women's handball organisations, we can conclude that these former athletes developed specific skills, and specific

personal and work competencies, for such positions as a result of their specific career development.

The authors would encourage further studies about career development in elite female sports to discover other socio-cultural and personal characteristics. It would be interesting to compare career development between countries with different handball traditions and according to handball level (also EHF quality ranking, number of clubs or players). Comparison of factors that enable successful sporting careers and satisfying quality of life may differ also from male to female, and research into causative factors for this difference is also of interest for future research.

Declaration of Conflicting Interests

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

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TEST-RETEST RELIABILITY, SMALLEST WORTHWHILE CHANGE, AND MINIMAL DETECTABLE CHANGE SCORES FOR FREQUENCY SPEED OF KICK TEST IN JUNIOR KICKBOXING ATHLETES

TESTNO-RETESTNA ZANESLJIVOST, NAJMANJŠA VREDNA SPREMEMBA IN MINIMALNA ZAZNAVNA SPREMEMBA PRI TESTU HITROSTI UDARCA PRI MLAJŠIH ŠPORTNIKIH V KICKBOXINGU

ABSTRACT

While there exists a significant body of research dedicated to performance tests specific to combat sports, the current literature lacks valid and functional methodologies for assessing kickboxing-specific tasks. The present study endeavored to establish the test-retest reliability, standard error of measurement (SEM), minimal detectable change (MDC), smallest worthwhile change (SWC), and typical error (TE) values of the Frequency Speed of Kicks Test (FSKT). Furthermore, this study sought to compare the reliability values of the FSKT with those of the countermovement jump test (CMJ). The study cohort consisted of twenty-eight junior male kickboxers. Participants performed the CMJ and FSKT twice across test and retest sessions. Pearson correlation analysis identified a significant correlation (r=0.717) between the CMJ and FSKT. Paired t-tests revealed no significant disparities between the test and retest values for both the CMJ and FSKT. However, the difference between the test and retest in the CMJ demonstrated a small effect size, while the FSKT showed a trivial effect size. Intraclass correlation coefficient (ICC) values for the CMJ and FSKT were deemed "good" (r=0.855) and "excellent" (r=0.963) respectively, in terms of reliability. The FSKT displayed superior absolute agreement between test and retest scores due to its lower SEM values when compared to the CMJ. The TE, used to estimate trial-to-trial variation, was lower in the FSKT than in the CMJ. Moreover, the results indicated a lower MDC value in the FSKT than the CMJ, suggesting that the FSKT could be more effective at detecting smaller performance changes compared to the CMJ. In conclusion, this study posits that the FSKT could be considered a reliable method, demonstrating reproducible results in the performance evaluation of kickboxing athletes, pending the development of a functional kickboxing-specific field test.

Keywords: sport-specific, field-test, combat sport, martial arts, practical importance

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IZVLEČEK

Medtem ko obstaja precej raziskav, posvečenih testom zmogljivosti, značilnim za borilne športe, v trenutni literaturi ni veljavnih in funkcionalnih metodologij za ocenjevanje nalog, značilnih za kickboxing. Namen študije je bil ugotoviti zanesljivost testiranja, standardno napako merjenja (SEM), najmanjšo zaznavno spremembo (MDC), najmanjšo vredno spremembo (SWC) in tipično napako (TE) testa hitrosti udarcev (FSKT). Poleg tega je bil cilj te študije primerjava vrednosti zanesljivosti testa FSKT z vrednostmi zanesljivosti skoka z nasprotnim gibanjem (CMJ). Študijsko skupino je sestavljalo osemindvajset mlajših kickboxerjev. Udeleženci so dvakrat izvedli test CMJ in FSKT s tremi dnevi počitka med testiranjem in ponovnim testiranjem. Pearsonov koeficient korelacije je pokazal pomembno povezanost (r=0.717) med CMJ in FSKT. Parni t-testi niso pokazali bistvenih razlik med testnim in ponovnim testiranjem za CMJ in FSKT. Vendar je razlika med testom in ponovnim testom pri CMJ pokazala majhno velikost učinka, medtem ko je FSKT pokazala trivialno velikost učinka. Vrednosti koeficienta interklasne korelacije (ICC) za CMJ in FSKT so bile v smislu zanesljivosti ocenjene kot "dobre" (r=0.855) oziroma "odlične" (r=0.963). FSKT je pokazal boljše absolutno soglasje med rezultati testa in ponovnega testa zaradi nižjih vrednosti SEM v primerjavi s CMJ. TE, ki se uporablja za oceno variacije med posameznimi poskusi, je bila pri FSKT nižja kot pri CMJ. Poleg tega so rezultati pokazali nižjo vrednost MDC pri FSKT kot pri CMJ, kar kaže na to, da bi bil FSKT lahko učinkovitejši pri odkrivanju manjših sprememb uspešnosti v primerjavi s CMJ. Ta študija torej kaže, da bi lahko FSKT veljal za zanesljivo metodo, ki kaže ponovljive rezultate pri ocenjevanju zmogljivosti športnikov v kickboxingu, dokler ne bo razvit funkcionalni terenski test, specifičen za kickboxing.

Ključne besede: športno specifični, terenski testi, borilni šport, borilne veščine, praktični pomen

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INTRODUCTION

Kickboxing is a full-contact combat sport including both an athlete's efforts of punching and kicking against an opponent and avoiding the punches and kicks of the opponent (Slimani, Chaabene, Miarka, & Chamari, 2017). However, studies investigating the performance of kickboxing athletes have widely used non-specific tests such as isokinetic strength, vertical jumps, cycle ergometer, treadmill or field running (Haugen, Breitschädel, Wiig, & Seiler, 2020; Machado et al., 2009; Ouergui et al., 2014; Salci, 2015). It is crucial to note that tests with non-specific tasks may decrease ecological validity since the nature of a kickboxing match requires intermittent or repeated actions with short rest periods (Salci, 2015; Slimani et al., 2017). However, in novel studies, a sport-specific test involving the maximum number of kicks for 10 s, which is called the frequency speed of the kick test (FSKT), has been used in taekwondo athletes (Santos & Franchini, 2016; Santos, Valenzuela, & Franchini, 2015; Santos, Lopes-Silva, Loturco, & Franchini, 2020). Although the FSKT also appears to be an appropriate test to measure kickboxing performance, no studies have used this test in kickboxing athletes.

The countermovement jump (CMJ) test has been one of the most popular and commonly reported methods to measure athletic performance such as muscular power, neuromuscular adaptation, and reactive strength in sports sciences over the last two-three decades (Barker, Harry, & Mercer, 2018; Haugen et al., 2020; Mirzaei, Norasteh, & Asadi, 2013; Özbay & Ulupınar, 2020). However, although vertical jump ability is directly related to competitive performance in some sports such as volleyball, basketball, football, and high jump, this movement pattern may not be crucial to evaluate performance in many sports. In addition, CMJ contains some difficulties in practice due to differences in instruments, testing procedures, calculation methods, and software, therefore, it may not be possible to conclude that the measurement results are free from many possible errors (Haugen et al., 2020; Street, McMillan, Board, Rasmussen, & Heneghan, 2001).

Reliability refers to the consistency of or the reproducibility of values of measurement in repeated trials on the same participants (Hopkins, 2000). Reliability analysis presents crucial information indicating the degree to which scores of a test or a method are free of measurement errors (Wilkinson et al., 2019). Thus, a reliable test allows us to reach a better precision of measurements and to detect the changes in test scores in research and practical settings (Hopkins, 2000; Zeljko, Gilic, & Sekulic, 2020). Reliability basically consists of both absolute and relative reliability (Bruton, Conway, & Holgate, 2000; Haley & Fragala-Pinkham, 2006;

Weir, 2005). Absolute reliability refers to the consistency of scores of individuals, whereas relative reliability refers to the consistency of the position or rank of individuals in the group relative to others (Weir, 2005). The main reliability values in investigations of sports sciences usually include within-subject random variation, systematic change in the mean, and retest correlation (Hopkins, 2000; Šuker, Grgantov, & Milić, 2015).

Paired t-test and Bland-Altman plot methods only refer to the absolute agreement while the Pearson correlation coefficient only refers to the measure of correlation (Koo & Li, 2016; Özbay, Ulupınar, Çınar, & Akbulut, 2019; Wilkinson et al., 2019). Therefore, these analyzes are considered less-ideal methods for deciding the precision of a test (Bruton et al., 2000; Koo & Li, 2016; Portney & Watkins, 2009). On the contrary, intra-class correlation coefficients (ICC), which is an index reflecting a more reasonable measure of reliability, refers to both degrees of correlation and agreement between measurements (Haley & Fragala-Pinkham, 2006; Hopkins, 2000; Koo & Li, 2016). ICC is the common metric in test-retest, intra-rater, and inter-rater reliability analyses (Koo & Li, 2016). ICC reflects not only the degree of correlation but also agreement between measurements unlike the Pearson product-moment correlation coefficient (Bruton et al., 2000). However, ICC may not be enough to interpret that measurement scores are reliable due to hypersensitive to the heterogeneity of the research sample, therefore, this value needs to be supported by other reliability analyses (Hopkins, 2000; Weir, 2005).

Absolute reliability provides information for differentiating a real change in performance from a change due to individual variation and measurement error and is mostly quantified as standard error of measurement (SEM) (Segura-Ortí & Martínez-Olmos, 2011). SEM, which is used as an indicator of agreement between measurements, is calculated from the ICC and standard deviation values (Weir, 2005). SEM is also used to calculate minimal detectable change (MDC), which is a more clinically useful value for interpreting reliability (Haley & Fragala-Pinkham, 2006). MDC refers to the smallest amount of reliable change in the scores to conclude that the difference is not attributable to measurement errors (Segura-Ortí & Martínez-Olmos, 2011). Thus a change amount exceeding the MDC is used to define a real (or true) change that is free from measurement errors (Haley & Fragala-Pinkham, 2006).

A measurement error indicates the observed value of a measure differs from its real value (Hopkins, 2000). In sports sciences, experimental research designs using test-retest analyses to determine the reliability of a method generally consist of the measurements that the same

investigator performed using the same equipment. The effects of learning, motivation, and fatigue are considered the possible reasons for systematic changes in the mean of a measure between successive trials, and their effects need to be eliminated from estimates of within-subject variation (Hopkins, 2000). Typical error refers to the standard deviation of a participant's repeated measurements and it is another practical indicator used to estimate trial-to-trial variation (Weir, 2005). It is stated that studies designed to determine the reliability of a test or method should be supported by calculations such as SEM, MDC, and TE together with ICC. The aim of the present study was to determine the test–retest reliability, estimated SEM, MDC, SWC, and TE of FSKT, and compare the reliability values of FSKT with CMJ.

METHODS

Participants

Twenty-eight junior male kickboxing athletes (mean and standard deviation; age: 16.4 ± 1.2 years; body mass: 67.7 ± 7.1 kg; height: 175.6 ± 7. cm; training experience: 5.0 ± 1.2 years) participated in this study. Athletes were competing at national level and training at least three sessions weekly. All athletes were free from any lower-body injury or neuromuscular disorder. Participants were instructed not to exercise strenuously or not to use any supplement during the research period. All participants provided written consent after being informed about the purpose, procedures, and possible risks. Parental written consent has been obtained for participants under 18 years. The research was approved by the Ethics Committee of the Institute of Winter Sports, Atatürk University, Erzurum, Turkey (SBFEK190066441-42).

Procedures

Participants performed the CMJ and FSKT with three days of rest between the test and retest sessions. In addition, participants performed these tests twice times with five min-breaks during the same session, however, the best score was considered valid for that session. In other words, the best scores collected from the test and retest sessions were used to evaluate test-retest analyses. Actually, the common method for determining the valid score of a participant in research designs measuring athletic performance is to choose the highest score in several attempts in a session and assume that this score is the best for the participant. However, we aimed to evaluate the reliability of the tests using the variation between two trials with a few days of rest, not within-session variation.

The purpose of FSKT was to perform the maximal quantity of kicks during the 10-second test. FSKT tests were recorded using an ultra-slow motion video camera (Sony PXW-FX9 6K Full-Frame, Japan). A kicking was considered a valid score when a participant hit the target area on the sandbag with the appropriate kicking technique. CMJ height was measured with the My Jump 2 mobile application and its validity and reliability were tested by previous studies (Balsalobre-Fernández, Glaister, & Lockey, 2015; Haynes, Bishop, Antrobus, & Brazier, 2019). To measure the CMJ height via a smartphone (iPhone 7) using this app, the same investigator manually selected the initial contact frame, the take-off frame from the floor, and the final landing frame and results were automatically presented by the app. Athletes were asked to rest their hands on the sides of their waist, keep their knees in full extension, and then flex their knees and jump vertically at the fastest possible speed during the CMJ test. Both tests were applied in the same period of the day to minimize circadian variation influence on performance.

Statistical Analysis

The SPSS package version 21.0 (IBM SPSS Statistics for Windows, Armonk, NY) was used for data management and analysis. The level of significance was predetermined to be $p \leq 0.05$ for all statistical analyses. Data are reported as mean ± standard deviation. Paired t-test was used to compare the mean values between the test and retest. To evaluate the magnitude of difference, Cohen´s d effect size was calculated and d values were classified to Hopkins scale. Pearson product–moment correlation coefficients were calculated to determine the strength of the relationship between the best scores of CMJ and FSKT.

Intra-class correlation coefficient ($ICC_{3,k}$), based on a two-way mixed model (the rater was considered a fixed effect and the participants were considered a random effect) with a consistency definition, was used to measure the test−retest relative reliability. An ICC above 0.750 was considered to demonstrate good reliability while ICC above 0.900 was considered to indicate excellent reliability (Portney & Watkins, 2009). Typical error of measurement was computed to estimate trial-to-trial variation (do Nascimento et al., 2017; Weir, 2005). Minimal detectable change (MDC) basically defines the smallest change that is not within the expected range of error, therefore, it was used to identify the required amount of change in a measurement to ensure that the difference was not attributable to error (Charter, 1996; Wilkinson et al., 2019). The smallest worthwhile change (SWC) was used to define the smallest meaningful change or smallest clinically important difference (Duthie, Pyne, Ross, Livingstone, & Hooper, 2006;

Özbay & Ulupınar, 2019; Özbay et al., 2019). The formulas used to support ICC in the reliability analysis are presented below.

Formula 1: $TE = SD_{differences} / \sqrt{2}$

Formula 2: $MDC = SEM \times 1.96 \times \sqrt{2}$

Formula 3: $SEM = SD_{mean} \times \sqrt{1 - r}$

Formula 4: $CV_{SEM} = SEM / Mean \times 100$

Formula 5: $SWC_{small} = 0.2 \times$ between-subject SD_{best}

Formula 6: $SWC_{moderate} = 0.6 \times$ between-subject SD_{best}

where $SD_{differences}$ = the standard deviation of the difference between successive two trials; SD_{mean} = the average of the standard deviations for the participants in two trial; SD_{best} = the standard deviation of best scores; r = the intra-class correlation coefficient; CV_{SEM} = the SEM as the coefficient of variation. The 1.96 value represents the z-score at the 95% confidence interval. SEM is the standard error of measurement.

RESULTS

Paired t-test demonstrated that there was no significant difference between test and retest mean values for both CMJ and FSKT (Table 1). However, difference between test and retest in CMJ had a small effect size. Reliability analysis results of the test-retest for ICC, TE, SWC, CV_{SEM}, and MDC are presented in Table 2. Results of the test-retest for ICC, TE, SWC, CV_{SEM}, and MDC are presented in Table 2. ICC values for CMJ and FSKT were considered to have good and excellent reliability, respectively. SEM was classified as “good” when lower than SWC. Figure 1 indicated that CMJ and FSKT had a significant Pearson product–moment correlation coefficient (r = 0.717).

Table 1. Performance results during the CMJ and FSKT (n = 28).

	Trial 1 (mean ± SD)	Trial 2 (mean ± SD)	Paired t-test value	p-value	Cohen's d (effect size)
CMJ (cm)	33.57 ± 3.83	34.51 ± 4.97	1.617	0.118	0.21, small effect
FSKT (kicks)	20.64 ± 2.56	20.82 ± 2.64	0.961	0.345	0.07, trivial effect

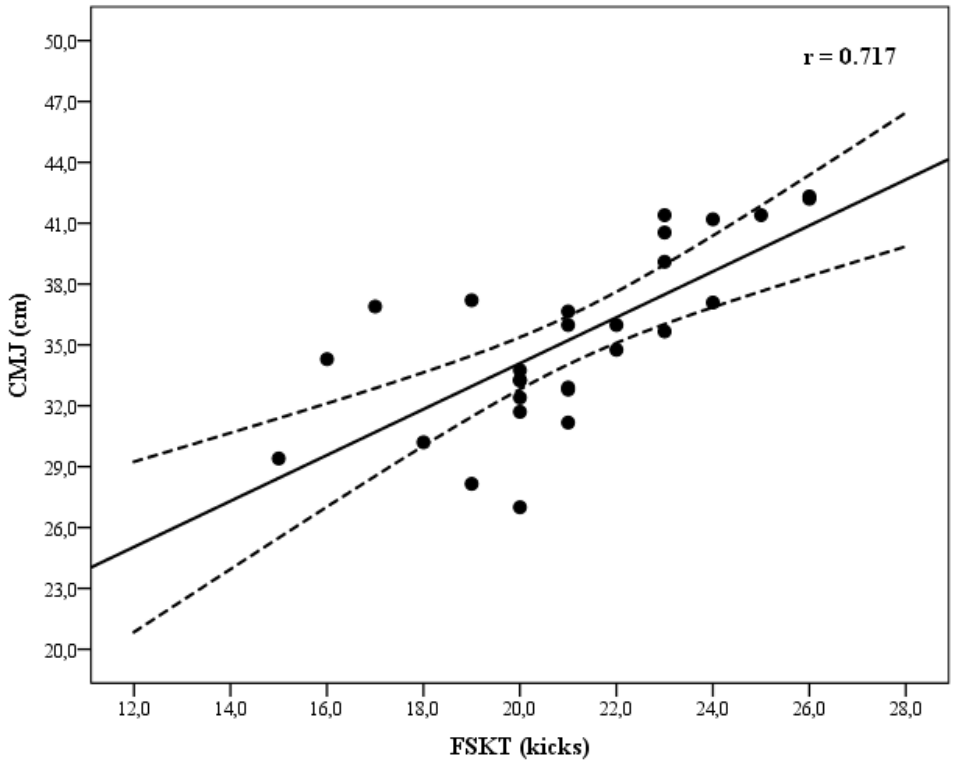
CMJ= countermovement jump; FSKT= frequency speed of kick test

Table 2. Test–retest reliability analyses of the CMJ and FSKT (n = 28).

	ICC (95% CI)	TE	CV_{TE} (%)	SWC_{small}	$SWC_{moderate}$	SEM	CV_{SEM} (%)	MDC
CMJ	0.855 (0.69–0.93)	1,14	3,40	0,76	2,28	0,62	1,82	1,73
FSKT	0.963 (0.92–0.98)	0,51	2,47	0,50	1,50	0,10	0,48	0,27

CMJ= countermovement jump; FSKT= frequency speed of kick test; ICC= intra-class correlation coefficient; CI= confidence interval; TE= typical error; CV_{TE}= the TE as coefficient of variation; SWC_{small}= smallest worthwhile change for small effect size; $SWC_{moderate}$= smallest worthwhile change for moderate effect size; SEM= standard error of measurement; the SEM as coefficient of variation; MDC= minimal detectable change.

Figure 1. Relationship between the best scores of CMJ and FSKT (n=28).



DISCUSSION AND CONCLUSION

To our knowledge, this is the first study to investigate the reliability of FSKT in kickboxing athletes. In this study, the reliability of FSKT for junior kickboxers was evaluated using complementary statistical procedures consisting of relative and absolute reliability analyses. The ICC criterion adopted in this study resulted in good (r = 0.855) and excellent (0.963) reliability classification for CMJ and FSKT, respectively (Portney & Watkins, 2009). However, if the lower limits of the confidence interval were considered, it could be made inference that the relative reliability of FSKT (95% CI = 0.92–0.98) is higher than that of CMJ (95% CI = 0.69–0.93). Current studies reported that ICC values of FSKT were 0.95 for taekwondo athletes with different competition levels (Santos et al., 2020), 1.00 for black-belt taekwondo athletes (Silva Santos & Franchini, 2016), and 0.95 for women taekwondo athletes (Santos & Franchini, 2018). Thus, the present study in addition to various studies proven that the relative reliability of FSKT is excellent.

FSKT had a greater absolute agreement between test and retest scores due to having lower SEM and CV_{SEM} values compared with CMJ. In addition, the effect size calculated from paired t-test analysis supported SEM and CV_{SEM} results since the differences between test and retest showed that CMJ had a small effect size while FSKT had a trivial effect size. Similarly, TE and CV_{TE}, which were used to estimate trial-to-trial variation, were lower in the FSKT than CMJ. A study reported that SEM, CV_{SEM}, and MDC values were 0.60, 2.85, and 1.67, respectively (Santos et al., 2020). These results are quite similar to the findings of our study. Hence, the various findings demonstrated that FSKT could present highly precise results and error-free. The MDC is the smallest change that falls outside the expected range of error and a difference amount exceeding the MDC threshold can be considered a “true” change (Haley & Fragala-Pinkham, 2006; Segura-Ortí & Martínez-Olmos, 2011). The current findings indicated that MDC value was lower in the FSKT than CMJ thus FSKT could allow to determine lower performance changes compared with CMJ.

Pearson product–moment correlation coefficient revealed a significant relationship between CMJ and FSK. Although this result suggested to be a relationship between the skills measured by these two tests, other analyzes indicated that FSKT can be a more reasonable test for kickboxing athletes. For example, SWC refers to the smallest value considered important in practice and the findings showed that FSKT represented a higher sensitivity for detecting an important change in practice, as SWC was lower in the FSKT than CMJ (Bernards, Sato, Haff,

& Bazyler, 2017; Duthie et al., 2006; Santos et al., 2020). TE and SEM values should be lower than SWC values for proper use of SWC (Bernards et al., 2017; do Nascimento et al., 2017; Santos et al., 2020). SEM values were lower than SWC_{small} (threshold value emphasizing the importance of a small effect in practice) for both tests. But TE value for CMJ was greater than SWC while TE value for FSKT was similar to SWC. Thus, $SWC_{moderate}$ (threshold value emphasizing the importance of a moderate effect in practice) values may be more appropriate to conclude that the results were completely outside the limits of error.

CMJ has been commonly used to assess athletic performances such as muscular power (İnce & Şentürk, 2019; İnce & Ulupınar, 2020), neuromuscular adaptation (Claudino et al., 2017; Mirzaei et al., 2013), and reactive strength (Barker et al., 2018) in a wide variety population for decades. However, using the biomechanical movement pattern required for CMJ as a test method may not be a valid approach to assess the performance of kickboxing athletes (Haugen et al., 2020; Slimani et al., 2017). Moreover, considering the difficulties in the CMJ measurements that can be caused by instruments, testing procedures, calculation methods, and software, using a sport-specific test seems a more appropriate method (Street et al., 2001). This study showed that relative and absolute reliability results were lower in the CMJ than in FSKT and the indicators of measurement error such as SEM indicating the absolute agreement and TE indicating the variation of trial-to-trial were higher in the CMJ. In addition, the CMJ results less allow monitoring of smaller changes because the results indicating that a change in performance can be considered error-free and practically important are higher in the CMJ than FSKT.

A comprehensive study investigating sport-specific performance tests in Olympic sports such as amateur boxing, fencing, judo, karate, taekwondo, and wrestling revealed to be more than 40 different tests in total (Chaabene et al., 2018). However, to our knowledge, unlike other combat sports, kickboxers do not have a valid and functional choice in terms of kickboxing-specific tests. Since FSKT only measures kicking ability, its use as a performance test for kickboxers cause a limitation, but it appears to be the most appropriate for kickboxers among valid and reliable tests described in the literature. Based on the many similarities of Kickboxing with combat sports such as karate, taekwondo, boxing, and muay thai (Salci, 2015; Slimani et al., 2017; Taskin & Akkoyunlu, 2020; Vertonghen & Theeboom, 2008), we aimed to investigate the extent to the reliability of a test developed for these sports can be when used in kickboxers. For example, FSKT was originally developed to measure a skill based on kicking as fast as possible in 10 seconds for taekwondo athletes (Santos & Franchini, 2016, 2018; Santos et al.,

2020). Therefore, our hypothesis was that FSKT could present reliable results in kickboxers since it appears to be an appropriate test to measure kickboxing performance compared with CMJ. Our findings confirmed the initial hypothesis and presented evidence that FSKT can provide reliable results until a specific test for kickboxers is designed. In conclusion, this study suggested that FSKT could be considered a reliable method and presented reproducible results in evaluating the performance of kickboxing athletes until a functional kickboxing-specific field test is developed.

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Declaration of Conflicting Interests

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

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A NEW APPROACH TO ACTIVE FLEXIBILITY MEASUREMENT IN STUDENTS OF SPORTS SCIENCES FACULTIES

NOV PRISTOP K MERJENJU AKTIVNE GIBLJIVOSTI PRI ŠTUDENTIH FAKULTET ZA ŠPORTNE VEDE

ABSTRACT

The aim of the study is the determination of the hamstrings, hip muscles, and lower and upper muscles' active flexibility. Thus, by using a new method of the measurement of active flexibility which is based on angle degree, we aim to provide information about the contribution ratio of hamstrings, hips, and lower and upper back muscles on reachability performance. A total of 26 physical education and sports science faculty girls (weight: 57.7kg, height: 164.2cm), and 128 boys (weight: 72.1kg, height: 176.9cm) was included. To measure the flexibility of the students the Kinovea-0.9.4-x64.exe program was used. Measurements included tests such as the LUBAD, LBLBAD, LBPAG, SRT and MSRT. In the data analysis one-way ANOVA, Pearson correlation, and the percentage formula: "%= (X / X) *100" was used. Correlations between reachability tests such as SRT and MSRT, and tests which are supposed to measure the lower and upper back effect of reachability LUBAD, LBLBAD are statistically significant ($p<0.05$). In girls, just 23%, and boys 26% of active flexibility is caused by hamstrings and hip muscles, while in the girls 77%, and in boys, 74% of the active flexibility was caused by the lower and upper back muscles. The girls resulted to use a higher ratio the upper back flexibility to cover the lack of hips, and hamstrings muscles flexibility while they perform reachability tests. Thus, the reachability is not caused just by hamstrings, and hips muscles, but also it is affected by the lower and upper back muscles' active flexibility.

Keywords: Sit-and-reach, Baseline (Modified) Sit-and-reach, Validity, Lower Back, Upper Back, Hamstrings

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IZVLEČEK

Cilj študije je določitev aktivne gibljivosti posameznih mišic (stegenskih, kolčnih in mišic spodnjega in zgornjega dela hrbta) in razmerja med njimi s pomočjo kotnih stopinj. V raziskavo je bilo vključenih 26 deklet s Fakultete za telesno vzgojo in šport (telesna teža: 57.7 kg, telesna višina: 164.2 cm) in 128 fantov (telesna teža: 72.1 kg, telesna višina: 176.9 cm). Za merjenje gibljivosti študentov je bil uporabljen program Kinovea-0.9.4-x64.exe. Meritve so vključevale teste, kot so LUBAD, LBLBAD, LBPAG, SRT in MSRT. Pri analizi podatkov so bili uporabljeni enosmerna ANOVA, Pearsonov koeficient korelacije in odstotna formula (uporabljena je bila formula "% = (X / X) *100). Korelacije med testi gibljivosti, kot sta SRT in MSRT, ter testi, ki naj bi merili gibljivost spodnjega in zgornjega dela hrbta LUBAD, LBLBAD, so statistično značilne ($p<0.05$). Pri dekletih prispevajo stegenske in kolčne mišice le 23% k aktivni gibljivosti pri zgoraj omenjenih testih, medtem ko pri fantih ta odstotek znaša 26%. Večji delež aktivne gibljivosti tako pri obeh spolih prispevajo mišice spodnjega in zgornjega dela hrbta (dekleta 77%, fantje 74%). Dekleta so slabšo gibljivost spodnjih okončin (stegenskih in kolčnih mišic) pri testih kompenzirala z boljšo gibljivostjo mišic zgornjega dela hrbta. To dokazuje, da so za aktivno gibljivost v večji meri odgovorne mišice zgornjega in spodnjega dela hrbta, in ne samo stegenske in kolčne mišice.

Ključne besede: predklon sede, predklon sede prilagojen, veljavnost, spodnji del hrbta, zgornji del hrbta, stegenske mišice

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INTRODUCTION

As the ability to assume and maintain extended positions using only the tension of the agonists and synergists while the antagonists are being stretched (Sabhachandani & Rani, 2011), active flexibility is a key factor in performance parameters in many sports branches such as gymnastics branches, dance, etc. High active flexibility and a good compromise between strength and flexibility are advisable for high-quality performance (Donti, Tsolakis, & Bogdanis, 2014; Purcell & Micheli, 2009). By providing higher active flexibility (mobility) actively moving through a range of motions known as with high correlation to competition performance may be significantly increased (Berisha, 2021a; Schwab, Diangelo, & Foley, 2006). As the flexibility decreases with age and high speed of development, in both cases, girls perform better than boys (Catley & Tomkinson, 2013; Coknaz, 2017; De Miguel-Etayo et al., 2014; Yalnız, 2016). Many countries such as all European countries, Kosovo, Australia, Turkey, Serbia, etc., (Catley & Tomkinson, 2013; Örjan, Kristjan, & Björn, 2005; Ortega et al., 2011; Wilczewski, Sklad, Krawczyk, Saczuk, & Majle, 1996) pose norm values and level of flexibility which in most situations is based on the values carried about by applying sit-and-reach test (SRT) (Castro-Pinero et al., 2010; Hui & Yuen, 2000). But, the accuracy of all previous results which still are in use depends on the validity of tests used to measure the flexibility.

Interestingly, although many types of research about sit-and-reach tests, there is little research evidence that any kind of sit-and-reach test adequately measures low-back, upper-back, or hamstrings flexibility. There is controversy in the literature as to whether sit-and-reach tests assess low-back flexibility and/or hip flexibility. Based on the fact that validity is the degree to which a test or test item measures what it is supposed to measure (Baumgartner, 2007; Morrow, 2011), sit-and-reach test measures reachability which is affected by anthropometric features and does not mean directly that it is valid to test for low-back, upper-back or hamstrings active flexibility. Reasons for this are anthropometric factors. Longer or shorter legs, longer or shorter arms, and a longer or shorter trunk may be reasons for better or worse reach performance (Remian & Manske, 2009). To avoid the affection of the anthropometric features on the sit-and-reach test results, it was developed a “modified sit-and-reach” method of measurement. The back-saver sit-and-reach test has been proposed as a healthier alternative to the classical sit-and-reach test (Plowman & Meredith, 2013). Unfortunately, as the classic method fail to measure and is affected by the long arms, similarly baseline (Modified Sit and Reach Test MSRT) method may be affected by the short arms. So, to measure the hips, lower body, upper

body, and hamstrings muscle flexibility, we should develop a method that measures that flexibility and is not affected by the anthropometric features.

Based on the need to develop a new method of active flexibility measurement, the aim of the study is the determination of the hamstrings, hip muscles, and lower and upper back muscles' active flexibility. Thus, by using a new method of the measurement of active flexibility which is based on angle degree, we aim to provide information about the contribution ratio of hamstrings, hips, and lower and upper back muscles on reachability performance.

METHODS

To carry out aimed conclusions which is the determination of the hamstrings, hip muscles, and lower and upper muscles' active flexibility level by using the angle degree method, the causal relational research model was used.

Participants

In this study, 26 physical education and sports science faculty girls whose average body weight was 57.7±6.15kg, and body height average of 164.2±4.38 cm, and 128 boys whose average body weight was 72.1±10.53 kg, and body height average of 176.9±5.20 cm were included. Athletes were informed about the activities and tests, which were made for the study. Besides this, students signed an informed consent after being informed about the benefits and risks (even though there was no predicted risk) of the applied activities and tests. The study procedures were approved by the local ethics committee at Istanbul Gelisim University in 18.08.2022 (meeting number: 2022-13), approval decision number 2022-13-37, and they were conducted according to the Helsinki declaration (2013).

Tests included in the study

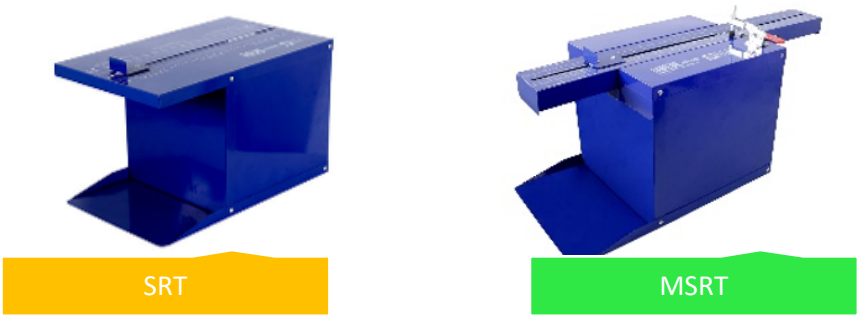
In order to measure the sit and reach performance SRT and MSRT tests were applied as they have been explained below. In the new approach to the assessments the LUBAD, LBLBAD, and LBPAG test protocols have been applied as they are explained below. Each participant has been photographed from the lateral side. Participants are dressed in thin t-shirts and short shorts that provide visibility to the body joints. The anatomical (see each test protocol below) zones used as the center angle degree s been marked. Besides using the seat-and-reach box, measurements were made by using the Kinovea-0.9.4-x64.exe program (Berisha, 2021b; Kinovea-0.9.4-x64.exe., 2021). The tests were made by all authors of the study. However, the

flexibility test protocols, anatomic zones for angle degrees, and analyses of them have been made by the first author of the study, who is a Ph.D. of sports science, an artistic gymnastics coach, and experienced in 2D biomechanics analysis.

Sit-and-reach Test (SRT): Several sit-and-reach tests are commonly used in health-related and physical-fitness test batteries to evaluate the hamstring and lower back flexibility (Hui & Yuen, 2000). The tests in which a fingertips-to-tangent feet distance is measured are probably the most widely used linear measures of flexibility (Figure 1a) (Castro-Pinero et al., 2010).

Modified Sit-and-reach Test (MSRT): The active flexibility was measured by using the modified sit-and-reach test. The test application was made by following the instructions of the seat reach test (Council of Europe 1983, Council of Europe 1987).

Figure 1. Sit and reach tests used in the study.



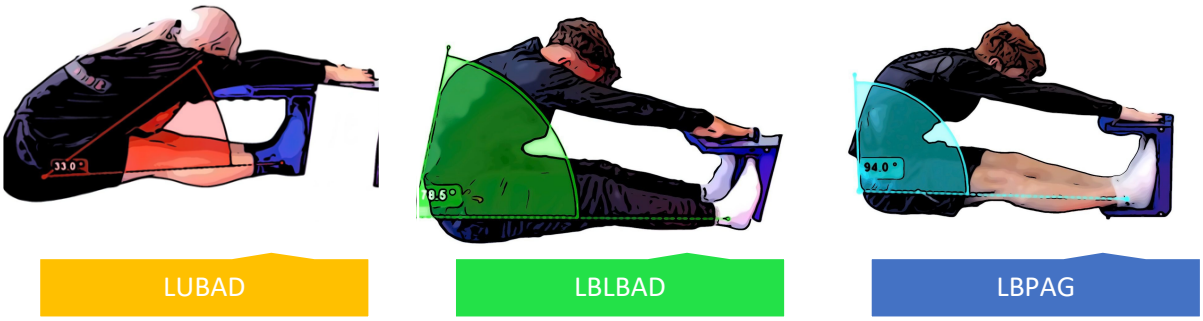
a) SRT (Sit-and-reach Test); b) MSRT (Modified Sit-and-Reach Test)

Lower-Upper Body Angle degree (LUBAD): The test measures the active flexibility of the hamstrings, hips, lower back, and upper back muscles. Thus, the test is designed to measure the reachability of the testers. Besides measuring the reach distance in cm, during the test lower-upper body angle degree was measured (as the center of angle was determined greater trochanter, first-line were from greater trochanter to acromion and second line from the greater trochanter to the lateral epicondyle of the femur) (see Figure 2a) (Süzen L.B., 2017).

Lower Body-Lower Back Angle Degree (LBLBAD): The test measures the active flexibility of the hamstrings, hips, and lower back muscles. Thus, the test is designed to leave out the upper back muscles' active flexibility during the reachability of the testers. The first line of angle starts from the lumbar spine, (L5) across the lumbar spine (L1) to the thoracic spine, and the second line starts from the lateral epicondyle of the femur which across the greater trochanter and meets the other line of the angle which come from the lumbar spine (see Figure 2b) (Süzen L.B., 2017)

Lower Body-Pelvic Angle Degree (LBPAG): The test measures the active flexibility of the hamstrings, and hips muscles. Thus, the test is designed to leave out the lower and upper back muscles' active flexibility during the reachability of the testers. The first line of angle starts from the end of the line and comes across the lateral epicondyle to the greater trochanter. Thus, pelvic torsion is measured which is expressed in angle degree (see Figure 2c) (Süzen L.B., 2017).

Figure 2. New approach of sit and reach measurement and back inclusion ratio on the reachability.



a) LUBAD (Lower-Upper Body Angle Degree); b) LBLBAD (Lower Body-Lower Back Angle Degree); c) LBPAG (Lower Body-Pelvic Angle Degree).

Data analysis

The data analysis has been made by using SPSS 26 packet program. The distribution (normality) of the data has been tested by using the skewness (> 1 - positive, 0 - normal, < - 1 - negative) and kurtosis (> +2 leptokurtic, 2 mesokurtic, < -2 platykurtic) values. Correlations between reachability tests and back angle degrees were tested by using Pearson correlation analysis. The significant correlation coefficient is $p<0.05$. The difference between angle degrees on the back (LUBAD, LBLBAD, and LBPAG) has been determined by using a one-way ANOVA (Post-Hoc Tukey) analysis. And, the rate of effect of back angles (LUBAD, LBLBAD, LBPAG) on the reachability (SRT, MSRT) "%= (X / X) *100" formula was used. To determine the inclusion ratio (%) of the lower and upper back muscles and hamstring, hips, and pelvic muscles LUBAD angle and LBPAG angle degrees were divided in the middle by the LBLBAD. To measure the flexibility of the students the Kinovea-0.9.4-x64.exe program was used.

RESULTS

Table 1. The descriptive statistics normality of the active flexibility and angle degree tests.

	Variables	Range	Min	Max	X̄±SD	Skew	Kurt
Girls (♀)	SRT	32.8	15.7	48.5	33.9±9.57	-.543	-.624
	MSRT	36.8	24.5	61.3	43.4±10.21	-.361	-.907
	LUBAD	43.2	32.5	75.7	48.9±11.15	1.013	.625
	LBLBAD	46.8	40.0	86.8	55.8±12.73	1.047	.616
	LBPAG	44.3	66.0	110.3	84.6±10.76	.265	-.087
Boys (♂)	SRT	40.7	10.3	51.0	29.7±8.11	-.058	-.104
	MSRT	45.4	19.6	65.0	42.5±8.57	.141	.030
	LUBAD	42.6	35.4	78.0	54.4±9.41	.314	-.131
	LBLBAD	55.6	34.3	89.9	64.4±12.53	.051	-.641
	LBPAG	33.50	74.10	107.60	90.9±6.96	.034	-.372

Sit and Reach (SRT), Modified Sit-and-reach Test (MSRT), Lower-Upper Body Angle Degree (LUBAD), Lower Body-Lower Back Angle Degree (LBLBAD), Lower Body-Pelvic Angle Degree (LBPAG).

Based on the angle degrees descriptive values given in Table 1, it can be seen that the distribution of the data results seems to be normal (mesokurtic), and not significantly skewed positively or negatively. The angle degrees that occurred in the back are different from a gender perspective (based on average values). While the differences between boys and girls in LUBAD are smaller in favor of girls, the differences in LBLBAD and LBPAG seem to be more important in favor of girls.

When results are analyzed from another perspective, the LUBAD angle degree is different from the angle degrees that occurred on other parts of the back such as LBLBAD and LBPAG, which is proof of the effects of back elasticity on the reachability measured by SRT and BLSRT test.

Table 2. Difference between angle degrees occurred in back while sit and reach test (Back curve effect on the sit reach ability).

Gender	Variables	X̄±SD	F	P	Tukey
Girls (♀)	[1] Lower-Upper Body Angle Degree	48.9±11.15	69.383	.000	1<3
	[2] Lower Body-Lower Back Angle Degree	55.8±12.73			2<3
	[3] Lower Body-Pelvic Angle Degree	84.6±10.76			
Boys (♂)	[1] Lower-Upper Body Angle Degree	54.4±9.41	463.68	.000	1<2
	[2] Lower Body-Lower Back Angle Degree	64.4±12.53			1<3
	[3] Lower Body-Pelvic Angle Degree	90.9±6.96			2>3

$p<0.05$, LUBAD: Lower-Upper Body Angle Degree, LBLBAD: Lower Body-Lower Back Angle Degree, LBPAG: Lower Body-Pelvic Angle Degree.

In Table 1, it can be seen that there are statistically significant differences between the LUBAD, LBLBAD, and LBPAG tests on the reachability during the execution of the sit-and-reach test and baseline sit-and-reach test in both genders ($p<0.05$). Expecting the differences between LUBAD and LBLBAD in girls, resulted to be not significantly different ($p>0.05$).

Table 3. Correlations between sit and reach (classic method) and baseline sit and reach.

Gender	Flexibility tests	Correlations	LUBAD	LBLBAD	LBPAG
Girls (♀)	Sit and Reach (cm) (SRT)	r	-.875**	-.793**	-.486*
		p	.000	.000	.012
	Baseline Sit and Reach (cm) (MSRT)	r	-.779**	-.715**	-.278
		p	.000	.000	.169
Boys (♂)	Sit and Reach (cm) (SRT)	r	-.829**	-.466**	-.765**
		p	.000	.000	.000
	Baseline Sit and Reach (cm) (MSRT)	r	-.666**	-.340**	-.604**
		p	.000	.000	.000

$p<0.05$, LUBAD: Lower-Upper Body Angle Degree, LBLBAD: Lower Body-Lower Back Angle Degree, LBPAG: Lower Body-Pelvic Angle Degree.

In Table 2 it can be seen that the girl's reachability in SRT and MSRT increases in parallel with the decreases of the LUBAD (SRT: r=-.875, MSRT: r=-.779), but not at the same ratio of correlations of LBLBAD (SRT: r=-793, MSRT: r=-.715) and LBPAG (SRT: r=-.486) resulted to be significant to the SRT and MSRT test, where the correlation ratio is meaningfully lower compared to the LUBAD correlation ratios. In addition, correlations between MSRT and LBPAG resulted to be significantly not different (r=-.278).

Similar results can be seen in boys, where the reachability in SRT (LUBAD: r=-.829, LBLBAD: r=-.466, LBPAG: -.765), and MSRT (LUBAD: r=-.666, LBLBAD: r=-.340, LBPAG: -.604) resulted to be statistically significant but the ratio of the correlation is meaningfully lower in LBLBAD and LBPAG compared to the correlation ratio of the LUBAD.

Figure 3. Girls' (A) and boys' (B) reachability percentage.

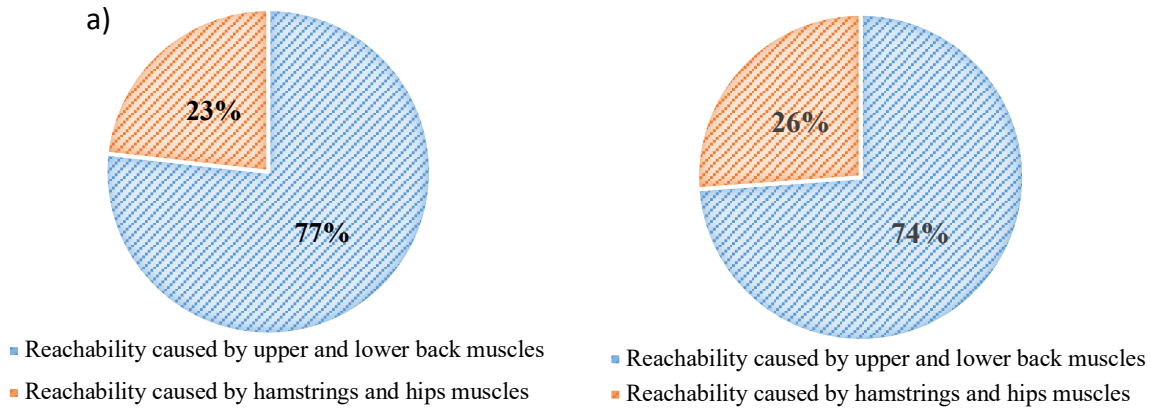


Figure 4a has shown that while the 77% of the reachability of the girl students is caused by the upper and lower back muscles, 23% of it is caused by the hamstrings and hips muscles' active flexibility. Similar to the girls, Figure 4b has shown that 74% of the reachability of the boy students is caused by the upper and lower back muscles, and 26% of it is caused by the hamstrings and hips muscles' active flexibility.

DISCUSSION

The study was made to develop a new method of active flexibility measurement which is being measured by using the methods or tests which's accuracy and ability to explain the results are low. The most common test in use for active flexibility is sit-and-reach which is earnestly affected by the anthropometric features and the ability to explain the ratio of muscle groups' inclusion is low. To address the problem, there is a method called the baseline method which is developed to remove the mentioned problem in the sit-and-reach test. Unfortunately, as the sit-and-reach method tends to show more flexible people whose arms, and the trunk is long or whose legs are short, similarly baseline sits and reach test tends to show more flexible people whose arms are short. There are studies in the literature where the measurement of flexibility was made by using different methods to increase the accuracy of measurement. In the study made by (López-Miñarro, Sáinz de Baranda, Rodríguez-García, & Yuste, 2008), there was used an inclinometer in order to measure the flexibility (López-Miñarro et al., 2008; Youdas, Krause, & Hollman, 2008).

So, let us discuss the new approach to measurements provided by this study. As can be seen in Tables 1 and 2, in both genders lower-upper body angle degrees were smaller than lower body-

lower back and lower body-pelvic angle degrees, which means that reachability in sit-and-reach and baseline sit-and-reach tests is not caused just by the hip's muscles flexibility. A significant amount of reachability is caused by upper back muscles' flexibility. This contradicts the sit-and-reach test and baseline sit-and-reach methods for testing reachability of only hamstrings and hips muscles.

Three measurement methods have shown that girls' active flexibility is higher than boys. In addition, the largest differences occur in lower body-lower back angle degrees, where girls' results are much better than boys. The pelvic tilt explained more than 60% of the variance (distance reached in the SR test) and lumbar flexion explained more than 80% of the variance (Muyor, Zemkova, Stefanikova, & Kotyra, 2014). In addition, findings of the study shown that while in the boys' differences between lower-upper body angle degree and lower body-lower back angle degree resulted to be significant, the same comparisons did not significantly differ among girls. In other words, in comparison to the girls, boys have to use more flexibility of the upper back and erector muscles to cover the lack of active flexibility of the lower back, hips, and hamstrings muscles. Among individuals with short hamstrings, increased flexion of the thoracic spine and decreased range of motion of the hip and lumbar spines were observed during a toe touch test (Gajdosik, Albert, & Mitman, 1994).

Furthermore, while 77% of the reachability of the girl students is caused by the lower and upper back muscles, 23% of it is caused by the hamstrings, and hips muscles' active flexibility. Similar to the girls, Figure 2 has shown that 74% of the reachability of the boy students is caused by the upper back, and 26% of it is caused by the hamstrings, and hip muscles active flexibility.

The analysis of different perspectives given in Table 2 has shown that besides expected significant correlations between lower-upper body and reachability tests such as sit-and-reach and baseline sit-and-reach, although a small amount of correlation between reachability tests and lower body-lower back and lower body-pelvis angle degrees resulted to be significant in both genders. These results are proof of the fact that reachability does not depend just on the flexibility of the lower back, hips, and hamstrings muscles. As was mentioned in the previous parts of the discussion which highlighted boys, both genders use the upper back and erector muscles' active flexibility to increase reachability measured by using the sit-and-reach and baseline sit-and-reach test. A similar result has been found in the literature reporting that a moderate correlation was found between the hip joint angle and the sit-and-reach test ($r=0.48$) (Kawano et al., 2010).

These results verify the validity of the main hypothesis of this study which claims that reachability is not caused just by the hamstrings and hips muscles as the sit and rich method is based on. Several sit-and-reach tests are commonly used in health-related and physical-fitness test batteries to evaluate the hamstring and lower back flexibility (Hui & Yuen, 2000). The tests in which a fingertips-to-tangent feet distance is measured are probably the most widely used linear measures of flexibility (Castro-Pinero et al., 2010). However, there is little research evidence that any kind of sit-and-reach test adequately measures low-back flexibility.

Based on the results of the study, reachability performance measured by the sit-and-reach and baseline sit-and-reach test is not limited to the lower back, hips, and hamstring muscles. Upper back muscles are directly involved in the reachability performance where the girls resulted to use in a higher ratio (77%) the upper back flexibility, in order to cover the lack of hips, and hamstrings muscles flexibility while they perform tests such as sit-and-reach and baseline sit-and-reach.

The method used in this study may be more beneficial to determine the level of active flexibility separately in the upper back, lower back, hips, and hamstrings muscles. In addition, in case the flexibility of these muscle groups is measured by using sit-and-reach test anthropometric features will interfere the results. The accuracy of muscles flexibility determination will be lower because among the factors that affect the reachability are not just muscles flexibility but also anthropometric features such as long arms and trunk. At the same time, long legs may cause a decrease in reachability which is expressed in centimeters (Remian & Manske, 2009).

CONCLUSION

Finally, it can be concluded that a measurement method of reachability and active flexibility of muscles such as the upper back, lower back, hips, and hamstrings, which is based on three (LUBAD, LBLBAD, LBPAD) angle degrees, is more valid and reliable method and provides more information compared to the previous methods such as sit-and-reach and baseline sit-and-reach tests which give results in centimeters and cannot separate the ratio of inclusion of the muscles and anthropometric features in reachability performance.

However, both sit-and-reach and baseline (modified) sit-and-reach tests are valid tests for measurement of the reachability on the bench without any explanation about which muscles are

the cause of the reachability, anthropometric features inclusion ratio, or without being able to explain which group of muscles have a lack of high active flexibility.

In the case of a needed reachability score, but no need for an explanation of the reachability and included factors, sit-and-reach and baseline (modified) sit-and-reach tests are valid to be used.

In the case of needed reachability score and necessarily needed explanation of the reachability and included factors such arm, trunk, and leg length or upper back, lower back, hips or hamstrings muscles inclusion ratio, a method is given in this study which is based on angle degrees (LUBAD, LBLBAD, LBPAD) is more valid and may give a result with more accuracy and details.

To increase the accuracy of our measurement method for active flexibility, where results are given in angle degrees, not in centimeters, carrying out the results using the x-ray method instead of using photographs of the sit-and-reach position would be more appropriate from an accuracy perspective. Another method of measurement for active flexibility which may be appropriate is the inclinometer.

Strengths and Limitations

The strength of the study is based on the fact that the new approach of active flexibility measurement provided by this study seems to be a more valid and reliable method and provides more information compared to the previous methods such as sit-and-reach and baseline sit-and-reach tests which give results in centimeters and cannot separate the ratio of inclusion of the muscles and anthropometric features in reachability performance.

The study is limited to physical education and sport science students. The developed new approach of active flexibility measurements may not be valid for the different categories of the population. The anatomical points of the angles were made on sportive light wear. Determining the anatomical points directly on the skin in future studies will reduce the measurement error.

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Declarations of Conflicting 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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ANALYSIS OF APNEA DIVING DEVELOPMENT TRENDS IN POOL DISCIPLINES FROM 2002 TO 2021

ANALIZA TRENDOV RAZVOJA POTAPLJANJA Z APNEJO V BAZENSKIH DISCIPLINAH OD LETA 2002 DO 2021

ABSTRACT

Apnea diving as a sport has evolved to such an extent that many professional divers have managed to achieve results that were considered impossible ten years ago. The predictions of doctors and experts in static apnea, long-distance diving and achievable depths have been exceeded. The aim of this research is to analyze this trend and determine the development curve for the best results in the world between professional apnea divers in pool disciplines over the last 20 years. The sample of subjects in this work consists of the three best world results of free-breath divers in pool disciplines (STA, DNF, DNY) from 2002 to 2021. The variables used in the research are dynamics without flippers (DNF), dynamics with flippers (DYN) and statics (STA) in men. The data was collected from the official websites of the International umbrella diving organizations - AIDA and CMAS. Collected data was processed using a method, algorithm and trend analysis program in the Statistica 13.0 software package. A polynomial regression analysis was used to analyze the development trend of the best results in a given year for each discipline. The coefficient of determination (STA Multi. R=0.77 p≥0.00, DYN Multi. R=0.87 p≥0.00, DNF Multi. R=0.90 p≥0.00) of the positive correlation of the results, while statistical significance was determined by the analysis as a consequence of the constant change in the results. According to the data obtained from the research, a linear increase in results in all three disciplines (statics, dynamics without flippers, dynamics with flippers) between 2002 and 2021 can be determined. According to the analyzed literature, important success factors are knowledge of certain physiological properties, the physical condition of the individual and the optimization of energy.

Keywords: apnea, trend analysis, static apnea, dynamic without fins, dynamic with fins

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IZVLEČEK

Potapljanje z apnejo se je kot šport razvilo do te mere, da je mnogim profesionalnim potapljačem uspelo doseči rezultate, ki so pred desetimi leti veljali za nemogoče. Napovedi zdravnikov in strokovnjakov s področja statične apneje, potapljanja na dolge razdalje in dosegljivih globin so bile presežene. Namen te raziskave je analizirati ta trend in določiti razvojno krivuljo za najboljše rezultate na svetu med profesionalnimi potapljači z apnejo v bazenskih disciplinah v zadnjih 20 letih. Vzorec preiskovancev sestavljajo trije najboljši svetovni rezultati potapljačev v bazenskih disciplinah apneje (STA, DNF, DNY) od leta 2002 do 2021. Spremenljivke, uporabljene v raziskavi, so dinamična apneja brez plavuti (DNF), dinamična apneja s plavutmi (DYN) in statična apneja (STA) pri moških. Podatki so bili zbrani na uradnih spletnih straneh mednarodnih krovnih potapljaških organizacij - AIDA in CMAS. Zbrani podatki so bili obdelani s programom za analizo metod, algoritmov in trendov v programskem paketu Statistica 13.0. Za analizo trenda razvoja najboljših rezultatov v posameznem letu za vsako disciplino je bila uporabljena polinomska regresijska analiza, medtem ko je bila statistična značilnost določena z analizo kot posledica konstantne spremembe rezultatov. Koeficient determinacije (STA Multi. R=0.77 p≥0.00, DYN Multi. R=0.87 p≥0.00, DNF Multi. R=0.90 p≥0.00) kaže pozitivne korelacije rezultatov. Glede na podatke, pridobljene z raziskavo, je mogoče ugotoviti linearno naraščanje rezultatov v vseh treh disciplinah (statična apneja, dinamična apneja brez plavuti in s plavutmi) med letoma 2002 in 2021. Glede na analizirano literaturo so pomembni dejavniki uspeha poznavanje določenih fizioloških lastnosti, telesna pripravljenost posameznika in optimizacija energije.

Ključne besede: apneja, analiza trendov, statična apneja, dinamična apneja brez plavuti, dinamična apneja s plavutmi

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INTRODUCTION

Ever since the first apnea diving competition was organized, there has been a debate about when the ultimate limits of this mystical sport will be reached, and what factors will be key to determining those limits. To date, free-breath divers have largely exceeded all predictions of doctors and experts in static apnea, long-distance diving and reachable depths. A common factor in all competitive disciplines is the duration of apnea, which can be prolonged by any means that increases total gas storage capacity, increases tolerance to asphyxia (suffocation) or slows metabolism (Schagatay, 2009). These main factors can be divided into several physiological and psychophysiological factors. As in other sports, the main goal in competitive apnea diving is to increase results above known limits. While a beginner can improve their results by pushing themselves closer to their personal limits, top apnea divers can increase their apnea time just by pushing their personal limits through training.

To achieve this, it is essential to identify factors predicting results and which of these factors can be improved by training. Great progress has been made in all diving disciplines in recent years, and in static apnea, the ten-minute barrier was broken for the first time, while the average person can hold their breath for only about 30 seconds (LeRoy, 2017). However, current training methods and strategies suggest that apnea duration can be extended even further, while freedivers themselves predict that the ultimate limit will be 15 minutes, which seems physiologically possible, due to the improvement and use of techniques to further slow down the metabolism (Schagatay, 2009). The main goal is to achieve maximum performance in one dive.

Records have been set at almost every competition and there is still no sign of this trend slowing down. The male world record in deep diving (CWT) is -130 m, the record in distance diving with flippers (DYN) is 300 m, and for breath-holding at rest (STA) is 11:35 min. Women's world records -114 m (CWT), 275 m (DYN) and 9:02 min (STA), 201 m (DNF), which are equivalent to men's world records set just a few years ago and are developing just as rapidly. Part of the explanation for this phenomenon is that the number of competitors is increasing and there is an increasing number of relevant scientific research on the world's best apnea divers. In addition, diving techniques and strategies have advanced significantly in recent decades. An undoubtedly important aspect of the development and spread of effective training methods is the emergence of systematic apnea training. The complexity of apnea diving is particularly evident in the need for excellent coordination in numerous dimensions, such as abilities and

traits in the current mental state of the competitor. The success of a apnea diver is determined by the synergy of technique, level of training for hypoxic and hypercapnic conditions, energy capacity and motor skills (Drviš, 2012). Previous research comparing apnea divers with people who do not do sports has shown differences in psychological factors that give astonishing results. The results indicate that apnea divers achieved lower scores in terms of anxiety and stress symptoms, compared to people who do not do sports. The results obtained below indicate that apnea divers are individuals who have fewer symptoms of stress and anxiety (Alkan, Akis, 2013). The main characteristic of apnea, which distinguishes it from other sports, is that in apnea the success and performance of divers under water is related to their psychological and physiological limits (Alkan, Akis, 2013). The average diver should aim for good cardiovascular conditioning and aerobic activity at least three days a week for a minimum of 30 minutes. In addition, good physical preparation can help the diver in general and better prepare them for the challenges of diving (Jablonski, 2000:121). Dujić et al. (2013:303) state that, "success in apnea diving depends on how well the diver tolerates the physiological and psychological stress associated with the depth and duration of the dive".

Man has the ability to adapt to the conditions of diving under water, thanks to the inherited mammal reflexes. It is precisely this kind of modification that enable the human body to adapt to the depths and endure more without breathing than would be possible without this reflex. Although man continuously surpasses former theories about the possibility of holding their breath underwater, practicing maximum apnea can lead to numerous health problems and long-term organ damage, however, the long-term risks of extreme apnea diving have not yet been sufficiently investigated. Exposure to extreme depths and long-term apnea can cause dangerous consequences and acute health problems such as "lung collapse, barotrauma caused by pressure changes during immersion and ascent, pulmonary edema and alveolar hemorrhage, cardiac arrest, fainting, nitrogen narcosis, decompression sickness and even death" (Dujić et al., 2013:302).

Newer research and studies are studying adaptation mechanisms that enable humans to dive to extreme depths of more than 100 meters without any breathing equipment. "These adaptive mechanisms include peripheral vasoconstriction, bradycardia with reduced cardiac output, reactive hypertension, and a blunted response to hypercapnia" (Scherhag et al., 2005). The aim of this research is to analyze this trend and determine the development curve of the best results in the world of professional apnea divers in pool disciplines in the last 20 years.

METHODS

The subject sample for this research consists of the three best world results of free-breath divers in pool disciplines (STA, DNF, DNY) from 2002 to 2021. The variables used in the research are dynamics without flippers (DNF), dynamics with flippers (DYN) and statics (STA) in men. The data was collected from the official websites of the International umbrella diving organizations - AIDA and CMAS. Collected data was processed using the method, algorithm and trend analysis program from the Statistica 14.0 software package. A polynomial regression analysis was used to analyze the development trend of the best results in a given year for each discipline. For the analyzed disciplines, one-dimensional changes in the condition of divers over the years are shown, where over a period of time a change in one quantitative variable was registered.

RESULTS

Table 1 shows the three best apnea diving results in the "statics" discipline in the period from 2002 to 2021, as well as descriptive statistics for the results shown. According to the given data, the most success in the statistics discipline was achieved in 2017 with a result of 10 min and 45 s.

Table 1. List of the three best results, expressed in minutes, in the "statics" discipline, arranged by year and with their descriptive statistics from 2002 – 2021.

	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
1.	5:31	6:31	8:58	7:34	8:33	8:40	8:17	9:03	8:42	10:23
2.	5:12	6:04	8:56	7:13	7:27	7:21	8:05	8:09	8:35	8:35
3.	5:03	5:35	8:07	6:56	7:18	7:16	7:57	8:02	8:15	8:18
A.S.	5:15	6:03	8:40	7:14	7:46	7:45	8:06	8:24	8:30	9:05
ST.DEV.	14.30	28.00	28.89	19.04	40.95	47.12	10.07	33.38	14.01	67.80
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
1.	10:05	9:19	10:32	8:21	9:14	10:45	9:42	9:35	9:02	8:52
2.	9:21	8:44	9:04	8:08	9:05	9:58	9:26	9:16	8:51	9:28
3.	8:38	8:06	9:04	8:33	8:57	9:36	9:05	9:12	8:50	8:53
A.S.	9:21	8:43	9:33	8:20	9:05	10:06	9:24	9:21	8:54	9:04
ST.DEV.	43.50	36.51	50.81	12.50	8.51	35.25	18.56	12.29	6.66	20.50

Legend: A.S. - arithmetic mean, ST. DEV. - standard deviation

Figure 1 shows the best results in the period from 2002 to 2021 in the discipline "statics". While analyzing the results, a relative growth is visible in the period from 2005 to 2017, with occasional intervals of decline (2013, 2015), while the best result was achieved in 2017, and in the years after that, a further decline was recorded compared to 2017. The coefficient of determination in Table 2 shows the link of moderate positive correlation of the results, while the analysis established statistical significance as a consequence of the constant change of the results.

Figure 1. Approximate display of the best results in the "statics" discipline, in the period from 2002 to 2021, according to the equation of the polynomial regression analysis of the first degree.

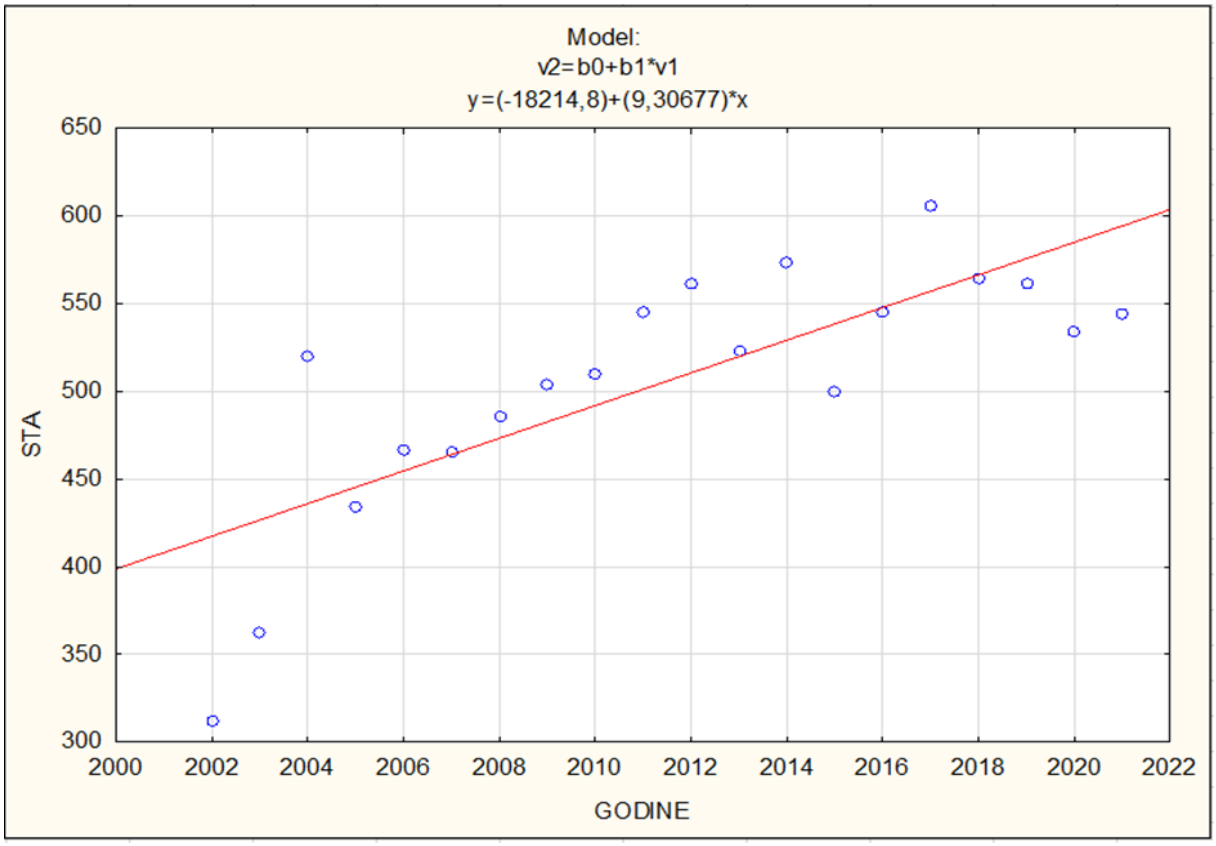

Table 2. The statistical processing of the best results in the "statics" discipline, in the period from 2002 to 2021.

STA	Multiple R	R^2	b		p
Polinom			b0	-18214.8	0.00
Years	0.77	0.60	b1	9.3	0.00

Legend: Multiple R - correlation coefficient, R^2 - coefficient of determination, b - regression coefficient, p - statistical significance.

Table 3 shows the three best results in the discipline "dynamics with flippers" in the period from 2002 to 2021. According to the collected data, the best result was achieved in 2019 at the European Championship held in Istanbul, Turkey.

Table 3. List of the three best results, expressed in meters, in the "dynamics with flippers" discipline, by year and with their descriptive statistics.

	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1.	109	153	163	156	207	244	250	233	265
2.	109	122	157	142	162	234	222	226	257
3.	106	122	157	140	162	226	215	207	244
A.S.	108.0	132.3	159.0	146.0	177.0	234.7	229.0	222.0	255.3
ST.DEV.	1.73	17.90	3.46	8.72	25.98	9.02	18.52	13.45	10.60
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1.	273	249	232	288	294	300	279	279	316
2.	261	232	228	275	277	285	275	265	284
3.	251	228	227	269	265	273	267	259	276
A.S.	261.7	236.3	229.0	277.3	278.7	286.0	273.7	267.7	292.0
ST.DEV.	11.01	11.15	2.65	9.71	14.57	13.53	6.11	10.26	21.17
	2020	**2021**							
1.	269	278							
2.	266	264							
3.	260	265							
A.S.	265.0	269.0							
ST.DEV.	4.58	7.81							

Legend: A.S. - arithmetic mean, ST. DEV. - standard deviation.

By analyzing the data from Figure 2, intervals of decline, stagnation and growth of the results can be observed over the years, while the best result was achieved in 2019. The coefficient of determination in Table 4 shows a strong positive correlation of the results, and further analysis established statistical significance based on the constant change in the results.

Table 4. The statistical processing of the best results in the "statics" discipline, in the period from 2002 to 2021.

DYN	Multiple R	R^2	b		p
Polinom			b0	-16310.4	0.00
Years	0.87	0.77	b1	8.2	0.00

Legend: Multiple R - correlation coefficient, R^2 - coefficient of determination, b - regression coefficient, p - statistical significance.

Figure 2. Approximate display of the best results in the the "dynamics with flippers" discipline, in the period from 2002 to 2021, according to the equation of the polynomial regression analysis of the first degree.

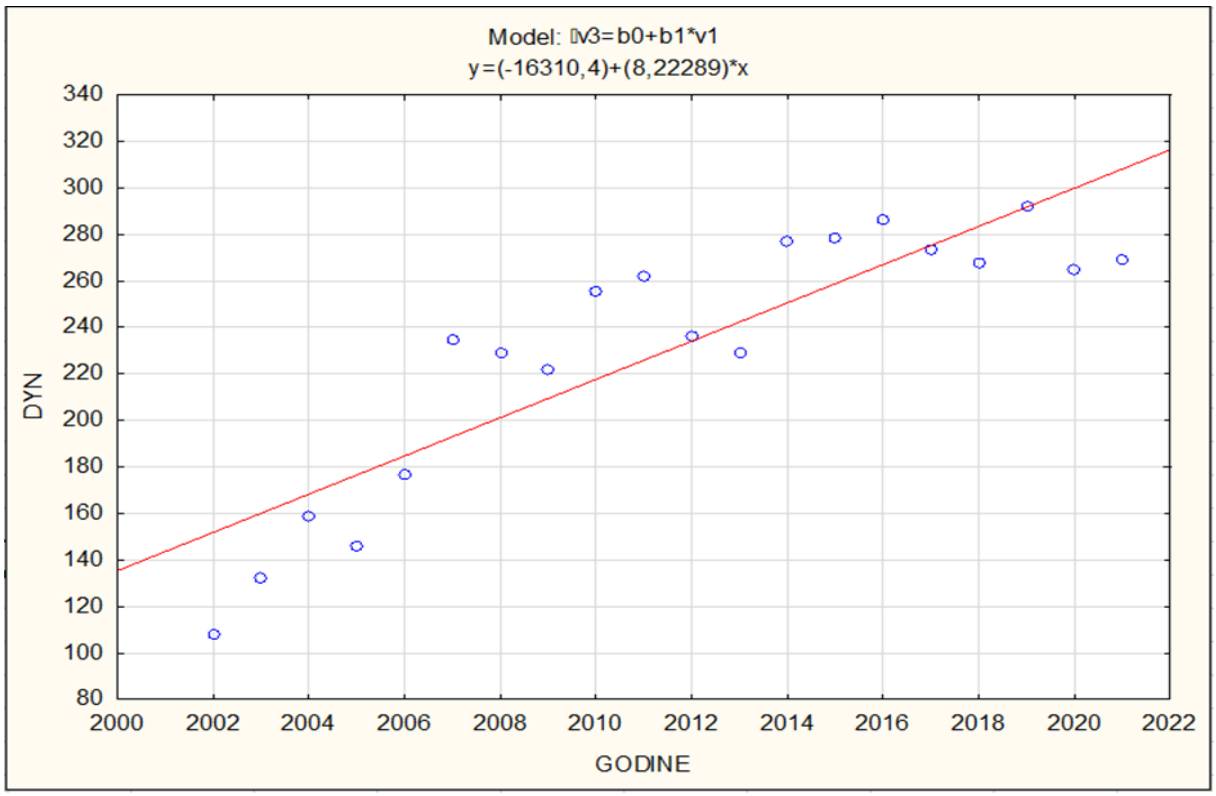

Table 5 shows the list of the three best results in the discipline "dynamics without flippers" in the period from 2002 to 2021. The best result in the mentioned discipline was 240 meters, achieved in 2019. Figure 3 presents a graph of the results achieved in the period from 2002 to 2021 in the discipline "dynamics without flippers", arranged according to the equation of the first-degree polynomial regression analysis. A significant increase in results was recorded in the period from 2006, after which the value grew linearly until 2012. After the drop in results in 2012, there was predominantly an increase in results, with smaller intervals of decline, until the best result was achieved in 2019. The coefficient of determination in Table 6 shows a strong positive correlation of the results, and statistical significance was established because it shows constant changes in the results.

Table 5. List of the three best results, expressed in meters, in the "dynamics without flippers" discipline, by year and with their descriptive statistics.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
1.	81	93	106	109	176	175	213	232	218
2.	81	88	104	106	139	155	175	166	200
3.	75	83	100	105	131	151	165	158	175
A.S.	79	88	103	107	149	160	184	185	198
ST.DEV.	3.46	5.00	3.06	2.08	24.01	12.86	25.33	40.61	21.60
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1.	207	200	206	226	203	211	215	208	240
2.	200	180	188	213	200	209	205	206	234
3.	196	179	184	205	200	208	201	203	236
A.S.	201	186	193	215	201	209	207	206	237
ST.DEV.	5.57	11.85	11.72	10.60	1.73	1.53	7.21	2.52	3.06
	2020	**2021**							
1.	229	204							
2.	225	226							
3.	218	200							
A.S.	224	210							
ST.DEV.	5.57	14.00							

Legend: A.S. - arithmetic mean, ST. DEV. - standard deviation.

Figure 3. Approximate display of the best results in the "dynamics without flippers" discipline, in the period from 2002 to 2021, according to the equation of the polynomial regression analysis of the first degree.

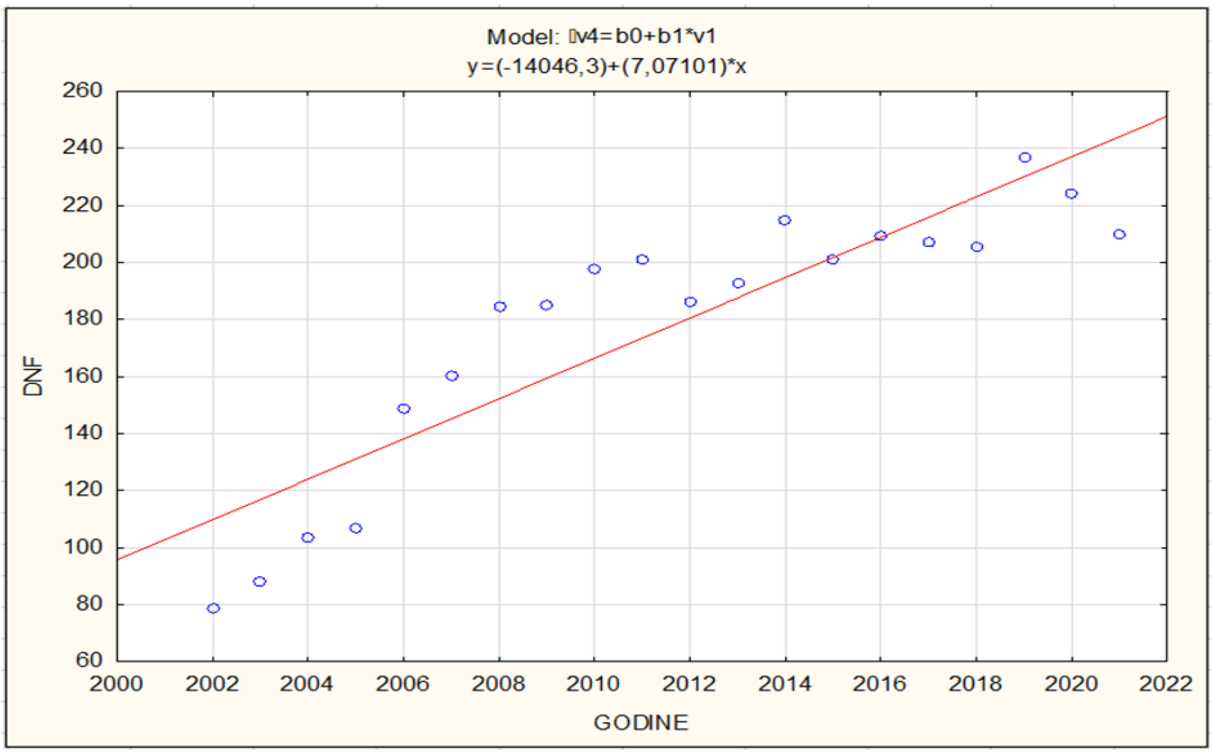

Table 6. The statistical processing of the best results in the "dynamics without flippers" discipline, in the period from 2002 to 2021.

DNF	Multiple R	R^2	b		p
Polinom			b0	-14046.3	0.00
Years	0.90	0.80	b1	7.1	0.00

Legend: Multiple R - correlation coefficient, R^2 - coefficient of determination, b - regression coefficient, p - statistical significance.

DISCUSSION

According to the data obtained from the research, a linear increase in results in all three disciplines (statics, dynamics without flippers, dynamics with flippers) between 2002 and 2021 can be determined. The linear improvement of results over the years can be seen through the conducted statistical analysis, however there are variations in certain years where there is stagnation, decline or a sudden increase in results. In the discipline of statics, the progress of the results is clearly visible (Table 2), but already in 2004, a sudden improvement of the results can be noticed. The sudden improvement in results can be confirmed by the exponential growth of scientific research in the field, for example, the "Handbook of Freediving" by Umberto Pelizzari and Stefano Tovaglieri has become part of the basic literature in the sport of freed apnea diving. In addition to the above, Dujić et al. (2013) conducted plentiful research in the field of apnea diving, studying the principles of action and consequences of apnea diving on the human body as well as techniques for preparing the body for immersion. In addition, there is a lot of literature that emphasizes the importance of fitness preparation for achieving results and success in competitive apnea diving (Drviš, 2012). At the same time, that year, the German apnea diver Tom Sietas achieved unattainable results for other competitors and set a new AIDA world record. Between 2005 and 2017, there is a clear constant increase in results, with a decrease in results in 2013 and 2015 (Figure 1). Snorkeling is a relatively young sport that is continuously growing in popularity. From this progressive improvement of the results, it can be concluded that the human limits in apnea diving have not yet been reached. Technically innovative equipment and the discovery of new training techniques combined with the growing popularity of this sport, leads to the conclusion that the results will continue to improve in the coming years (Pelizzari, Tovaglieri, 2004).

Analyzing the development trend of the three best results in the dynamics with flippers pool discipline in the 2002 to 2021 period (Table 3, Figure 2), an exponential improvement of results is visible. The best result of 316 meters, in the discipline of dynamics with flippers, was achieved in 2019. In the last two decades, competitive apnea diving has shown great progress. For example, from 12 men's and women's world records that were achieved in the six main competitive disciplines in January 2009, only three remained unchanged the following year. The main problem with divers is whether the safety measures implemented during training and competition can keep up with human limits in the length, depth and duration of the dive (Schagatay, 2010). Patrician et al. (2021) emphasizes that it is important to understand the factors that determine the breath-holding period: besides the extreme interest in human physiology, as well as in the preparation of athletes for apnea competitions, it is important to know the safety and medical points of view in order to improve the rules within the AIDA and CMAS organizations.

Exploration of the results in the discipline of dynamics without flippers in the period from 2002 to 2021 shows a continuous improvement of the results, which can also be explained by the fact that over the years this sport has become a common subject of research, arousing the interest of scientists by breaking through both physiological and psychological assumptions about human abilities. By analyzing the trend of competition results, it can be concluded that there has been a big shift forward in the last 20 years (Table 6; Figure 3). In apnea diving, a sport that does not depend so much on technological innovations, but on human physiological and psychological characteristics, the limitation of energy consumption is more important than speed. Preparation before the competitions itself has also changed over the years, and is equally important for a good result. Previous research shows that different preparation strategies can be used before diving, but there is no "recipe" that promises good results. A few years ago, the standard warm-up consisted of immersion and various breathing techniques, in comparison to more recently where a method without warm-ups and breathing exercises before the competition is common. Top divers also started using this newer strategy (Schagatay, 2010). For example, one of the breathing exercises before diving is described by Patrician et al. (2021:2), saying that most divers practice lung-packaging - glossopharyngeal insufflation before diving, because performing this preparation "can increase lung volume from 11 to 26 percent". Bouten et al. (2019) conducted an eight-week study where they analyzed the effects and impacts of apnea training. They concluded that the volume of the spleen can be increased using apnea training. Contraction of the spleen is a very important response to acute apnea and causes the release of

red blood cells into the bloodstream. Patrician et al. (2021:5) also discusses the importance of splenic contraction because "hemoconcentration via splenic contraction would increase CO2 (assuming all else remains equal) by ~5%, which may provide a protective benefit immediately after emergence to avoid hypoxic loss of consciousness". In addition, the spleen has been used as a site for additional storage of red blood cells in a large number of mammals. In humans, marine mammals and some endurance runners such as horses, this storage capacity can be called upon when increased oxygen transport is required. Spleen contraction in humans was first described in Ama divers and is induced mainly by hypoxia and accompanied by hypercapnia (Richardson, 2008, according to Schagatay, 2014). Lemaître, Joulia and Chollet (2010:413) conducted a study of the physiological effects during apnea training in which elite apnea divers participated, and the results displayed that "the apnea divers showed reduced acidosis, oxidative stress and basal metabolic rate, and also increased values of hepatocytes, hemoglobin mass and lung volume. The results obtained indicate that apnea training can be an effective substitute for hyperbaric or normobaric hypoxia for increasing aerobic and/or anaerobic results".

Snorkeling is a sport that increasing arouses interest among athletes, but also among scientists who research and explain the principles by which it is possible to achieve evidently growing results, which require excellent physiological and psychological abilities. From the very beginnings to the latest results in apnea diving, all the predictions of doctors and experts in static apnea, long-distance diving and reachable depths have been surpassed. The results of the research showed a progressive growth of results over the years, with occasional intervals of stagnation and decline. Constant progress of results in competitive apnea diving in all three disciplines was recorded (Figure 1, Figure 2, Figure 3).

It is assumed that the evolution of this sport and the exponential growth of literature in the field of apnea diving has resulted in a significant, continuous increase in results. According to the analyzed literature, an important success factor is the knowledge of certain physiological properties, the physical condition of the individual and the optimization of energy. In addition to the above, it is extremely important to carry out adequate preparation and maintain good physical condition in order to reduce the possibility of injuries and avoid long-term health consequences. In order to determine the exact factors that influenced the improvement of the results, it is necessary to carry out more detailed analysis that include preparations before diving, training methods and other factors that can affect the achievements of apnea divers. According to previous research, there are physiological factors that can affect the time a diver

spends under water, such as lung capacity, spleen size, etc. Considering the trend of growth in results in the last twenty years and new methods of training as well as preparation of athletes before diving, we can expect this trend to continue in the coming years.

Declaration of Conflicting Interests

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

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BLOOD BIOCHEMICAL CHANGES AFTER DRAMATIC INCREASE IN RUNNING TRAINING VOLUME: EXPLORATORY STUDY IN 3 ELITE SOLDIERS

BIOKEMIČNE SPREMEMBE V KRVI PO DRAMATIČNEM POVEČANJU OBSEGA TEKAŠKE VADBE: RAZISKOVALNA ŠTUDIJA PRI TREH ELITNIH VOJAKIH

ABSTRACT

Ultra-Endurance running training is a powerful stressor for all biological systems and depends mainly on its volume and intensity. Although the high physical demands, soldiers are an unstudied group and information on exercise indicators are essential. This study aimed to observe the changes in serum biochemical indicators in previously endurance trained elite soldiers after a 17-week training program with a dramatic increase in running volume. Three subjects (#1: 26 years, 169,5cm; #2: 27 years, 167,9cm; #3: 27 years, 180,7cm) running daily between 10-12 km/day, increased their running volume to prepare the participation in a 100-km ultramarathon race. For 17 weeks the training program included 10-12 sessions per week, corresponding to 200-260 km. Average daily running volume was 35.8±6.2 km. Blood samples were taken for analysis of urea, creatinine, glucose, cholesterol and triglycerides, AST, ALT, CK, aldolase, Na, chloride, P, Ca, K, Fe, Mg and cortisol. Despite a marked drop in iron and a rise in phosphorus, the overall mineral status remained within laboratory reference values. ALT, AST, Aldolase showed slight changes while a marked increase was found in CK. Creatinine decreased and urea maintained the high starting values. Changes of glucose, cholesterol and triglycerides had no clinical significance. After the 17-week the cortisol increased to outside of the reference values in two participants. This study shows that a dramatic increase in running training volume experienced by previous trained runners is mainly reflected in basal blood chemistry through the reduction of iron and creatinine and increase of cortisol.

Keywords: endurance training, enzymes, cortisol, iron

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IZVLEČEK

Vadba teka za izjemno vzdržljivost je močan stresor za vse biološke sisteme in je odvisen predvsem od njegovega obsega in intenzivnosti. Kljub visokim fizičnim zahtevam so vojaki neraziskana skupina, zato so informacije o kazalnikih vadbe bistvenega pomena. Namen te študije je bil opazovati spremembe biokemičnih kazalnikov v serumu pri predhodno vzdržljivostno treniranih elitnih vojakih po 17-tedenskem programu vadbe z dramatičnim povečanjem obsega teka. Trije preiskovanci (#1: 26 let, 169,5 cm; #2: 27 let, 167,9 cm; #3: 27 let, 180,7 cm), ki so dnevno pretekli med 10 in 12 km/dan, so povečali obseg teka, da bi se pripravili na udeležbo na ultramaratonskem teku na 100 km. Program vadbe je 17 tednov vključeval 10-12 vadb na teden, kar ustreza 200-260 km. Povprečni dnevni obseg teka je bil 35.8 ± 6.2 km. Odvzeti so bili vzorci krvi za analizo sečnine, kreatinina, glukoze, holesterola in trigliceridov, AST, ALT, CK, aldolaze, Na, klorida, P, Ca, K, Fe, Mg in kortizola. Kljub izrazitemu padcu železa in porastu fosforja je splošno stanje mineralov ostalo znotraj laboratorijskih referenčnih vrednosti. ALT, AST in aldolaza so se rahlo spremenile, medtem ko se je CK izrazito povečala. Kreatinin se je zmanjšal, sečnina pa je ohranila visoke začetne vrednosti. Spremembe glukoze, holesterola in trigliceridov niso bile klinično pomembne. Po 17 tednih se je kortizol pri dveh udeležencih povečal in presegel referenčne vrednosti. Ta študija kaže, da se drastično povečanje obsega tekaške vadbe, ki so ga doživeli predhodno trenirani tekači, odraža predvsem v bazalni biokemiji krvi z zmanjšanjem železa in kreatinina ter povečanjem kortizola.

Ključne besede: vadba za vzdržljivost, encimi, kortizol, železo

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INTRODUCTION

Changes induced by a single physical load are temporary and return to basal level within few days. Nevertheless, arduous training regimens imposing continuous loads can elicit changes that persist over time. Long-distance running training is a powerful stressor that induces specific adaptations according to the intensity, volume and frequency of training loads. Prolonged endurance running can lead to biochemical changes consistent with tissue destruction that provoke leakage of intracellular muscle components into the extracellular fluid (Bäcker, Richards, Kienzle, Cunningham, & Braun, 2023). Several enzymes can leak to plasma after long lasting exertion. Strenuous exercise leading to liver hypoxia can cause cell injury with subsequent release of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) (Pettersson et al., 2008). Despite AST enzyme reflects the integrity of hepatocytes the behavior of its plasmatic expression, in particular its post-exercise increase, in addition to the elevation of myoglobin, troponin I, fragments of the myosin heavy chain and total creatine kinase concentrations, are relevant indicators in the diagnosis of lesions of skeletal muscle tissue and cardiac muscle tissue (Clarkson, Kearns, Rouzier, Rubin, & Thompson, 2006). In order to show overload or liver damage AST/ALT ratio (De Ritis ratio) has been used (Ndrepepa, 2023) and when elevated it may indicate increased risk associated with hepatic and extrahepatic diseases indicating abnormalities at the level of basic metabolism. While AST and ALT are enzymes related with damaged hepatic cells, skeletal muscle injury produces high serum levels of Aldolase and creatine kinase (CK) (Brancaccio, Lippi, & Maffulli, 2010). The adaptations are mainly dependent on the subjects' training level although age, gender, race, muscle mass and climatic conditions can interfere with overall responses (Brancaccio, Maffulli, & Limongelli, 2007). Rodrigues dos Santos (2017) showed that after a 50-km running less trained runners, when compared to their more trained counterparts, showed a much higher rise in CK, AST, ALT, and Aldolase therefore, it seems that the training level determines the enzymatic response to effort. In addition, in the same study it was observed that the less trained runners had a delayed recovery. It seems that higher basal values of CK are associated with higher training volume and the reduction of training volume is reflected in the reduction of plasma CK (Houmard et al., 1990).

Studies on the behavior of blood lipids induced by exercise are inconsistent being difficult to establish a dose-response relationship (Leon & Sanchez, 2001). It seems that regular exercise provokes a 24% mean reduction in blood triglycerides (Trejo-Gutierrez & Fletcher, 2007). Immediately after exercise, plasma triglyceride concentration decreases with the concomitant

increase of free fatty acids indicating a strong lipid mobilization. And it seems that 24 hours of rest are sufficient to recover baseline values (Barakat, Kerr, Tapscott, & Dohm, 1981).

Long-lasting running leads to changes in the hypothalamic-pituitary-adrenocortical axis, increasing plasma cortisol concentration that only decreases significantly 2 days after exertion (Bobbert et al., 2005). It is also known that there is a close relationship between the iron status and physical performance in humans (McClung & Murray-Kolb, 2013). Exercise-induced hemolysis has been implicated in the sub-optimal status of endurance-trained athletes (Weight, Byrne, & Jacobs, 1991). Sodium, potassium, calcium, magnesium, and chloride are the crucial electrolytes that regulate muscle contraction (Kuo & Ehrlich, 2015). Sodium and chloride are the major electrolytes for hydric balance but are easily restored with an adequate and normal salted diet (Maughan & Shirreffs, 1997). When athletes during workouts match their fluid losses with the available commercial sport drinks, a significant intake of minerals is achieved and fluid balance and training capability is restored (von Duvillard, Arciero, Tietjen-Smith, & Alford, 2008).

High training volume is crucial for 100-km race performance (Knechtle, Knechtle, Rosemann, & Lepers, 2010) what put a big challenge for body's adaptation. This study sought to verify the biochemical changes induced by a severe increase in training volume, for 17 weeks, in previous moderate trained runners preparing for participation in a 100-km ultramarathon race.

METHODS

Participants

Three male soldiers from the Portuguese Army Elite Corps (Special Forces) participated in this study. Participant's age and height were as follows: subject #1 (26 years; 169.5 cm), subject #2 (27 years; 167.9 cm), and subject #3. (27 years; 180.7 cm). These participants were not typical athletes but very active elite soldiers that run as a fundamental part of their physical military preparation and, have more than 5 years of running training. They regularly engage in military orienteering races and sporadically in civil road races. Their periodical medical screening showed no health constraints, besides participants were non-smokers and non-alcoholic drinkers. During the year prior to this study participants usually ran 10-12 km daily. The participants can be considered non-elite runners (average rate of 4 min/km for the half-marathon) very far from middle- and long-distance elite runners' performance (average rate ≤

3 min/km at half-marathon). Prior to signing an informed consent form participants were informed about the benefits and risks of taking part in the current study, which was approved by the ethics board of the Faculty of Sport of the University of Porto. Experimental procedures were in accordance with Helsinki Declaration and ethical principles for medical research involving human subjects.

Training protocol

With the objective to compete in a military ultramarathon (100 km) participants executed 10-12 training sessions per week, totalizing 200-260 km. Average daily running volume was 35.8±6.2 km. Running intensity was controlled by Polar heart rate monitor with sensor chest strap. Low to moderate running pace was selected (130-160 beats per minute corresponding to 70-85% maximum heart rate) for continuous uniform running with 2 fartlek sessions per week (10 accelerations of 300m) inducing heart rates close to the maximum. They practiced twice a day on Tuesdays, Wednesdays, Thursdays, Fridays and Saturdays; and had only one workout on Sundays (the longest one) and on Mondays (the shortest one). Every four weeks during the first 3 months a performance test (30 km) was conducted which improved over time (week 4: 2h00; week 8: 1h57; week 12: 1h55). The performance test was preceded by a resting day. In the last week before testing, volume training was reduced in half while maintaining the usual intensity.

It should be noted that with the exception of fartlek training session, the continuous uniform running sessions were conducted at intensities below those which the participants were previously accustomed. The fundamental training goal was the completion of an ultramarathon (100-km) at an adequate pace to avoid overexertion while achieving the best performance possible.

Nutrition

Throughout the duration of the study, participants were requested to maintain their usual dietary diversity, increasing energy and carbohydrate intake *ad libitum*. During the study participants had no nutritional supplements. During training they usually drank a commercial isotonic drink.

Parameters evaluated

Blood Chemistry: Urea, creatinine, glucose, cholesterol, triglycerides, aspartate aminotransferase (AST), alanine aminotransferase (ALT), creatine kinase (CK), aldolase, calcium and phosphorus were measured with an auto-analyser Hitachi 705. Sodium, potassium,

and chloride were analysed with a flame photometer Korning 480. Iron and magnesium were assessed by manual technique. Cortisol was analysed by radioimmunoassay. All blood samples were collected after an overnight fast (12h) and a 24 hours compulsory rest period following the last workout, to attenuate the effects of hemodynamic variations and acute hemodilution induced by prior workout. The blood sample collection took place before and after the 17-week protocol.

RESULTS

Table 1 shows a marked decrease in body mass in all participants. Almost all biomarkers experimented slight variations and remained within clinical reference values with the exception of cortisol that exceeded the reference values in two participants with the other participant in the upper borderline. While serum iron and creatinine decreased, phosphorus increased in all participants. Initial chloride values are above the reference values, decreasing after training.

Table 1. Weight and Biochemical alterations induced by 17 weeks of training.

Variables (reference values)	Subject #1			Subject #2			Subject #3		
	M1	M2	M2-M1	M1	M2	M2-M1	M1	M2	M2-M1
Body mass (kg)	68.5	66.5	-2	69.3	65.5	-3.5	80.0	75.5	-4.5
Urea (2.9-8.9 mmol/L)	5.3	8	2.7	10.7	9.2	-1.5	8	7.5	-0.5
Creatinine (60-132 µmol/L)	129	93	-36	109	94	-15	111	85	-26
Glucose (3.6-6.1 mmol/L)	4.94	6.16	1.22	4.77	4.77	0	5.72	5.49	-0.23
Cholesterol (3.9-7.2 mmol/L)	4.1	4.3	0.2	4.4	3.9	-0.5	4.5	3.5	-1
Triglycerides (0.45-1.69 mmol/L)	0.6	0.8	0.2	0.7	1	0.3	1	1.1	0.1
AST (0-0.58 µkat/L)	0.31	0.23	-0.08	0.38	0.33	-0.05	0.41	0.28	-0.13
ALT (0-0.58 µkat/L)	0.33	0.23	-0.1	0.28	0.29	0.01	0.31	0.31	0
AST/ALT (<1)	0.94	1	-	1.36	1.14	-	1.32	0.90	-
CK (60-400 U/L)	78	124	46	112	138	26	98	116	18
Aldolase (0-6 U/L)	1.1	1	-0.1	1.5	1.3	-0.2	1.1	1.1	0
Cortisol (0-25 µg/dL)	18.8	**27.3**	8.5	18.9	**28.4**	9.5	18	24.4	6.4
Iron (9-31.3 µmol/L)	20.9	15	-5.9	18.8	12.9	-5.9	31.7	20.4	-11.3
Calcium (2.1-2.6 mmol/L)	2.32	2.39	0.07	2.27	2.19	-0.08	2.17	2.3	0.13
Phosphorus (1-1.5 mmol/L)	1	1.29	0.29	**0.84**	1.16	0.32	**0.84**	1.23	0.39
Magnesium (0.75-1.25 mmol/L)	0.8	0.87	0.07	0.95	0.94	-0.01	0.95	0.9	-0.05
Sodium (136-145 mEq/L)	138	139	1	137	138	1	139	138	-1
Potassium (3.8-5.5 mmol/L)	4.4	4.2	-0.2	4	4.4	0.4	4.8	4.9	0.1
Chloride (96-106 mmol/L)	**109**	105	-4	**109**	100	-9	**108**	100	-8

Reference values from Kratz et al. (2004)

Note: kg: kilograms; mmol/L: millimoles per litre; µmol/L: micromoles per litre; µkat/L:micro-katal per liter; U/L: units per litre; µg/dL micro-grams per deciliter; mEq/L: Milliequivalents per litre; M1: first assessment (week 0); M2: second assessment (week 17); M2-M1: differences between assessments. Bold means values are outside normal range.

DISCUSSION

A high volume of running training is essential to prepare and complete a 100-km ultramarathon with the best possible performance (Knechtle et al., 2010). This basic condition places enormous metabolic, hormonal, and enzymatic challenges with several disturbances in body homeostasis and the magnitude of alterations correlates well with the severity of exercise.

Findings of this longitudinal study showed that 17 weeks of high-volume training, as preparation for an ultra-marathon, resulted in a decreased BMI and iron levels and increased levels of CK, cortisol, phosphorus and chloride.

Long-term exercise acutely promotes plasma and serum increase in various biomarkers as glucose, calcium, phosphorus, urea, creatinine, ALT, AST, CK (Kratz et al., 2002), mainly derived from the increased protein catabolism.

Athletes are prone to display high resting urea concentrations when they practice daily (Warburton, Welsh, Haykowsky, Taylor, & Humen, 2002). This condition was verified in our study, with subject #1 sharply increasing his basal urea (50.9%) while the other two subjects maintained their high starting values after the 17-week training period. The elevation and maintenance of high plasma urea are according to the daily succession of intensive workloads that accentuate protein metabolism (Atherton & Smith, 2012). After a 100-km ultramarathon race, in 765 min, eight runners increased their serum urea from 5.69 ± 1.06 mmol/L to 9.61 ± 1.96 mmol/L. Three possible mechanisms may explain this rise: (i) reduced rate of elimination provoked by exercise, (ii) hypohydration, or (iii) increased urea production from the breakdown of amino acids during exercise. It seems that urea concentration after exercise depends on exercise duration (Haralambie & Berg, 1976). After three long-distance cross-country ski races Refsum & Strömme (1974) found production rates of urea about 60-80 per cent higher than in resting conditions. The return to the pre-race urea level lasted several days. For these authors, increase in serum urea was mainly due to decreased excretion and, to a lesser extent, to higher production what conflicts with other authors. On the other hand, Frank et al. (2009) suggest the high urea values may be a consequence of both training and diet. We sought that the prolonged duration of training sessions and the consequent protein catabolism may be the main reason for our values.

Prolonged physical exercise increases serum creatinine. The longer the duration of the effort, the greater the increase in plasma creatinine (Janssen, Degenaar, Menheere, Habets, & Geurten, 1989). Plasma levels of creatinine tend to normalize 24 hours after exertion (Warburton et al.,

2002). The marked decrease in the plasma levels of creatine seen in our participants is probably due to either, an exercise-induced increased glomerular filtration rate or an increase in the secretory component of the renal handling of creatinine (Irving et al., 1990). It seems that prolonged exercise tends to increase some biomarkers of kidney injury due mainly to hypohydration (Bongers et al., 2018). However, changes are transitory and in healthy and trained subjects, it is supposed to have no clinical significance. The marked decrease in plasma concentration of creatinine (-21.7%) verified in this study seems to be related to the increase in the rate of glomerular clearance and express a good renal function. In healthy athletes, glomerular clearance rate can remain high 48 hours after endurance exercise (Irving et al., 1990) reducing plasma creatinine concentration. The reduced values of creatinine found after the training period may be also related to the reduction of body mass, as according to Banfi, Del Fabbro, & Lippi (2006) a correlation was found between creatinine concentration and Body Mass Index. Our results are corroborated by Rodrigues dos Santos et al. (2007) who showed similar results after an ultramarathon in kayak.

Plasma glucose values, within laboratory references, indicate that an overnight fasting was well matched by the glucose content of the last meal or by cortisol-induced increasing in gluconeogenesis (Goldstein et al., 1992). The present results suggest that in trained athletes, changes in plasma lipids are slight even when training volume is dramatically increased, which is partially corroborated by Nagel et al. (1989). The plasma increase in tissue enzymes depends on exercise intensity (Fry, Morton, & Keast, 1991), the training level (Rodrigues dos Santos, 2017), and the biomechanical expression of effort . After getting accustomed to longer running distances, the effect of training leads to a better muscular coordination resulting in less tissue damage and consequently a reduced release of intracellular enzymes into the blood stream. Our results show that the enzymes ALT and Aldolase changed slightly while AST decreased sharply (-23.6%). ALT enzyme is higher in the cytoplasm, compared to the mitochondrial values (Glinghammar et al., 2009), a fact that could, in part, justify a greater efflux into the blood circulation, with repercussions at the plasma level in case of post-exercise liver damage. This marked decrease points to a hepatic adaptation to training (Mikami, Sumida, Ishibashi, & Ohta, 2004). The AST/ALT ratio (>1 in 2 participants) which might point to overload or hepatic damage shouldn't be a point of concern as the high CK levels indicates that the muscle tissue is the most likely source of these enzymes as response to exercise (Pettersson et al., 2008). Moreover, we found a reduction in AST from M1 to M2 as regular exercise, according to

Margaritis et al. (1999) seems to attenuate the effects of exercise, reducing plasmatic concentrations of AST.

After intensive exercise, serum CK remains high more than 24 hours (Brancaccio et al., 2007; Rodrigues dos Santos, 2017). Usually basal values of CK are higher in trained subjects (Mougios, 2007) exceeding the normative references for sedentary individuals. The slight increase (18.6%) verified in this study expresses the adaptation to the long-lasting workouts. These results are in line with the values found after an ultramarathon in kayak (Rodrigues dos Santos et al., 2007). In fact, the plasma expression of CK by exercise can be induced by different processes: i) hypoxia and/or muscular ischemia reactions resulting from exhaustive and prolonged exercise and ii) loss of homeostasis of calcium ions with direct consequences on the sarcolemma, mitochondria and sarcoplasmic reticulum (Armstrong, Warren, & Warren, 1991).

Long endurance exercise promotes a marked increase in serum cortisol (Rudolph & McAuley, 1998). After an initial increase, cortisol levels seems to increase with exercise intensity (Duclos, Corcuff, Rashedi, Fougère, & Manier, 1997). The high response in cortisol levels observed in our sample might indicate a good adaptation to the high catabolic environment induced by the demands of the training volume with high stress and fuel needs (Urhausen & Kindermann, 2002). On the other hand, impaired cortisol adaptation could be indicative of overtraining (Urhausen & Kindermann, 2002). Moreover, our data was collected in the morning and cortisol have been shown to peaking by this time a and lowering its values at night (Rudolph & McAuley, 1998).

As expected in response to sustained physical activity (McClung et al., 2009) iron levels decreased in our sample. The significant decrease of serum iron in this study (-31.8%) might have been caused by several mechanisms. The most common described in the literature include losses in sweat and urine, activity of hepcidin and could be related to hemolysis due to mechanical forces and oxidative stress (Kapoor et al., 2023) or dilutional pseudoanemia (Bärtsch, Mairbäurl, & Friedmann, 1998). Despite the decline in iron levels in all participants, only subject #2 decreased to values near the reference limits for men (≥13 g/dL). Low iron levels have been linked to reduced performance and fatigue due to reduced oxygen transport to muscles (Kapoor et al., 2023). Nevertheless, it seems, after ten days of total rest, serum iron tends to recovery to normal values (Rodrigues dos Santos et al., 2007).

The sharp increase (25.9%) of plasma phosphorus seen in this study may be related to the dietary profile of the participants. It was shown that dairy products and cereals/grains having inorganic phosphate additives significantly increase serum phosphorus concentration (Moore, Nolte, Gaber, & Suki, 2015). The increase in serum phosphorus seen in this study does not seem to have any clinical significance and is matched with the body's requirements for ATP and phosphorylated metabolic intermediates (Baker, McCormick, & Robergs, 2010). Long-lasting exercise may be associated with hypomagnesaemia, hypokalaemia and hyponatraemia (Warburton et al., 2002) but return to basal values 3 days after exertion (Spiropoulos and Trakada, 2003). Our values, all within the clinical references, demonstrate electrolyte balance at rest despite the normal disturbances experimented during exercise.

Changes in Na, K, and Mg are slight and without clinical significance what was partially corroborated by Rodrigues dos Santos et al. (2007). Knechtle et al. (2011) found prevalence of exercise-associated hyponatremia in male ultraendurance athletes what conflicts with our results. At the start of the study, chloride concentration was high, beyond clinical references in all participants. As previous training level was moderate, the hypothesis of exercise-induced renal dysfunction should be ruled out. These high values point to a high ingestion of dietary salt what is common in Portuguese cuisine. Our results are in line with those found in a Portuguese ultramarathon kayaker (Rodrigues dos Santos et al., 2007). The reduction in plasma chloride after intervention may be related to the increase in sweating rate and subsequent fluid intake, mainly water, that did not matched chloride losses by sweating.

The main limitation of our study, despite the number of participants, that being higher could allow us to have more robust results, is the lack of diet control. Future studies must have diet in consideration since many changes in blood parameters might be due to diet.

Despite these limitations, according to our data it seems the biochemical eexpression in response to exercise is related to level of training (in this case athletes trained in prolonged efforts) makes it possible to carry out efforts of this magnitude, with greater tolerance to biochemical changes, mainly enzymatic alterations related to foci of muscle and liver injury.

CONCLUSION

Our data show previous endurance trained participants might adapt to the increase in running volume with a marked decrease on body mass accompanied by a greater tolerance for prolonged

and intense efforts expressed by a slight variation in most of biochemical indicators. However, the present study shows a significant increase in biomarkers such as cortisol, creatinine and a relevant reduction in iron levels in the body.

Declaration of Conflicting Interests

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

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