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EDITORS FOREWORD

It is with sincere pleasure and pride that we present the first issue in 2021 of Kinesiologia Slovenica.

Special thanks are due to our Editorial Advisors, eminent scientists in these fields, who guide us with their experience and important suggestions in this great endeavour; to our excellent Editorial Board members, whose depth of experience covers a very wide spectrum of kinesiology; and to the publishing group, which day after day, thanks to their valuable contributions, makes the growth of this journal possible. Reviewing a manuscript is time-consuming and unpaid, and often reviewers are bombarded with requests to review content from several journals simultaneously. I would like to take this opportunity to thank all the reviewers who helped us create the first issue of the 2021 issue of the journal Kinesiologia Slovenica.

In this issue we present 14 original scientific papers from Slovenia, Serbia, Croatia, Slovakia, Turkey, Montenegro, and Finland. We wish you a pleasant reading and many research and scientific questions in the future.

I wish you an enjoyable read.

With best regards,

Dr. Saša Đurić

Deputy Editor-in-Chief

PREDGOVOR

Z iskrenim zadovoljstvom in ponosom predstavljam prvo številko revije Kinesiologia Slovenica v letu 2021.

Posebna zahvala gre našim uredniškim svetovalcem, uglednim znanstvenikom na teh področjih, ki nas s svojimi izkušnjami in pomembnimi predlogi vodijo; našim odličnim članom uredniškega odbora, katerih izkušnje zajemajo zelo širok spekter kineziologije; in založniški skupini, ki iz dneva v dan zaradi svojih dragocenih prispevkov omogoča rast te revije. Pregled rokopisa je dolgotrajen in neplačan proces, pogosto pa recenzentje zasipajo s prošnjami za istočasno pregledovanje vsebin iz več revij. Ob tej priložnosti se zahvaljujem vsem recenzentom, ki so nam pomagali ustvariti prvo številko letnika 2021 revije Kinesiologia Slovenica.

V tej številki predstavljamo 14 izvirnih znanstvenih člankov iz Slovenije, Srbije, Hrvaške, Slovaške, Turčije, Črne Gore, in Finske. Želimo vam prijetno branje in veliko znanstveno-raziskovalnih vprašanj tudi v prihodnje.

Želimo vam prijetno branje.

Z lepimi pozdravi,

Dr. Saša Đurić

Namestnik odgovornega urednika

Bojan Leskošek [1]
Rok Blagus [1,2]*

THE RELIABILITY OF THE DIFFICULTY GRADING OF SPORT CLIMBING ROUTES

ZANESLJIVOST OCENJEVANJA TEŽAVNOSTI ŠPORTNOPLEZALNIH SMERI

ABSTRACT

This is the first study aiming to evaluate the reliability of assigning a difficulty grade to a climb. Each of the 70 climbers, divided by their abilities into group A (intermediate) and group B (advanced), climbed 5 different routes, and independently suggested a grade for the routes. Although the reliability was generally high (Kendall W = .89 and .86, intraclass correlation coefficient ICC = .82 and .89 in groups A and B, respectively), the grades proposed by a single climber have too large a standard error of measurement to confidently claim that two routes with different grades are truly of different difficulties. The most important factor associated with the accuracy and bias of grading, was the gap between a climber's ability and a route's difficulty (easier routes were graded less accurate, advanced climbers underestimated the true difficulty of the routes). The following factors were also found important for grading; their effect however, was lower, or was only found in some routes or in one group: success (failed attempts were graded higher), tiredness, sex and body height (but only unadjusted for sex). Surprisingly, no significant effects were found for climbing experience, ability level, and style of climbing (onsight, flash).

Keywords: rock climbing, performance, accuracy, validity

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IZVLEČEK

Gre za prvo raziskavo zanesljivosti ocenjevanja v športnem plezanju. Vsak od 70 plezalcev, po sposobnostih razdeljenih v skupini A (srednja) in B (visoka), je poskusil preplezati 5 različnih smeri in neodvisno od ostalih predlagal oceno težavnosti smeri. Čeprav je bila zanesljivost ocenjevanja na splošno visoka (v skupinah A in B: Kendall W = 0,89 in 0,86, koeficient intraklasne korelacije ICC = 0,82 in 0,89), imajo ocene, ki jih predlaga en sam plezalec, preveliko standardno napako merjenja, da bi lahko za dve smeri podobnih težavnosti zanesljivo trdili, da se težavnost teh dve smeri v resnici razlikuje. Najpomembnejši dejavnik, povezan z natančnostjo in pristranskostjo ocenjevanja, je bila razlika med plezalno sposobnostjo plezalca in zahtevnostjo smeri (lahke smeri so bile nasploh ocenjene manj natančno, visoko sposobni plezalci pa so podcenjevali resnično težavnost lahkih smeri). Za ocenjevanje smeri so bili pomembni tudi naslednji dejavniki, ki pa imajo manjši vpliv ali pa se je vpliv kazal samo v nekaterih smereh ali skupinah plezalcev (A ali B): uspeh vzpona (neuspeli poskusi so bili ocenjeni višje), utrujenost, spol in telesna višina (slednja le neprilagojena za spol). Presenetljivo pa plezalne izkušnje, stopnja plezalne sposobnosti (A ali B) in slog plezanja (na pogled, flash) niso pomembno vplivali na zanesljivost ali pristranskost ocenjevanja.

Ključne besede: plezanje, zmogljivost, natančnost, veljavnost

INTRODUCTION

Sport climbing is a type of rock climbing which was initially an outdoor sport performed on natural rock. It has recently gained high popularity largely due to the emergence of indoor climbing facilities making the sport more accessible to a wider public audience (Valenzuela, de la Villa, & Ferragut, 2015; Watts, 2004). Sport climbing is now a well-established competitive sport with athletes competing in three disciplines: speed, boulder and lead. The sport has been approved as part of Tokyo and Paris Olympics program. Outdoor sport climbing on natural rock is mostly limited to lead climbing and bouldering (Schöffl & Kuepper, 2006); in both, the goal is to reach the top of the route by free climbing, i.e. progressing using only the natural features in the rock without weighting the rope or pulling on carabiners clipped to anchors (Draper, Dickson, Fryer, & Blackwell, 2011). A successful attempt of the route counts only if the route was climbed in lead (the climber clips the belay rope into preplaced equipment attached to bolts) and done by following the free climbing ethics (the climber progresses using handholds and footholds without weighting the rope). The route can be climbed successfully in three valid styles: onsight, flash and redpoint (Draper, Dickson, Blackwell, et al., 2011; Draper, Dickson, Fryer, et al., 2011; Draper et al., 2016). The most valued (and difficult) style is onsight (OS), in which a climber has no prior knowledge of the route. Flash (F) ascents are made in the first try, in which any prior information is allowed. A redpoint (RP) ascent is completed by a climber that has previously climbed any part of the route at least once. After the first successful ascent of a route, the first ascensionist gives it a name and suggests a grade. The grade should objectively describe the difficulty of the route, which may depend on several factors, e.g. the technical difficulty, the power required to execute the single moves, or the stamina needed for long passages in a route without good rest points. However, grades of sport climbing routes are subjective (Morrison & Schöffl, 2007) and are based on the comparison of the difficulty of a particular route with other routes of similar style. After the first ascent, other climbers may agree with the grade suggested by the first ascensionist, or they suggest lower and/or higher grades. Although different individual grades are given by different climbers for the same route, usually only one (consensus) grade is published in a guidebook. The consensus grade is usually given by the author of a guidebook, preferably after consulting other climbers that have successfully climbed or at least tried the route. Different grading scales are used, with the French and the YDC (Yosemite Decimal System) scales probably the best known and most commonly applied (Draper et al., 2016). These grading scales are widely utilised to measure performance, to discriminate between ability groups in studies on rock climbing (de Moraes

Bertuzzi, Franchini, Kokubun, & Kiss, 2007; Grant et al., 2001; Saul, Steinmetz, Lehmann, & Schilling, 2019; Wall, Starek, Fleck, & Byrnes, 2004), and also as a basis for comparison, e.g. they may be used to describe the progress in a single climber's career or the overall progress of climbing over time (Draper, Jones, Fryer, Hodgson, & Blackwell, 2008; Morrison & Schöffl, 2007; Sherk, Sherk, Kim, Young, & Bemben, 2011; Valenzuela et al., 2015).

Especially important is the comparison function of a grade in outdoor climbing, where no (official) competitions exist and the grades serve as the basis for ranking the routes and the climbers. The subjective evaluation of athletes' performances is common in sports, e.g. in gymnastics, figure skating, wrestling and dance (Bučar, Čuk, Pajek, Karacsony, & Leskošek, 2012). Contrary to other sports, however, there are no written rules and no officially recognised judges that evaluate an athlete's performance when outdoor climbing. Additionally, in climbing, especially in the most difficult routes that are not repeated for several years or even decades, there is only one "judge" that evaluates his/her own performance.

Several questions arise from the fact that the individual grades for the same route are different, variable. First, how variable are they, and what are the factors that may influence this variability? Second, should a procedure be constructed that may "extract" a "valid" consensus grade from these individual grades; and if it does, how many individual grades are needed to achieve this–is every rater eligible to propose a grade, etc.? Third, how sensitive are the grading scales, i.e. how different should be the grades of two routes, so that we may be "certain" one is more difficult than the other? To answer these questions, we conducted a study enrolling a sample of 70 climbers. Each climber attempted to climb 5 indoor routes and suggested, completely independently from other climbers, his or her opinion about the difficulty grade of the route. We studied the reliability of the proposed difficulty grades and factors related to variability and bias of the grading of sport climbing routes.

METHODS

Study protocol

The study was conducted on a lead climbing wall in the Climbing Centre Ljubljana (CCL), Slovenia. On three consecutive working days in October 2015, visitors of the climbing centre were invited to participate in the study. If they agreed to participate and met the inclusion criteria (able to lead climb routes with difficulties of 6a and above according to the French scale), they signed an informed written consent about the conditions of their participation. After their usual warmup they climbed 5 new routes (assigned A1 to A5 for group A and B1 to B5 for group B) in an order they chose. All routes were positioned on the main 850 m2 indoor climbing wall inside the CCL (http://www.plezalnicenter.si/english-page/); they were 15.0 to 16.4 m high and set by two experienced route-setters, who regularly set the routes on this wall. After lowering down from the top of each route, participants immediately had to record, on a prepared form, their grade proposition, ascent style (OS, F) and whether they were able to successfully complete the route in a selected style. No communication regarding the difficulty of the route was allowed between the participants. Only one attempt per route was allowed. As is a common practice in CCL, the letter, "+" and slash grades were allowed also for easier routes, e.g. 4a, 5a+, 5b+/c. The study was conducted with the institutional ethical approval.

Participants

The accidental sample consisted of 70 climbers. Each participant took part in a short survey, from which some basic demographic and physical characteristics and information about self-reported climbing level were obtained. According to their self-reported climbing level and their most difficult redpoint (RP) ascent in the last 12 months, they were included in either group A (intermediate group: RP level 5c–6c+), or group B (advanced group: RP level 7a upwards) (Draper et al., 2016); some exceptions were made by the authors after interviewing the participants: if a climber was currently not in good enough shape to reach the top (successfully or not) of all 5 routes, he/she may be transferred from group B to group A). The basic characteristics of the intermediate and the advanced groups are provided in Table 1. No significant differences between the groups were observed for age, sex, and self-reported body height and weight ($p > .05$), while the advanced climbers were significantly more experienced and had higher OS and RP levels.

Table 1. Basic characteristics of the study sample. The reported p-value is either from a two-sample equal variances t-test, Mann-Whitney test or Pearson's chi-squared test, where appropriate.

	Group A	Group B	*p*-value
Total count	41	29	
Sex	23 male, 18 female	23 male, 6 female	.078
Age (years)	13–49, *M* = 29.9, *s* = 9.9	12–50, *M* = 31.4, *s* = 10.6	.551
Body height (cm)	157–185, *M* = 172.2, *s* = 8.2	150–189, *M* = 173.7, *s* = 9.7	.514
Body weight (kg)	47–85, *M* = 65.5, *s* = 10.9	40–94, *M* = 68.6, *s* = 10.6	.241
Climbing experience (years)	1–25, *M* = 5.2, *s* = 5.2	2.5–30, *M* = 13.3, *s* = 8.6	< .001†
Hardest climb OS (ever)	5c–7a+/b, *Mdn* = 6b+	6c/c+–8a+, *Mdn* = 7a+/b	< .001†
Hardest climb RP (ever)	6a+–8a+, *Mdn* = 6c	7a+–8c/c+, *Mdn* = 7c/c+	.016†
Hardest climb OS (last year)	5a–7a, *Mdn* = 6a+/b	6c/c+–7c/c+, *Mdn* = 7a+	.006†
Hardest climb RP (last year)	5a–7b+, *Mdn* = 6b+	7a–8a+/b, *Mdn* = 7c	< .001†
Hardest climb OS (last month)	5a–6c/c+, *Mdn* = 6a+	6c–7c/c+, *Mdn* = 7a	.245†
Hardest climb RP (last month)	5a–7a+/b, *Mdn* = 6a+/b	6c–8a+, *Mdn* = 7a+/b	< .001†

Note. OS = onsight; RP = redpoint; M = mean; s = standard deviation; Mdn = median.
† The analysis considered numeric grades.
P-values reported are from Mann-Whitney test.

Data analysis

Grades on the French scale were transformed to a numeric scale (i.e. decimal climbing grade): each number grade was worth 1 "point", each letter grade above "a" adds 1/3 point, and each "+" adds 1/6 of a point (e.g. grade 6b+ was transformed into 6 + 1×1/3 + 1/6 = 6.5). "Slash" grades add 1/12 to an adjacent lower grade, e.g. 6b+/6c was translated into 6.5 + 1/12 = 6.583. Converting grades on the French scale to numeric scale is common in sport climbing research (Draper et al., 2016; Watts, 2004). Our numeric grades can be converted to IRCRA reporting scale (Draper et al., 2016) by using a simple linear transformation (Table 2). Numeric grades were summarized with mean, median, standard deviation and interquartile range.

Table 2: A comparison of different grading scales.

French/sport	UIAA	YDC	Watts	IRCRA	Numeric
4b	V-	5.6	0.00	6	4.33
4c	V	5.7	0.25	7	4.67
5a	V+	5.8	0.50	8	5.00
5b	VI-	5.9	0.75	9	5.33
5c	VI	5.10a	1.00	10	5.67
6a	VI+	5.10b	1.25	11	6.00
6a+	VII-	5.10c	1.50	12	6.17
6b	VII	5.10d	1.75	13	6.33
6b+		5.11a	2.00	14	6.50
6c	VII+	5.11b	2.25	15	6.67
6c+	VIII-	5.11c	2.50	16	6.83
7a	VIII	5.11d	2.75	17	7.00
7a+	VIII+	5.12a	3.00	18	7.17
7b	IX-	5.12b	3.25	19	7.33
7b+		5.12c	3.50	20	7.50
7c	IX	5.12d	3.75	21	7.67
7c+	IX+	5.13a	4.00	22	7.83
8a	X-	5.13b	4.25	23	8.00
8a+		5.13c	4.50	24	8.17
8b	X	5.13d	4.75	25	8.33
8b+	X+	5.14a	5.00	26	8.50
8c	XI-	5.14b	5.25	27	8.67
8c+		5.14c	5.50	28	8.83
9a	XI	5.14d	5.75	29	9.00

Note: UIAA – Union Internationale des Associations d'Alpinisme, YDS – Yosemite Decimal System, IRCRA – International Rock Climbing Research Association. Sources: (Draper et al., 2016; Watts, 2004).

Agreement between the raters in each group was computed by the Kendall coefficient of concordance W (corrected for ties); 95% confidence interval for W was obtained with bootstrap (Davison & Hinkley, 1997). Intra-rater reliability was evaluated under the two-way random model with intraclass correlation coefficients (ICC), under the consistency (ICCC) and agreement (ICCA) models. Under the agreement model, standard error of measurement (SEM) was computed as $SD \times (1 - ICCA)^{1/2}$ and minimal differences needed to be considered real (MD) as $MD = SEM \times 1.96 \times 2^{1/2}$ (Weir, 2005).

To evaluate the factors of the grading bias, the association between the individual grades, and style of climbing (OS, F), type of ascent (successful, failed), sex, age, height and other variables from the questionnaire, was estimated with linear mixed effects models, where the subject was included in the model as a random effect, and the route number as a fixed effect. Separate analyses were performed for groups A and B. Interaction between the route number and the covariate was considered. The significance of the interaction term was verified with the likelihood ratio test; in case of a non-significant interaction effect the model without the interaction was considered. For the continuous covariates, a possible non-linear association was modelled by using cubic splines. In case of a non-significant non-linear term the linear association was considered.

To evaluate factors that affect the accuracy (discrepancy) of grading, the outcome variable was defined as the absolute difference between the individual grade of the route and the mean grade for that route. This outcome was then associated with the covariates by using the same approach as presented for the bias of grading. A multivariate linear mixed effects model was used to compare the reliability of grading in groups A and B, adjusting for sex, years of climbing and the highest RP level, which were included in the model because of potential confounding. To take into account the difference in the difficulty of the routes in both groups, the difference between the OS level and the mean grade of each route was also included in the multivariate model.

A p-value of less than .05 was considered as statistically significant. The analysis was performed with the R language for statistical computing, R version 3.0.3.

RESULTS

The distribution of individual grades is given in Figure 1. For each route, there are between 6 and 10 different grades. However, in most cases, only 2 or 3 grades prevail. Slash grades (e.g. 4c+/5a) are uncommon. In group A, "+ grades" (e.g. 5b+) are rare, while in group B, they are more common, except for the route B3, where they are much less frequent. As the distribution of grades is in most cases approximately symmetrical, average and median grades are similar (Table 3).

Figure 1. Frequency distributions of grades for routes 1–5 of A and B groups of climbers.

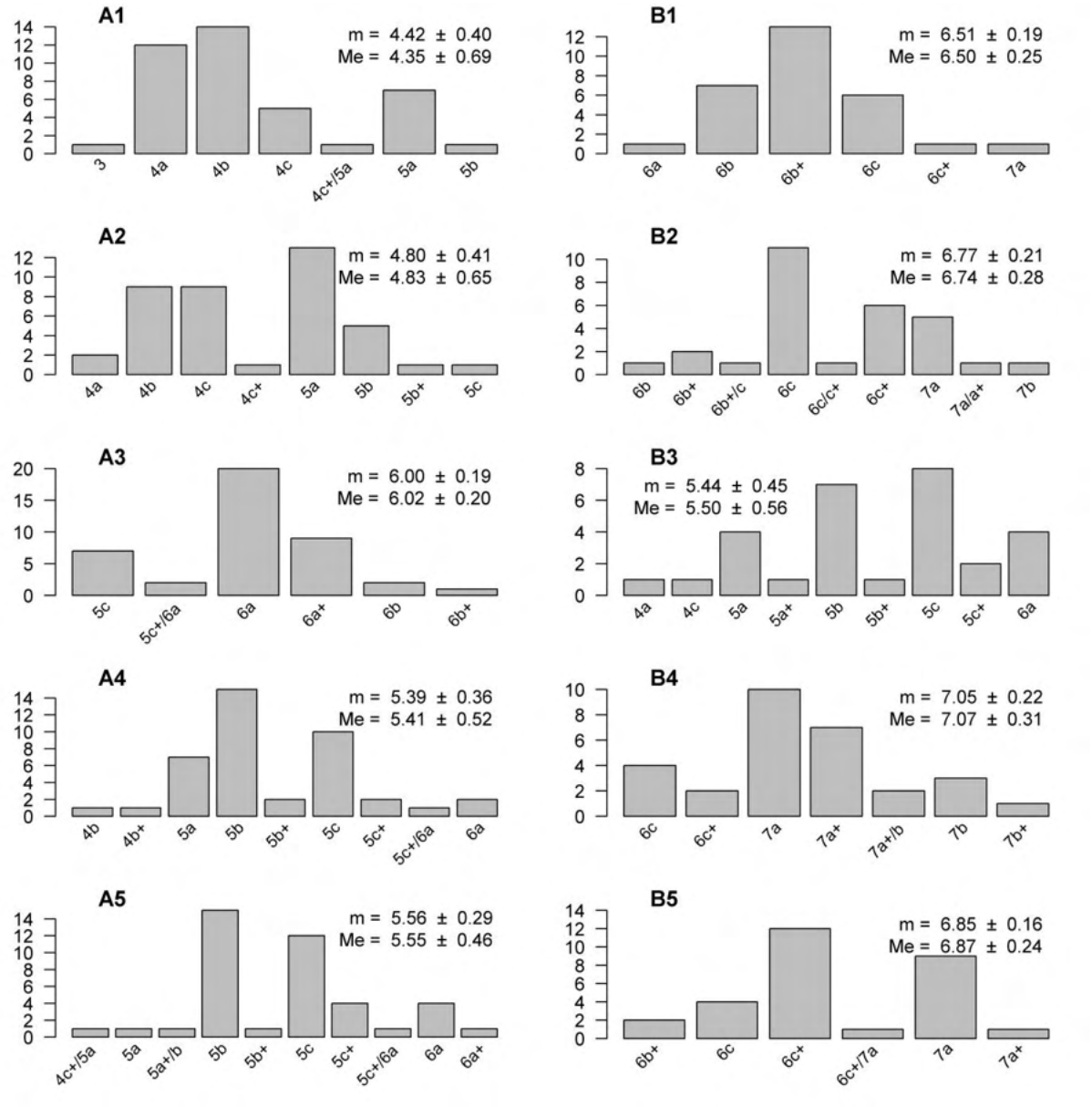


Table 3. Distributional statistics of routes' numeric grades and their average (m1–5).

Route	Group A					Group B				
	M	*Mdn*	*s*	*IQR*	% success	*M*	*Mdn*	*s*	*IQR*	% success
1	4.42	4.35	.40	.69	100%	6.51	6.50	.19	.25	86%
2	4.80	4.83	.41	.65	98%	6.77	6.74	.21	.28	83%
3	6.00	6.02	.19	.20	56%	5.44	5.50	.45	.56	100%
4	5.39	5.41	.36	.52	90%	7.05	7.07	.22	.31	55%
5	5.56	5.55	.29	.46	93%	6.85	6.87	.16	.24	66%
$m_{1–5}$	5.23	5.27	.21	.31	87%	6.52	6.50	.18	.19	78%

Note. M = mean; Mdn = median; s = standard deviation; IQR = interquartile range; % success = percentage of climbers who successfully climbed (i.e. onsighted or flashed) the route.

The variability of grades, as expressed by the standard deviation and interquartile range, is generally around 2 times higher in group A than in group B. In each group, there is one exception, with route A3 having a much lower variability than other group A routes, and route B3 having a much higher variability than other routes of group B. The success rate, i.e. the percentage of climbers who successfully onsighted or flashed a route, was higher (87%) in group A than in group B (78%).

Agreement on rankings of the 5 routes is high among climbers of both groups (Table 4), although a little higher in group A (Kendall coefficient of concordance W = .89), than in group B (W = .86). Intraclass correlation coefficients (for a single judge) under both the agreement and the consistency model is somewhat higher in group B than in group A. Related to that, standard errors of measurement (SEM) and minimal differences needed to be considered real (MD) are lower in group B.

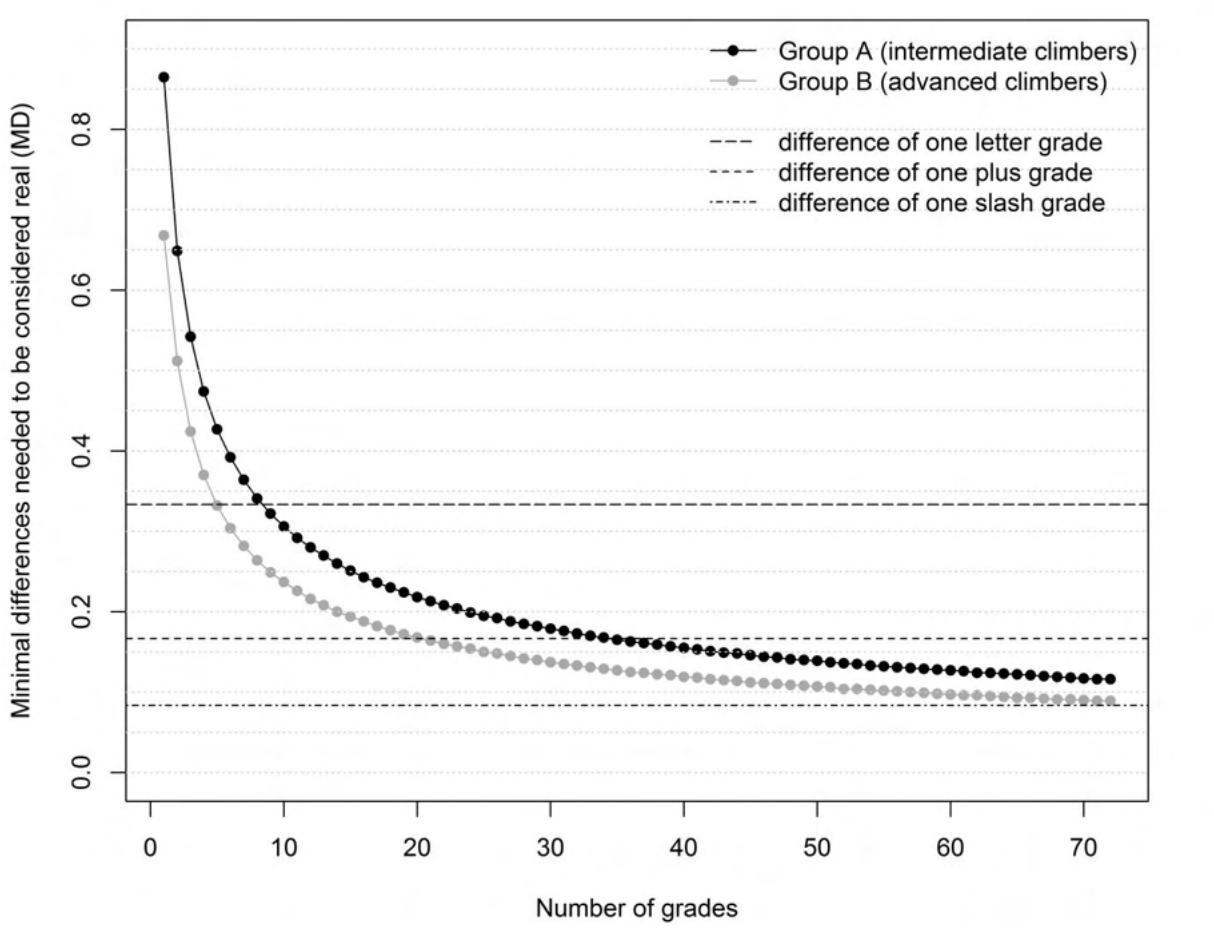
Table 4. Statistics related to the reliability of climbing grades.

	Group A value, [95% CI]	Group B value, [95% CI]
Kendall *W*	.89 [.58, 1.00]	.86 [.42, 1.00]
Mean correlation between judges	.85	.95
Standard deviation of all grades	.66	.63
Intraclass correlation coefficient (agreement)	.78 [.54, .97]	.85 [.67, .98]
Intraclass correlation coefficient (consistency)	.82 [.61, .97]	.89 [.74, .99]
Standard error of measurement (*SEM*)	.31	.24
Minimal differences to be considered real (*MD*)	.86	.67

Note. CI = confidence interval.

If the routes in group A are graded only by one climber, the MD is .86 of the grade, corresponding to a difference of more than two letter grades on the French grading scale, while in group B, the MD is .67, corresponding to a difference of exactly two letter grades. In group A, 9, 35 and 139 individual grades are needed to be 95% certain that the true differences in the difficulty of two routes is one letter, plus and slash grade, respectively (Figure 2); in group B, 5, 21 and 82 individual grades are needed to achieve the same.

Figure 2. Minimal difference between numeric (decimal) grades of two sport climbing routes needed to be 95% certain that the two routes are really of different difficulty as a function of the number of individual grades for group A and group B.



Factors of bias in grading

There was a significant difference in mean grades between the successful and failed attempts in group B. Climbers in group B, failing to successfully complete the route gave, on average, higher grades (mean difference: .15, 95% CI [.04, .26], p = .007). Women in group B graded route number 3 significantly higher than men (mean difference: .36, 95% CI [.11, .61], p = .005). Route B3 was graded lower by taller climbers (mean difference, expressed as a difference in height of 10 cm: .10, 95% CI [.00, .21], p = .058), but this was a consequence of confounding by sex, as no association between the grade and height was observed when adjusting for sex (p-value for height when adjusting for sex p = .325). No association between the grades and the style of the ascent (OS/flash), age, weight of the climbers, BMI, years of, best OS ascent, best

RP ascent, amount of climbing in the past year, amount of climbing in the past month, percentage of outdoor climbing and percentage of indoor climbing within CCL was observed ($p > .05$).

Factors of accuracy in grading

There was a significant difference in grading accuracy between routes A3 and A1 (on average, a .20 higher accuracy was observed for route A3 than A1, 95% CI [.11, .29], $p < .0001$), routes A5 and A1 (on average, a .08 higher accuracy was observed for route A5 than A1, 95% CI [.00, .17], $p = .048$) as well as routes B3 and B1 (on average, a .22 less accurate grading was observed for route B3 than for B1, 95% CI [.13, .30], $p < .0001$), while the accuracy of grading between the other pairs of routes was not significantly different (A2 and A1 $p = .830$, A4 and A1 $p = .177$, B2 and B1 $p = .334$, B4 and B1 $p = .239$, B5 and B1 $p = .878$).

Women in group A graded the climbs more accurately than men (.05, 95% CI [.00, .12], $p = .046$), but this was not observed in group B ($p = .693$). Similarly, taller people in group A were less accurate (expressed as a difference in height of 10 cm: .04, 95% CI [.00, .01], $p = .023$). When sex and height were simultaneously included in the model for the accuracy of grading in group A, none of the factors exhibited a significant association ($p = .825$ and $p = .275$, for sex and height, respectively), which was a consequence of strong collinearity between sex and height.

Climbers in group B with a higher OS level graded route B3 significantly less accurately than climbers with a lower OS level (.34, 95% CI [.15, .54], $p = .001$). This was not observed for other routes or in group A ($p > .05$). We identified an influential observation, a climber with a very high OS and RP level, who graded route B3 significantly lower than the other climbers. When removing this observation, climbers in group B with a higher OS level graded the routes significantly less accurately (.09, 95% CI [.01, .18], $p = .033$). Grades of route A1 were significantly more accurate if the climbers spent more time climbing indoors (expressed as a difference of 10 percentage points: .03, 95% CI [.01, .06], $p = .020$). This was not observed for the other routes or in group B ($p > .05$).

No association between the accuracy of grading and type of a climb (successful, failed), style of the ascent (OS/F), age, weight, years of climbing, amount of climbing in the past year, amount of climbing in the past month and the percentage of indoor climbing within CCL was observed ($p > .05$).

In the multivariate analysis (Table 5) climbers in group A graded the climbs significantly less accurately when adjusting for the other covariates (.12, 95% CI [.04, .20], p = .003, Model 1). However, when the difficulty gap (the difference between the best ever OS level and the mean grade of a specific route) was included in the model (Model 2), the difference in the accuracy of grading between the groups was no longer significant, and the only significant independent factor for the accuracy of grading was the difficulty gap. Climbers with a larger difference between their best OS level and the mean grade of the route graded the climbs significantly less accurately when adjusting for the other factors (.11, 95% CI [.08, .15], p < .0001).

Table 5. Multivariate models for the accuracy of grading.

	Coefficient	*SE*	95% CI	*p*-value
Model 1				
Group B:A	-.12	.04	[-.20, -.05]	.003
Sex F:M	-.03	.02	[-.09, .02]	.146
Climbing experience	.00	.00	[-.01, .01]	.817
Best RP level (ever)	.02	.03	[-.03, .08]	.396
Model 2				
Group B:A	-.00	.04	[-.08, .09]	.995
Sex F:M	-.04	.02	[-.09, .01]	.097
Climbing experience	.00	.00	[-.01, .01]	.948
Best RP level (ever)	-.05	.03	[-.11, .02]	.111
Difficulty gap†	.12	.02	[.08, .15]	< .0001

Note. SE = standard error of the estimated regression coefficient; CI = confidence interval.
† Difficulty gap is the difference between the best OS level and the mean grade of the route

DISCUSSION

This is the first study to examine the reliability of assigning a difficulty grade to a climb. As expected, the climbers did not completely agree about the difficulty of any of the routes. However, even though they had only one attempt at the route and were not allowed to communicate about the difficulty of the route with each other, the reliability of grades was relatively high. ICCs for an individual climber were comparable to those observed for the highly trained and experienced judges in the artistic gymnastics of the European championships (Leskošek, Čuk, Pajek, Forbes, & Bučar-Pajek, 2012) or University games (Bučar et al., 2012). A similar trait is observed based also on the Kendall W coefficient, with the only exception that here, the reliability is slightly higher in group A than in group B. Note that the difference is very small, and probably a consequence of the larger difficulty range of the routes climbed in

group A than in group B; it is known that the coefficients of intra-rater reliability increase when the rated objects (in our case routes) are more heterogeneous (Weir, 2005).

A higher reliability of grading in group B is observed when considering the standard error of measurement (SEM), which shows the typical error when a randomly selected climber grades a typical route. MD values, which determine the smallest true difference in the difficulty of two routes, for which one can be 95% confident that one route is harder than the other, are consistent with the SEM values. MD in group A and group B, expressed on the French grading scale, are around two letter grades. As an example, this means that if a typical climber graded a route 6c, then we can be 95% confident that the other route is truly easier if it was graded 6a or less. This example clearly emphasizes that caution is needed when comparing the difficulty of different routes or the accomplishments of different climbers. Claims which route is the hardest, or which climber is the best, are commonly made based on a difference of one plus grade, however, the true difference between two routes, each with only one individual grade, should be at least four times larger, so that we could claim this with 95% confidence. Based on our study, 21 (advanced group) and 35 (intermediate group) individual grades are required to reliably declare the true difference of one plus grade as real. This is also important when evaluating the performance of climbers that is based only on their hardest ascent (either climbed OS or RP), which is common in rock climbing research (Draper et al., 2016).

The only identified source of bias when grading the difficulty of the climbs in our study was the unsuccessful completion of the climb. In our study, the climbers in the advanced group (group B) who did not successfully complete the climb gave, on average, significantly higher grades. The magnitude of the bias was in the range of one plus grade. This was not observed in the intermediate group, which was to a large extent the consequence of a very small number of unsuccessful attempts (less than 10%, except for the hardest route), reducing the power of the statistical analysis. This is important in practice as it suggests that the climbers that successfully complete the climb should be more eligible to propose a grade, otherwise the consensus grade could be biased.

Grades for different routes exhibited significantly different accuracy. The easier routes in both groups of climbers were graded significantly less accurately than the harder routes. Consistent with this result, the climbers with higher climbing level in the advanced group graded the climbs significantly less reliably. The multivariate model showed more accurate grading in the advanced group when controlling for sex, climbing experience and RP level. This effect

disappeared, however, when the difference between the climbing level and the difficulty of the route was included in the model. This is important, as it suggests that the only factor associated with the reliability of grading is the gap between the climbing level and the difficulty of the route. The climbers in our study were mainly regular visitors of the climbing centre and were therefore very familiar with the grading scale used there. This could explain why climbing experience was not a significant factor for the reliability of grades in the multivariate model. Climbing Centre Ljubljana is one of the very few places in Slovenia where it is possible to climb on graded indoor lead routes; therefore, our study sample was in that sense very homogenous. It would be interesting to conduct a study with a heterogeneous sample, where we expect that factors other than the difficulty gap could be related to the reliability of climbing grades.

We used a simple linear transformation of the French grades into numeric grades. There are other linear transformations of the grading scales to a numeric scale (Draper et al., 2016; Watts, 2004). Note however, that using any linear transformation to a numeric scale will lead to identical conclusions as presented herein. What should, however, be investigated in the future, is the appropriateness of assuming linearity throughout the range of the grading scale when converting the grades to a numeric scale for the purpose of a statistical analysis. Namely, it gets progressively more difficult for a climber to make progress on the grading scale as he/she moves from easier to harder grades, i.e., it takes more time (and effort) for a climber to progress by e.g. one letter grade, as the climbers progresses to higher grades. While this holds for any sports discipline (say 100-meter sprint), it would be interesting to see if this, given the subjective nature of grading sport climbing routes (as opposed to objective measurement of time in say the 100-meter sprint), also translates to the scale at which the difficulty of a climb is measured (which is clearly linear for the 100-meter sprint).

The grade given to a route is the main and usually the only indicator of performance in (outdoor) sport climbing. It is used to compare climbers' ability and routes' difficulty. It is also used in scientific research, e.g. as a basis for forming ability groups of climbers or for evaluating the effect of training intervention. Therefore, it is crucial to know the metric characteristics of a climbing grade scale. This is the first study to establish these characteristics. It was found that the grade, given by a single climber, is in general unreliable (inaccurate) and biased. Several factors, which were suspected to influence reliability and bias were examined, but only few were found significant. Between those factors the difficulty gap between climber's ability and route difficulty was found as the most important. In some cases also other factors were found

important, i.e. unsuccessful attempts, tiredness and sex. Surprisingly, some other factors, e.g. body height (adjusted for sex), ability level and climbing experience were not found significant. Based on these findings several recommendations arise. First, it was found that several tens of independent individual grades are needed for the average (or median) grade to be sufficiently accurate (i.e. within one "tick mark" of the difficulty scale). Additionally, to prevent bias of the average grade, only rested climbers, which have actually successfully climbed the whole route in valid style and whose ability is close to the difficulty of the route, should be considered for proposing the grade of the route.

In conclusion, if a climbing grade is to be used as a criterion for evaluating the climber's ability, it needs to be based on sufficiently large number of individual grades given by climbers whose climbing ability is close to the difficulty of the route. Importantly, the number of required individual grades depends on the smallest difference of the climber's ability that one would like to measure (evaluate). E.g., if this difference was one plus grade then, based on our study, around 20 independent individual grades for advanced group of climbers and more than 30 for intermediate group are required.

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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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RELATIONSHIP BETWEEN THE 30-SECOND BURPEE TEST VARIATION AND ANTHROPOMETRIC AND MOTOR DIMENSIONS IN FEMALE UNIVERSITY STUDENTS

POVEZANOST 30-SEKUNDNE RAZLIČICE BURPEEJEVEGA TESTA Z ANTROPOMETRIČNIMI IN MOTORIČNIMI SPREMENLJIVKAMI PRI ŠTUDENTKAH

ABSTRACT

The 3-minute Burpee test has been widely reported in the literature, however the motor abilities assessed by the 30-second Burpee test (30SBT) variation are not clearly defined. The aim of this study was to investigate the association between the 30SBT and components of physical fitness, including anthropometric and motor characteristics, in the study participants. The sample consisted of 75 female students of Teacher Education Faculty, University of Belgrade. Pearson´s correlation coefficient showed that 30SBT was negatively related to body height ($r = -0.529$, $p < 0.01$) and body mass ($r = -0.350$, $p < 0.01$) as anthropometric variables, and also positively correlated with body coordination ($r = 0.517$, $p < 0.01$), agility ($r = 0.380$, $p < 0.01$), upper-body ($r = 0.373$, $p < 0.01$) and trunk strength ($r = 0.257$,both $p < 0.05$) and flexibility ($r = 0.259$, $p < 0.05$) as motor abilities. However, when we applied a regression analysis, the best-fit model demonstrated a clear significant causal relationship only between measures of body height and burpee test scores ($R^2 = 0.279$, $p < 0.01$) and also between burpee test performance with coordination and agility ($R^2 = 0.313$, $p < 0.01$). This findings suggest that the effectiveness of the 30-second Burpee test is highly dependent on motor abilities such as coordination and agility, and that body height has a negative impact on Burpee test performance. Given that the test is time-efficient and also economically and organizationally practical, the authors suggest that the 30-second Burpee variation should be implemented in physical education classes to assess motor dimensions of preschool, school, and university populations.

Keywords: agility, coordination, motor test, physical education

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IZVLEČEK

Kljub temu da je o 3-minutnem Burpee testu v literaturi že veliko napisanega, motoričnih sposobnosti, ocenjenih s 30-sekundno različico Burpeejevega testa (30SBT), še niso jasno opredeljene. Cilj te študije je bil raziskati povezavo med 30SBT in komponentami telesne pripravljenosti, vključno z antropometričnimi in motoričnimi značilnostmi. Vzorec je sestavljalo 75 študentk iz Pedagoške fakultete, Univerze v Beogradu. Pearsonov korelacijski koeficient je pokazal, da je 30SBT negativno povezan s telesno višino ($r = -0,529$, $p < 0,01$) in maso ($r = -0,350$, $p < 0,01$) ter pozitivno povezan s koordinacijo ($r = 0,517$, $p < 0,01$), okretnostjo ($r = 0,380$, $p < 0,01$), močjo zgornjega dela telesa ($r = 0,373$, $p < 0,01$), močjo trupa ($r = 0,257$, oba $p < 0,05$) in gibljivostjo ($r = 0,259$, $p < 0,05$). Najustreznejši model regresijske analize, je pokazal pomembno vzročno zvezo le med meritvami telesne višine in rezultati burpee testa ($R^2 = 0,279$, $p < 0,01$) ter med uspešnostjo burpee testa z usklajenostjo in gibljivostjo ($R^2 = 0,313$, $p < 0,01$). Ugotovitve pričujoče študije nakazujejo, da je učinkovitost 30-sekundnega Burpee testa odvisna od gibalnih sposobnosti, kot sta koordinacija in gibljivost, ter da telesna višina negativno vpliva na uspešnost Burpee testa. Glede na to, da je test časovno učinkovit ter tudi ekonomsko in organizacijsko praktičen, avtorji predlagajo, da je treba 30-sekundno različico Burpeeja uporabiti pri pouku športne vzgoje, z namenom ocene motoričnih spremenljivk predšolske, šolske in univerzitetne populacije.

Ključne besede: gibljivost, koordinacija, tibalni test, športna vzgoja

INTRODUCTION

Motor or physical abilities are terms that are defined differently depending on the author. Simply defined, motor abilities are genetically determined characteristics that influence motor performance and predominantly refer to dimensions such as coordination, flexibility, precision, balance, and various types of strength, power and endurance (Bala, 2010; Lammle, Tittlbach, Oberger, Worth, & Bos, 2010). The term associated with motor abilities is physical fitness, which includes anthropometric and body composition components in addition to motor abilities (American College of Sports Medicine [ACSM], 2013). Physical fitness assessment is one of the most important tasks in physical education (PE) and can be conducted by both laboratory tests and field-based tests. Given that the laboratory testing is limited in the school setting, field-based testing is reasonable alternative, since it is time-efficient, economical and organizationally feasible (Ruiz et al., 2011).

There are numerous tests in the PE literature and one of the most commonly used is the Eurofit battery tests. Eurofit has been shown to be a reliable indicator of both health-related and performance-related fitness, and its validity has been confirmed for preschool, school, and university populations (MacDoncha, Watson, McSweeney, & Donovan, 1999; Fjortoft, Pedersen, Sigmundsson, & Vereijken 2000; Tsiglis, Douda, & Tokmakidis, 2002). However, in recent years, the Burpee test has become a very popular physical exercise that finds its application in testing the physical performance of athletes, recreational athletes, or members of the military (Bingley, Witchalls, McKune, & Humberstone, 2019). The Burpee test includes movements such as squats, back-kicks and planks, and now there are numerous variations, such as the duration of the test, the presence of the jump, the positions of the arms during the squat phase, etc. (Podstawski, Kasietzuk, Boraczynski, Boraczynski, & Choszcz, 2013). Based on duration, the most commonly used variations of the test in practice are the 3-minute test (3MBT), the 1-minute test (1MBT), and the 30-second Burpee test (30SBT), which requires participants to complete the highest possible number of cycles (i.e., burpees) in a given amount of time. Previous research has shown that the Burpee test is an effective tool for measuring endurance performance for both children and younger adults, with 3MBT and 1MBT shown to be more reliable variants for assessing muscle endurance compared to the 30SMBT (Boracyznski, Boraczynski, Podstawski, Mankowski, Choszcz, & Honkanen, 2015; Menz, Marterer, Amin, Faulhaber, Hansen, & Lawley, 2019; Podstawski et al., 2019). In addition to muscle endurance, 3MBT has been associated with cardio-respiratory fitness (Sakamaki, 1983) and also with anthropometric features (Podstawski et al., 2013; Podstawski, Zurek, Clark,

Laukkanen, Markowski, & Gronek, 2019a). Podstawski et al. (2013) investigated the relationship between 3MBT and morphological measures in young university female students (19-23 years). They found that anthropometric dimensions such as body height, body mass, and body-mass index were negatively correlated with 30MBT test scores.

Although recent studies have paid considerable attention to the effectiveness of the 3MBT, there is little information in the current literature on what motor abilities and, more generally, aspects of physical fitness can be assessed by the shorter variation of the Burpee test. Given that modified versions of the test differ in spatiotemporal structure (Podstawski et al., 2019), it is logical to assume that different test versions could be used to assess different motor abilities. Moreover, as the longer test durations (≥ 1 min) provoke high level of fatigue and perceived effort (Podstawski, Markowski, Choszcz, & Zurek, 2016; Boryslawski, Podstawski, Ihasz, & Zurek, 2020), shorter test versions might be more sustainable for untrained populations and children. In this regard, the results of McCoy & Young's (1954) early work have shown that the 10-second Burpee test is a useful tool for assessing coordination and agility, suggesting that shorter Burpee variations address other aspects of motor abilities. However, which motor abilities and to what extent are associated with the 30-second Burpee variation is still largely unknown.

The aim of the current study was to investigate the association between the 30-second Burpee test results, a standardized motor test results derived from the Eurofit test battery, and anthropometric characteristics of the participants. We hypothesized that the 30MBT i) is a significant predictor of strength endurance, agility and coordination and ii) is significantly associated with anthropometric dimensions.

METHODS

Participants

Sample size was justified by a priori power analyses, using G-power software with a target correlation value (r) of 0.3, alpha level of 0.05, and power (1-ß) of 0.80 (Eng, 2003). Seventy five female students from Teacher Education Faculty, University of Belgrade, voluntarily participated in this study. The participants were healthy, had no history of musculoskeletal injuries and did not participate in physical exercise programs of more than 90 minutes per week (regular classes). In addition, subjects completed the International Physical Activity

Questionnaire (IPAQ) to provide information about their physical activity level (Craig et al., 2003). All participants were fully informed about experimental procedures and potential risks and signed a written informed consent prior to participation in the study. The study was approved by the Institutional Ethics Committee and conducted in accordance with the Declaration of Helsinki.

Procedure and testing

The anthropometry and motor testing were conducted on two separate days. On the first day, anthropometric measures and motor abilities were assessed, while on the second day, the 3SBT was performed. The tests took place 7 days apart and were performed during regular classes in the gym of Teacher Education Faculty, University of Belgrade. All subjects were familiarized with the motor tests during two pre- visits before data collection and were advised to avoid physical activity and solid food intake 2 hours before the testing.

Body height (BH), body mass (BM) and body-mass index (BMI) were taken as anthropometric measures. BH was measured using a Martin's portable anthropometer (Siber-Hegner, Switzerland) with an accuracy of 0.1 cm, while BM was evaluated using an electronic scale (accuracy 0.1 kg). BMI was calculated using the standardized formula ($BMI=BM[kg]/BH[cm]^2$) proposed by the World Health Organization (WHO, 2015).

The test battery comprised a total of 7 items and was administered according to a standardized protocol (Adam et al., 1987; Tsiglis et al., 2002; Leskošek, Strel, & Kovač, 2007; Bala & Popović, 2007): for assessing movement coordination - Obstacle course backwards (0.1s); for assessing explosive leg power - Standing long jump (m); for assessing body balance - Flamingo balance test (s); for assessing upper body strength-endurance - Pull-up endurance (s); for body flexibility assessing - Wide-legged seated forward bend (m); for assessing trunk strength - Sit-ups in 30 seconds (freq); for body agility assessing - 10x5 meter Shuttle run (s).

30SBT measures the number of exercise repetitions (burpees; freq) in 30 seconds. Subjects begin the test standing with arms at their sides. Then the body is brought into a squat position by bending the knees and hips, placing the hands placed on the floor in front of the feet. Shifting the feet backward, the body comes into the push-up position with the arms extended. From this position, the body returns to the supported squat position and finally to the upright standing position. The jump phase was not allowed. (Podstawski et al., 2019a).

Statistical analysis

Descriptive statistics, including means, standard deviation (SD), minimum (MIN), and maximum (MAX) values, were computed for anthropometric and motor test variables. Pearson's moment correlation was used to examine the relationship between 30SBT scores, Eurofit battery test scores, and anthropometric dimensions. According to Hopkins, Marchall, Batterham & Hanin (2009), the r coefficients were classified as trivial (0.00-0.09), small (0.10-0.29), moderate (0.30-0.49), large (0.50-0.69), very large (0.70-0.89), nearly perfect (0.90-0.99) and perfect (1.00). To find the best predictive model for the 30SBT, a backward multiple regression model was applied. Statistical analysis was processed using the IBM SPSS Statistics software package (version 21, SPSS Inc, Chicago, IL, USA). $P \leq 0.05$ was taken as the statistically significant determinant.

RESULTS

Descriptive data for the anthropometric and motor test variables are presented in Table 1.

Table 1. Descriptive statistics for tested variables

Variables	**Mean**	**SD**	**MIN**	**MAX**
Body height (m)	1.67	0.06	1.53	1.86
Body mass (kg)	61.32	11.54	43.0	110.0
Body-mass index (kg/m²)	21.78	3.50	16.56	39.44
Obst Cours Back (s)	18.99	4.52	11.15	33.0
Flamingo (s)	173.43	19.88	90.0	180.0
10x5m Shuttle Run (s)	19.20	11.0	28.0	85.0
Stand Long Jump (m)	1.53	0.23	1.01	2.30
Wide Leg Seat Forw (m)	1.12	0.13	0.84	1.46
Sit-Ups 30sec (freq)	22.16	4.19	14.0	34.0
Pull-Upp End (s)	29.1	19.28	0.01	85.0
30- sec Burpee (freq)	13.43	1.67	9.0	18.0

Anthropometric dimensions and motor tests

All anthropometric characteristics were significantly associated with the coordination and flexibility tests ($p < 0.01$). Body height was negatively correlated with the pull-up endurance test ($p < 0.05$), while a negative correlation was observed for body mass and body-mass index with the Flamingo ($p < 0.01$), long jump ($p < 0.05$), sit-ups ($p < 0.05$) and pull-up endurance ($p < 0.01$) tests (Table 2).

Table 2. Correlation matrix for anthropometric and motor features

	BH (m)		**BM (kg)**		**BMI (kg/m²)**	
Variables	*r*	*p*	*r*	*p*	*r*	*p*
Obstacle course backwards (s)	.451	.000	.513	.000	.386	.001
Flamingo balance (s)	-.005	.964	-.445	.000	-.518	.000
10 x 5m Shuttle run (s)	.119	.309	.008	.943	-.048	.681
Standing long jump (m)	.001	.943	-.264	.022	-.291	.011
Wide legged seated forward (m)	.373	.001	.385	.001	.299	.009
Sit-ups in 30s (freq)	-.032	.782	-.252	.029	-.271	.019
Pull-up endurance (s)	-.237	.041	-.514	.000	-.487	.000
30 sec Burpee (freq)	-.529	.000	-.350	.002	-.162	.165

BH – body height, BM – body mass, BMI – body-mass index

Body height and body mass were negatively associated with 30-second Burpee test scores ($p < 0.01$), while the correlation between body-mass index and 30-second Burpees was not significant ($p = 0.165$) (Table 2). When a model with two predictor variables (body height and body mass) was applied, a significant negative correlation was observed only between 30-second Burpees and body height ($p < 0.01$, adjusted $R^2 = 0.269$). The equation for the model was -14.230 - 0.529 x body height (Table 3).

Table 3. Regression analysis predicting Burpee test scores from predictor anthropometric variables

Variable	***B***	**SEB**	**ß**	**R²**
Model 1				0.286
Body height	-12.833	3.159	-0.477**	
Body mass	-0.014	0.017	-0.098	
Constant	35.797	4.826		
Model 2				0.279
Body height	-14.231	2.675	-0.529**	
Constant	37.266	4.485		

**p < 0.01

Motor battery test and 30-sec Burpee

In general, a large number of small to moderate correlations were observed among the motor test trials. The coordination test was significantly associated with almost all of the other motor tests, with the exception of Wide legged seated forward test ($p = 0.102$). Conversely, for the balance test, a significant negative association was only observed only with the results of the Obstacle Course Backward test ($p < 0.01$), while for Wide Legged Seated Forward test this was only the case with the 30-second Burpee test ($p < 0.05$). Not surprisingly, the results obtained for long jump, sit-ups, and pull-up endurance were significantly positively correlated ($p < 0.01$),

as they all represent different types of strength. The strongest correlation was found for the Obstacle Course Backward and the 30-second Burpee test ($p < 0.01$). In addition, the 30-second Burpee test correlated significantly with the agility ($p < 0.01$), upper-body endurance-strength ($p < 0.01$), and trunk strength tests ($p < 0.05$), but not with the balance ($p = 0.102$) and lower-body explosive strength ($p = 0.188$) tests (Table 4).

Table 4. Correlation matrix for tested motor variables

Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
(1) OCB (s)	/	-0.297**	0.347**	-0.307**	0.196	-0.431**	-0.468**	-0.517**
(2) FLA (s)	-0.297**	/	-0.059	0.102	-0.037	0.196	0.195	0.190
(3) 10 x 5m (s)	0.347**	-0.059	/	-0.347**	0.140	-.423**	-0.114	-0.380**
(4) SLJ (m)	-0.307	0.102	-0.347**	/	0.056	0.451**	0.489**	0.154
(5) WLSF (m)	0.196	-0.037	0.140	0.056	/	-0.022	-0.101	-0.259*
(6) Sit-ups (freq)	-0.431**	0.196	-0.423**	0.451**	-0.022	/	0.496**	0.257*
(7) PEND (s)	-0.468**	0.195	-0.114	0.489**	-0.101	0.496**	/	0.373**
(8) 30SBT (freq)	-0.517**	0.190	-0.380**	0.154	-0.259*	0.257*	0.373**	/

OCB – obstacle course backwards, FLA – flamingo balance, 10 x 5m – Shuttle run, SLJ – standing long jump, WLSF – wide legged seated forward, PEND – pull-up endurance, 30SBT – 30 sec burpee, *$p < 0.05$, **$p < 0.01$

Backward linear regression extracted a best-fitting model in the prediction of Burpee test scores that included the variables Obstacle course backward and 10x5 Shuttle run ($p < 0.01$, adjusted $R^2 = 0.301$). According to this model, coordination and agility explained 30% of the 30-second Burpee test scores. The equation for the model was 19.498 - 0.162 x coordination test - 0.156 x agility test (Table 5).

Table 5. Regression analysis predicting Burpee test scores from predictor motor variables

Variable	***B***	**SEB**	**ß**	**R^2**
Model 1				0.368
Obst Cours Back	-0.127	0.043	-0.343**	
Pull-up endurance	0.020	0.010	0.227	
Sit-ups 30sec	-0.048	0.049	-0.120	
Wide leg seat forw	-1.704	1.250	-0.134	
10x5m Shuttle run	-0.183	0.076	-0.267*	
Constant	21.717	2.355		
Model 2				0.359
Obst Cours Back	-0.120	0.043	-0.326**	
Pull-up endurance	0.016	0.009	0.180	
Wide leg seat forw	-1.847	1.241	-0.146	
10x5m Shuttle run	-0.155	0.070	-0.226*	
Constant	20.279	1.827		
Model 3				0.339
Obst Cours Back	-0.129	0.043	-0.349	
Pull-up endurance	0.016	0.009	0.182	
10x5m Shuttle run	-0.163	0.071	-0.238	
Constant	18.549	1.422		
Model 4				0.313
Obst Cours Back	-0.162	0.038	-0.438**	
10x5m Shuttle run	-0.156	0.071	-0.228*	
Constant	19.498	1.318		

* $p < 0.05$, **$p < 0.01$

DISCUSSION

The study was conducted to determine the relationship between the 30-second Burpee test and anthropometric and motor characteristics in teachers education female students. The results of correlative analysis indicate that 30-second Burpee performance is negatively related to body

height and body mass as anthropometric variables and also positively correlated with body coordination, agility, strength and flexibility as motor abilities. However, based on the regression analysis, the main results demonstrated a clear significant relationship only between the measures of body height and burpee test scores and also between burpee test performance and coordination and agility. This findings suggest that the effectiveness of the Burpee test is strongly dependent on motor abilities such as coordination and agility, and that body height has a negative influence on Burpee test performance.

Monitoring in PE is extremely important as it provides necessary information about the biological and motor development of children at different ages (Cale, Hariss & Chen, 2012). However, there is limited data on the level of physical fitness levels of both teachers and education teacher students. In addition to PE theoretical knowledge, teachers should demonstrate a certain level of physical fitness, given that preschool and early school-aged children learn new movements through visualisation rather than verbal method and also by the fact that obese teachers elicit negative reactions from children and are not considered as role models for PE (Archilbald, Hendricks, Boehner, & Chen, 2010; Breslin, Murphy, McKee, Delaney, & Dempster, 2012). In this study, we found that the average BMI was approximately 22 kg/m² as a reliable indicator of weight status, which classifies teacher students within the norm (WHO, 2015). Interestingly, correlation analysis showed that BMI, unlike body height and mass, was not significantly related to Burpee test performance. Furthermore, using regression analysis, only the model with body height was a significant predictor of Burpee test performance, explaining approximately 25% of the variance in test results. In contrast, Podstawski et al. (2013) concluded that all anthropometric measures (body height, mass and BMI) had a significant negative relationship with the Burpee test among teacher students. However, they evaluated a 3-min Burpee variation, which is more related to muscle-endurance ability and also used the simplest correlation method to examine the relationship between anthropometric and motor measures. Nevertheless, our results based on the linear regression method clearly demonstrate that only the longitudinal measures have a negative effect on the 30-second Burpee exercise. This is mostly explainable by the fact that a longer torso and longer extremities in taller participants require a longer time for the body to reach the squat position and return to the plank position during the burpees, resulting in a lower number of cycles during the 30-second trial compared to subjects with shorter body dimensions. Therefore, our finding could indicate a potential misleading interpretation of the Burpee test results, as subjects so not generally have the same body height. A possible solution to this issue could be to relativize the

Burpee test results (cycles/body height), as is the case when determining relative muscle strength in resistance training (absolute strength/body mass) (Fleck & Kraemer, 2014), yet future studies should be designed to address this problem.

The main objective of this study was to determine which motor abilities could be addressed by 30SBT. Although, 30SBT correlated significantly with various motor tests, including coordination, agility, strength, and flexibility tests, the best-fit model single out the Obstacle course backward and the 10x5m Shuttle run to be the most significant predictors of 30SBT scores. This finding suggests that 30-second burpee performance is highly dependent on coordination and agility, and that the 30SBT could be used to assess these specific physical fitness components. Previous studies have shown that longer burpee durations (≥ 1 min) are associated with strength-endurance capacity (McRae et al., 2012; Boraczynski et al., 2015; Podstawski et al., 2019a), but based on the findings of this study, coordination and agility appear to be more involved in shorter burpee variations. This is in good agreement with an early work of McCoy & Young (1954), who suggested that the 20-second Burpee test could be used mainly to assess coordination and agility compared to other motor aspects. Considering that the Burpee test is a complex motor exercise characterized by an efficient change of body position and also by a harmonious contractions of muscles in the upper, lower and middle regions, it is understandable why motor abilities such as agility and coordination are strongly involved in this particular movement. However, it should be noted that in our study, coordination and agility explained approximately 30% of the 30SBT scores, implying that other factors are significantly involved in the execution of the 30-second Burpee test variation. This may particularly relate to coordination, as coordination is a multidimensional construct (Avella & Bizzi, 2005; Lammle et al., 2010) and can be assessed with different test batteries (Fjortoft et al., 2011; Lopes, Stodden, Bianshi, Maia, & Rodrigues, 2012). For instance, different aspects of coordination, such as coordination in rhythm or speed performance in complex motor tasks, are assessed by different measurement techniques (Sakai, Hikosaka & Nakamura, 2004; Schott, Alof, Hultsch, & Meermann, 2007). We used the Obstacle course backward test, which is a reliable tool to assess coordination ability by reorganizing the dimension of movement stereotypes (Bala, 2010; Mandić, Pelemiš, Džinović, & Kojić, 2019), but there is a good possibility that other types of coordination could be significantly involved in the performance of the 30-second Burpee exercise.

Apart from being a predictor of 30SBT, the coordination test was significantly associated with almost all other motor aspects, with the exception of flexibility. Although, we did not further

examine these associations with additional statistical analyses, coordination appears to be a fundamental component of ability to succeed in other test tasks related to the dimensions of balance, agility and strength. Similar observations have been made in previous research for both young children and adolescents (Rausavljević, Katić, Žvan, & Viskić-Štalec, 1998; Fjortoft, 2000; Doder & Malacko, 2008; Deprez, Dos-Santos, Silva, Lenoir, Philippaerts, & Vaeyens, 2015; Mandic et al., 2019). Mandic et al. (2019) found a strong association between the Obstacle course backward test with strength, balance, and agility in preschool children, while Deprez et al. (2015) indicated that motor coordination is a significant predictor of explosive leg power in adolescent soccer players. In line with these reports, we demonstrated that this relationship is also present in the university population and that coordination is an important determinant of physical fitness performance in adulthood. However, as our sample consisted of untrained females, it is quite possible that this mediating role of coordination is more pronounced in adult individuals with low physical activity levels.

Limitations and strengths

Although there are several studies that have investigated the relationship between anthropometric and motoric variables with Burpee exercise, this is the first to find the best predictive model for the 30-second variation. We used numerous tests to assess different motoric dimensions, which is highly important given that Burpee is complex exercise. In addition, our research design included a large sample that would be representative enough about physical fitness among female university teachers. On the other hand, we used only one specific test to assess coordination ability, which is one of the limitation of the study. The second relates to the strength-endurance test (i.e., pull-up endurance), as it only measures segmental strength-endurance capacity (upper-body) and not whole-body. The third limitation is the lack of a cardio-respiratory endurance test, as a valuable component of overall physical fitness level. Therefore, future studies should implement various coordination, strength, and cardio-respiratory endurance tests to investigate whether other components of physical fitness are associated with the 30-second Burpee performance.

CONCLUSION

In conclusion, the 30-seconds Burpee test is a useful tool for assessing motor abilities, especially coordination and agility. From an anthropometric standpoint, body height has a negative impact on burpee performance, and should be taken into account during test trials.

Considering that the test is accessible to a large number of subjects and also involves low cost and equipment requirements, the 30-second Burpee variation should be implemented in the PE curriculum to assess the motor dimensions of preschool, school, and university populations.

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Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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SPORT FACTORS AS CORRELATES OF SMOKING, DRINKING AND MULTIPLE SUBSTANCE MISUSE IN ADOLESCENCE: CROSS-SECTIONAL STUDY

ŠPORTNI DEJAVNIKI KOT KORELATI KAJENJA, PITJA IN VEČKRATNE ZLORABE SUBSTANC V MLADOSTNIŠTVU: ŠTUDIJA PRESEKA

ABSTRACT

Sport participation is frequently considered as protective factor against substance misuse (SUM) in adolescence, but there is an evident lack of empirical studies which examined this problem taking into account various facets of sport participation (sport factors). This study aimed to evaluate possible associations between various sport factors and SUM in older adolescents from Croatia. The sample comprised 788 adolescents (16-to 18 years of age, 45% females). Variables included sport factors (participation in individual and team sports, competitive achievement in sports, and experience in sports), and SUM data (cigarette smoking, harmful alcohol drinking (HD), and simultaneous HD and smoking [multiple-SUM]). Boys were more involved in sports, and were more likely to be engaged in HD and MSUM than girls. Logistic regressions provided no evidence about significant association between sport factors, and smoking and HD. Sport factors were significantly associated to multiple-SUM, with lower likelihood of MSUM in adolescents who achieved better sport success (OR: 0.57, 95%CI: 0.40-0.78), who were involved in individual sports (OR: 0.71, 95%CI: 0.50-0.91), and team sports (OR: 0.80, 95%CI: 0.56-0.99). Sport factors may be observed as being protective against multiple-SUM, which is explained by characteristics of the sport participation in youth (i.e. orientation toward success, age-bonding, adult supervision).

Keywords: psychoactive substances, physical exercise, puberty, protective factors, risk factors

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IZVLEČEK

Udeležba v športu se pogosto šteje kot zaščitni dejavnik pred zlorabo prepovedanih substanc v mladostništvu. Do sedaj še ni bilo narejenih empiričnih študij, ki bi preučevale to težavo ob upoštevanju različnih vidikov športnega udejstvovanja. Glavni cilj študije je bil ovrednotiti možne povezave med različnimi športnimi dejavniki in zlorabo prepovedanih substanc pri starejših mladostnikih iz Hrvaške. Vzorec je zajemal 788 mladostnikov (starih med 16 in 18 let, od tega 55% mladostnikov in 45% mladostnic). Spremenljivke so vključevale športne dejavnike (udeležba v individualnih in ekipnih športih, tekmovalni dosežki v športu in izkušnje v športu), podatke o zlorabi prepovedanih substanc (kajenje cigaret, škodljivo uživanje alkohola ter sočasno uživanje alkohola in kajenje [multi-SUM]). Ugotovili smo, da se fantje več ukvarjajo s športom kot dekleta in pri njih tudi opažamo višjo konzumacijo alkohola in multi-SUM v primerjavi z dekleti. Z logistično regresijo nismo ugotovili značilnih povezav med športnimi dejavniki, kajenjem in sočasnim kajenjem ter pitjem alkohola. Športni dejavniki so bili značilno povezani z večkratnimi vsotami z manjšo verjetnostjo MSUM pri mladostnikih, ki so dosegli boljši športni uspeh (OR: 0,57, 95% IZ: 0,40-0,78) tako pri individualnih (OR: 0,71, 95% IZ : 0,50-0,91) kot pri skupinskih športih (OR: 0,80, 95% IZ: 0,56-0,99).

Ključne besede: psihoaktivne snovi, telesna dejavnost, mladostništvo, zaščitni dejavniki, dejavniki tveganja

INTRODUCTION

Consumption of cigarettes (i.e. smoking) is decreasing globally, but smoking is still one of the leading preventable causes of death worldwide (Bilano et al., 2015). The problem is aggravated in those countries where smoking is culturally and socially-acceptable behavior, since in those circumstances there are no strict social boundaries against such practice. Consequently, it results even in early smoking initiation and later nicotine dependence. With approximately 30% of adolescents who smoke, Croatia is within the EU countries with one of the highest prevalence of smoking among adolescents, and there is a growing interest in developing the policy aimed at prevention of smoking in the country (Kraus & Nociar, 2016).

Alcohol consumption is another type of substance misuse which is prevalent in Croatia. Partially, this is associated to Mediterranean style of living, where alcohol consumption (mostly wine) is regular, although drunkenness and intoxication is not socially accepted (Devcic et al., 2018). Alcohol is known to be related to significant health problems (i.e. blackouts, hallucinations, liver damage, infertility), while consumption of alcohol may result even in various negative social consequences as well (i.e. violence, unsafe sex, intoxicated driving) (Sanchez-Ramirez & Voaklander, 2018). Therefore, factors which may be directly or indirectly associated to alcohol drinking among adolescents are repeatedly investigated (Devcic et al., 2018; Zenic et al., 2019).

Scientific and professional authorities are greatly concerned about reducing the prevalence of smoking and alcohol drinking (substance misuse- SUM), globally In doing so, special attention is paid on youth, mostly because it is widely accepted that the age of 21 years is “critical” with regard to preventive efforts, simply because it is well known that those adolescents who do not initiate with smoking/drinking until the late adolescent, will likely never do so (Zenic, Terzic, Rodek, Spasic, & Sekulic, 2015). One of the globally accepted approaches in prevention is identification of the factors that can be related to SUM. Among others, factors related to participation and competitive achievement in sports (sport factors) are particularly interesting (Bjelica et al., 2016; Zenic, Terzic, et al., 2015).

Sport provides numerous benefits to youth, and among others it has also been suggested that participation in sport and exercise may prevent youth from various problematic-behaviors including smoking and drinking (Sekulic & Zenic, 2014). The idea of theoretically protective effects of sport participation against smoking and drinking in adolescence is based on simple fact that sports promote overall well-being, and participation in sport positively influence

development of various pro-social behaviors and self-discipline (Eime, Young, Harvey, Charity, & Payne, 2013). Therefore, it is expected that adolescents who are involved in sports are less likely to smoke and drink (Moore & Werch, 2005). The background of association between sport and substance misuse (SUM) in adolescence is profoundly explained by Wichstrøm & Wichstrøm, who presented protective- , but also theoretical risk-factors of sport participation with regard to SUM (Wichstrøm & Wichstrøm, 2009). In brief, authors identified age-segregation (sport is organized in age-groups), time-occupation (sport participation is time-consuming), orientation toward success, and adult supervision as factors which would prevent SUM in athletic adolescents. Meanwhile, sport is recongized as „social-activity“, which presents a factor of increased risk for SUM in adolescence (Wichstrøm & Wichstrøm, 2009).

Collectively, empirical evidences about correlation between sport participation and SUM in adolescence are not consistent. Specifically, the prevalence of smoking was regularly lower in adolescent athletes than in their non-athletic peers, but when investigations observed regions where smoking was socially acceptable (i.e. southeastern Europe and Balkan countries) the highest prevalence of smoking was found in former athletes, (Idrizovic, Zenic, Tahirajl, Rausavljevic, & Sekulic, 2015; Tahiraj et al., 2016; Zenic, Ostojic, et al., 2015). With regard to alcohol, studies more often did not than did confirm protective effects of sport participation against alcohol drinking in adolescence (Bedendo, Opaleye, Andrade, & Noto, 2013; Bjelica et al., 2016; Cerkez, Culjak, Zenic, Sekulic, & Kondric, 2015; Vest & Simpkins, 2013). Collectively, some investigators reported lower levels of alcohol consumption in athletic adolescent (Sigfusdottir, Kristjansson, Thorlindsson, & Allegrante, 2008), but a great deal of studies evidenced higher risk for alcohol consumption in those adolescences who were involved in sports (Bedendo et al., 2013; Bjelica et al., 2016; Cerkez et al., 2015; Vest & Simpkins, 2013). Generally, differences in findings may be explained regarding differences in the type of sport (i.e., individual vs. team-sports), level of sport participation (i.e. success in sport), gender-specific associations, etc. (Cerkez et al., 2015; Modric, Zenic, & Sekulic, 2011; Tahiraj et al., 2016).

Despite the increasing interest about the problem, there is a still evident lack of research where different facets of sport participation were observed as potential correlates of consumption of various psychoactive substances, especially with regard to multiple SUM (MSUM). Namely, there is no doubt that those adolescents who simultaneously consume cigarettes and alcohol are at particular risk for development of various detrimental health- consequences and social—problems associated with SUM. On the other hand, there is an evident lack of investigation

where this problem is investigated in relation to sport-factors, while to the best of our knowledge no study directly examined these issues specifically in Croatian adolescents. Therefore, the aim of this investigation was to evaluate the associations which may exist between sport factors, and cigarette smoking, harmful alcohol drinking and MSUM (simultaneous smoking and harmful drinking) in older adolescents from Croatia.

METHODS

Participants and design

In this study, we observed 17-to-18-year-old adolescents (n = 788, 45% females). The sample comprised adolescents from southern regions in Croatia, from three cities located on the Adriatic coast, namely Split, Makarska and Dubrovnik.- While the idea of the study was to evidence sport factors potentially related to SUM, it was necessary to obtain a sample of participants in the regions with similarity in cultural heritage, specifically, similar in social acceptance of specific substances. Multistage sampling was used. First, we selected by lottery one-third of the high schools in the studied cities. In the next phase, one-third of all high school final grades were selected via lottery from the previously selected schools, resulting in a sample of 39 classes. The survey was administered on a single day, meaning that all high school seniors who were at school on that day were invited to participate. Before the study, the complete procedure and aim of the testing were explained to all participants and at least one parent, and parental consent was obtained. Testing was strictly anonymous, meaning that no personal data were collected (e.g., date of birth, city of birth, or specific club or sport participation). Multiple-choice answers were offered where possible (see the Results for more details).

Testing occurred in a group of at least 13 examinees. Each examinee was told that the testing was strictly anonymous, that he/she could refuse to participate and that they could leave some questions and/or the entire questionnaire unanswered, and that the returning of the questionnaire will be considered as their consent for the participation in the study. Each examinee received two questionnaire forms and one envelope. When the testing was completed, each examinee placed one form (answered or unanswered) in the envelope, sealed it and placed in the closed box, while the second one was destroyed in paper shredder. On the next day, the envelopes were opened by an investigator who had not tested the participants. The study fulfilled all ethical guidelines and received the approval of the Ethical Board of University of Split, Faculty of Kinesiology.

Variables

The previously validated questionnaires were used in order to collect data (Cerkez et al., 2015; Zenic, Peric, Zubcevic, Ostojic, & Ostojic, 2010; Zenic et al., 2019). Variables comprised gender (male – female – other), age (in years), sport factors and SUM data.

SUM data included cigarette smoking, alcohol drinking, and MSUM (derived from answers provided for smoking and drinking, please see later). Participants were asked about their smoking habits and alcohol consumption. Smoking was tested on a six-point scale ("Never smoked" – "Quit"– "From time to time, but not daily" – "Daily less than 10 cigs" – "More than 10 cigarettes daily"). For the purpose of this study and statistical calculations (see below for details) the participants were observed as "non-smokers" (first two responses) and "smokers". Alcohol consumption was measured using the AUDIT questionnaire. In this questionnaire, participants answer ten items and the scores for each item range from 0 to 4, which defines the hypothetical range of a minimum of 0 to maximum of 40. The results were later divided into "harmful drinking" (HD; scores of 11 or above) and "non-harmful drinking" (scores below 11), which allowed us to observe the results as a categorical variable (Cerkez et al., 2015; Pallesen, Josendal, Johnsen, Larsen, & Molde, 2006). Those participants who declared smoking and harmful alcohol drinking were categorized in MSUM.

The sport factors included questions on (i) involvement in team sports, such as basketball, handball, football/soccer, (ii) involvement in individual sports, such as martial arts, track and field, swimming (both asked on scale including: Never been involved, Quit, Currently involved; later dichotomized on involved – non-involved) (iii) highest competitive achievement in sports (Never competed/did not participate in sports, Local competitions, National/International level competitions); and (iv) time of involvement in sports (Never involved, <1 year, 2-5 years, >5 years).

Statistics

Distributions of variables were checked by Kolmogorov Smirnov test, and descriptive statistics included means and standard deviations (for AUDIT scores and age), and frequencies and percentages (for remaining variables).

Gender-differences between genders in raw AUDIT scores and age were established by independent samples t-test. Mann Whitney test (MWZ) was used to calculate the differences between genders in sport-factors, and smoking prevalence observed on ordinal scale, while Chi

square test ($\chi 2$) was calculated to identify the differences in prevalence of MSUM and harmful drinking between boys and girls.

Logistic regression was used to evidence the associations between sport factors with binomial criteria (smoking [yes-no], harmful drinking [yes-no], and MSUM [yes/no]). The odds ratio (OR) and the corresponding 95% confidence interval (95%CI) were reported. The logistic analyses were calculated as crude model (Model 0), and then adjusted for gender (Model 1).

RESULTS

No significant difference between genders was evidenced in age (17.1±1.3 and 17.0±0.9 for boys and girls, respectively; t-test = 0.09, $p > 0.05$), while alcohol consumption observed as AUDIT raw score was higher in boys (5.86±4.86 and 3.22±2.98, for boys and girls respectively; t-test: 6.03, $p < 0.001$).

Table 1 presents descriptive statistics for ordinal variables (sport factors and SUM data), with differences between genders calculated by Mann Whitney and $\chi 2$. The 12% of boys and 43% of girls have never been involved in any type of sports. Boys were more involved in sports than girls, and this was evident for participation in individual sports (MWZ = 8.97, $p < 0.001$), participation in team sports (MWZ = 10.4, $p < 0.001$), sport achievement (MWZ = 5.96, $p < 0.001$), and sport experience (MWZ = 11.45, $p < 0.001$). The 30% of boys and 26% of girls were smokers, while harmful drinking was evidenced for 12% of boys and 9% of girls. The prevalence of harmful drinking ($\chi 2 = 8.68$, $p < 0.01$), and prevalence of MSUM ($\chi 2 = 12.34$, $p < 0.001$), were higher in boys.

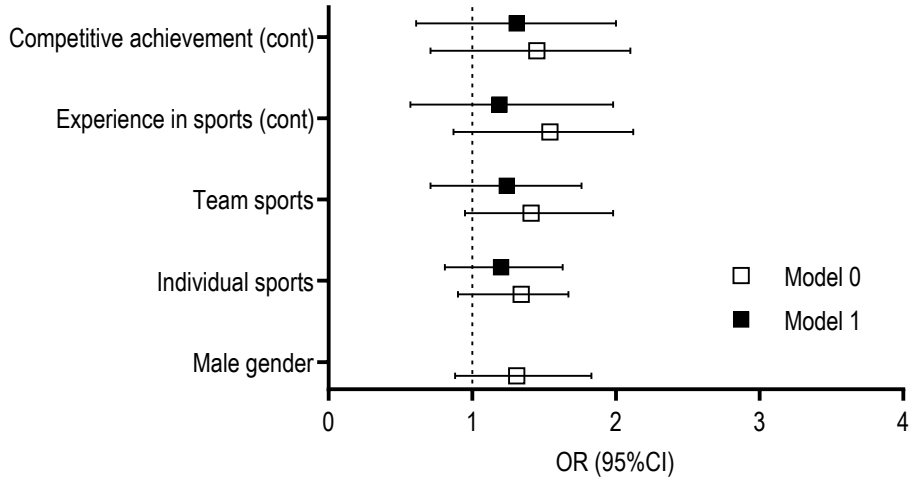
Table 1. Descriptive statistics (F – frequencies, % - percentage) and differences between genders (MWZ – Mann Whitney Z test, χ2- Chi square test) in studied sport factors and substance misuse data

	Boys		Girls		MWZ/ χ^2	
	F	%	F	%	MWZ/ χ^2	p
Smoking						
Never	276	64.5	248	70.1		
Quit	24	5.6	14	4.0		
From time to time, but not daily	80	18.7	64	18.1		
< 10 cigarettes daily	22	5.1	12	3.4		
> 10 cigarettes daily	26	6.1	16	4.5	1.68	0.09
Harmful drinking χ^2						
No	362	84.6	324	91.5		
Yes	66	15.4	30	8.5	8.68	0.01
Multiple substance misuse χ^2						
No	51	11.9	17	4.8		
Yes	377	88.1	337	95.2	12.34	0.001
Participation in individual sports						
Never	136	31.8	28	7.9		
Quit	146	34.1	108	30.5		
Yes, still participating	146	34.1	218	61.6	8.97	0.001
Participation in team sports						
Never	146	34.1	40	11.3		
Quit	194	45.3	122	34.5		
Yes, still participating	88	20.6	192	54.2	10.4	0.001
Competitive achievement in sports						
Not participated/never competed	180	42.1	232	65.5		
Local competitions	212	49.5	98	27.7		
National/International competitions	36	8.4	24	6.8	5.96	0.001
Time of the involvement in sports						
Never involved	54	12.6	154	43.5		
< 1 year	82	19.2	90	25.4		
2-5 years	140	32.7	72	20.3		
> 5 years	152	35.5	38	10.7	11.45	0.001

The results of the logistic regression calculations, where sport factors were correlated with dichotomized smoking prevalence are presented in Figure 1. In brief, some of the sport factors

were significantly associated with smoking prevalence in crude model (Model 0). However, the higher prevalence of smoking and greater involvement in sport among boys actually resulted in non- significant associations between sport factors and smoking evidenced in Model 1. In other words, none of the sport factors was correlated with smoking when gender was included in regression calculation as covariate (model 1).

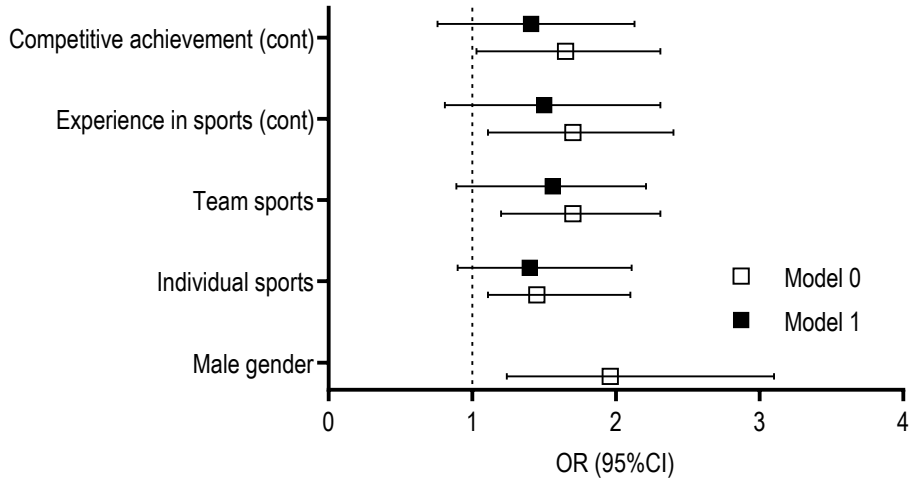
Figure 1. Correlates of cigarette smoking among studied adolescents (OR – Odds Ratio, CI – Confidence Interval, Model 0 – crude logistic regression calculation, Model 1 – logistic regression calculation including "gender" as confounding variable)



Legend: Individual sports – participation in individual sports (yes – no), Team sports – participation in team sports (yes – no), Experience in sports (time of the involvement in sports – observed as continuous variable). Competitive achievement (competitive achievement in sports – observed as continuous variable)

When regressions were calculated for harmful alcohol drinking criterion, gender was once again a strong confounding factor of the associations between sport-factors and criterion (Figure 2). In brief, there was no single significant correlation between predictors and occurrence of harmful drinking in studied adolescents for Model 1 (regression model which included "gender" as covariate).

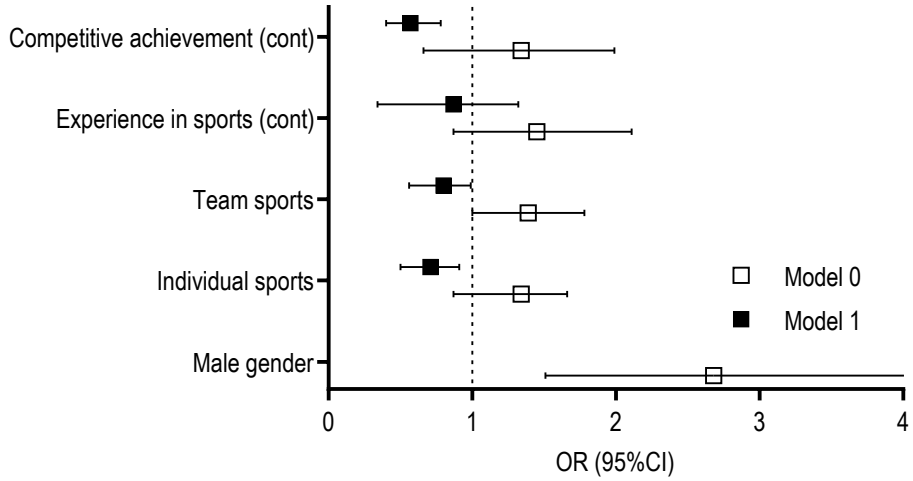
Figure 2. Correlates of harmful alcohol drinking among studied adolescents (OR – Odds Ratio, CI – Confidence Interval, Model 0 – crude logistic regression calculation, Model 1 – logistic regression calculation including "gender" as confounding variable)



Legend: Individual sports – participation in individual sports (yes – no), Team sports – participation in team sports (yes – no), Experience in sports (time of the involvement in sports – observed as continuous variable). Competitive achievement (competitive achievement in sports – observed as continuous variable)

Sport factors were significantly associated to MSUM (Figure 3). Specifically, variables explaining sport engagement were correlated with criterion – MSUM in Model 1 (logistic regression calculation which included "gender" as covariate). The strongest correlation was evidenced for "sport achievement" (OR: 0.57, 95%CI: 0.40-0.78), followed by "participation in individual sport" (OR: 0.71, 95%CI: 0.50-0.91), and "participation in team sports" (OR: 0.80, 95%CI: 0.56-0.99), all indicating certain level of protective effect of sport participation against MSUM.

Figure 3. Correlates of multiple substance misuse (simultaneous smoking and harmful alcohol drinking) among studied adolescents (OR – Odds Ratio, CI – Confidence Interval, Model 0 – crude logistic regression calculation, Model 1 – logistic regression calculation including "gender" as confounding variable)



Legend: Individual sports – participation in individual sports (yes – no), Team sports – participation in team sports (yes – no), Experience in sports (time of the involvement in sports – observed as continuous variable). Competitive achievement (competitive achievement in sports – observed as continuous variable)

DISCUSSION

There are several most important findings of this study. First, sport factors were not associated with cigarette smoking and alcohol drinking in studied adolescents when two types of substances were observed separately. Second, there was relatively consistent association between sport factors and MSUM, with lower likelihood of MSUM in athletic adolescents, especially those who achieved better sport success. Third, participation in individual sports seems to be stronger protective factor of MSUM than participation in team sports.

Sport factors in relation to smoking and drinking in adolescence

When smoking and alcohol drinking were observed separately as criteria, our results didn't confirm protective effects of sport participation against SUM in studied adolescents. In explaining such findings a short presentation of the theoretical influence of sport on SUM in adolescence is needed. In one of the most comprehensive overviews about theoretical framework for the association between sport and SUM Wichstrøm and Wichstrøm explained

several facets that may positively or negatively affect the risk of SUM in the athletic context (Wichstrøm & Wichstrøm, 2009). The first protective aspect is related to age segregation. Briefly, age segregation is common in sports and children often participate in training and competition exclusively with their age-matching peers. It logically reduces the possibility to be accompanied with older adolescents who (more frequently) consume substances. Second protective aspect is related to time occupation (i.e. sports training and competitions take time, and therefore, there is less time for activities associated with SUM). Third, sport is regularly characterized by adult supervision (adult coaches are regularly involved), and this may limit any type of problem behavior. Fourth, in sport strong orientation toward success is present. Since consumption of cigarettes and alcohol reduces the physical capacities, it logically alters the sport results and achievement, and consequently athletic adolescents would avoid it. However, apart from all these "protective effects of sport participation", potential risk should also be emphasized. In brief, there is no doubt that sport is a "social activity", and therefore may present a certain risk of a higher likelihood of SUM. Collectively, many but not all characteristics of sports may reduce the risk of SUM in adolescents, which may help even in explaining our findings.

When it comes to alcohol, some previous studies pointed to higher levels of alcohol consumption in athletic adolescents than in their non-athletic peers (Lisha & Sussman, 2010; Modric et al., 2011; Peretti-Watel, Beck, & Legleye, 2002). However, some authors evidenced sports participation as being protective against alcohol use (Donato et al., 1994). Since previous studies were inconsistent with regard to association between sport and alcohol drinking, it is not surprising that we foundnonsignificant association between sport participation and alcohol drinking. (Donato et al., 1994; Lisha & Sussman, 2010; Modric et al., 2011; Peretti-Watel et al., 2002). In explaining, the findings of the recent report when authors prospectively examined alcohol consumption and alcohol initiation in adolescents are particularly interesting (Zenic et al., 2019). In this study, athletic adolescents started to consume alcohol earlier than their non-athletic peers (i.e. before 16 years of age), but alcohol consumption in non-athletic adolescents increased in the forthcoming period of life (from 16 to 18 years of age). Such dynamic were explained by „social context of sport participation and alcohol consumption in post-sport social gatherings" (Zenic et al., 2019). If we accept such tendencies even for our participants, it is not surprising that we found no correlation between sport factors and alcohol consumption.

Previous studies have reported the presence of different associations between sport-factors and cigarettes smoking in children and youth (Sekulic, Ostojic, Ostojic, Hajdarevic, & Ostojic,

2012; Tahiraj et al., 2016). Therefore, it is not surprising that our results did not confirm protective effects of sport-participation against smoking in studied adolescents. While most of the sport factors observed herein can be contextualized it the term of "social influence of sport related gatherings" and higher possibility for cigarette smoking in such occasions, one of the sport factors which definitively deserves attention is a factor of "sport achievement". In brief, knowing the negative influence of smoking on physiological capacities (Misigoj-Durakovic et al., 2012), it was clearly expected that sport achievement will be identified as protective factor against smoking in adolescence. However, irrespective of the clear logic for "protective effect of sports against smoking", the opposite mechanism also appears. Namely, in the studies socio-cultural environment (southern Croatia), cigarette smoking is generally "socially accepted behavior" (Samardzic, Marvinac, & Prlic, 2009). According to social ecological theory in order to understand human development and lifelong changes (including behavioral changes), the entire ecological system in which growth and development occur should be taken into account (Bronfenbrenner, 1994). While adolescents must function in various environments, constantly trying to position themselves in the most comfortable one, the fact that sport participation was not protective against smoking in social environment where smoking is generally accepted, is not surprising.

Sport factors in relation to MSUM in adolescence

The interest in evidencing the potential differential effects of individual/team sport participation on SUM in adolescence in relatively novel in scientific literature. It is generally based on specific socio-cultural contexts of individual and team sports, which may generate the differential influence on SUM as well. Briefly, participation in team-sports regularly includes various types of post-sport social gatherings where substance are regularly consumed (Sekulic, Bjelanovic, Pehar, Pelivan, & Zenic, 2014). It logically puts team-sport athletes in danger of SUM. On the other hand, post-sport gatherings are not so frequent in individual sports. Also, some individual sports (i.e. martial arts) are organized in weight categories, while in some individual sports body mass and physique directly influence the sport outcome and result (i.e. aesthetic sport disciplines). Therefore, those athletes regularly avoid alcohol because of its energetic value (7kcal/g), and consequent caloric intake. Further, athletes in some individual sports (e.g. aesthetic sports) are highly concerned about their body weight (Pustivšek, 2019), and studies conformed positive tendencies toward smoking in such sports due to its effect on basal metabolism (e.g. smoking increases basal metabolism), and appetite suppression (Zenic

et al., 2010). Putting it all together, there is no doubt that, at least theoretically, individual and team sports should be observed separately with regard to SUM behavior.

Irrespective of mentioned differences between individual and team sports, both type of sports are found to be protective against MSUM, meaning that adolescent athletes are less likely to simultaneously consume cigarettes and alcohol. Therefore, previously specified protective mechanisms against SUM (e.g. age segregation, time occupation, adult supervision, orientation toward success) collectively dominate over "risk factor of sport participation" (i.e. sport as social activity), at least in the case of MSUM. Most likely, young athletes are generally concerned about various negative aspects of SUM and avoid such behavior irrespective of the "nature" of the type of sport they are coming from. In this context, the "nature" reflects various aspects, including organizational and socio-cultural characteristics (individual vs. team sports in the light of group-traveling, social-gatherings), psychological- (i.e. higher or lower necessity of arousal for the purpose of sport competition), or physiological-metabolic-aspects (i.e. necessity of proper body weight, importance of physiological capacities in achieving sport result). It is altogether additionally accentuated in those athletic adolescents who achieved higher competitive result.

From the authors' perspective as experienced sport pedagogues, the difference between participation in individual- and team-sports in the magnitude of their protective influence on multiple SUM is not surprising. The individual athletes are naturally more focused on their own capacities than team-sport athletes, simply because success of the individual athletes in directly and unconditionally related to their own psycho-physiological capacities. In other words, while team-sport athletes can in some circumstances achieve high sport-result on the basis of quality of their team-mates (i.e. being member of good team), this is hardly achievable in individual-sport settings. Collectively, it results even in stronger protective effect of individual-sport participation against MSUM in studied adolescents.

Limitations and strengths

The cross-sectional study design is the most important limitation of the investigation. Therefore, although some established associations may be logically interpreted (i.e. differential effects of individual and team sports on MSUM), for a more accurate depiction of the studied problem prospective analysis is needed. Second, the study is commenced with specific sample of adolescents in the region where some sports are particularly popular among youth, and where

smoking is socially accepted behavior even in youth. Therefore, the results are generalizable to similar samples.

This is one of the first studies where specific sport factors are observed as being associated with SUM, and MSUM. Therefore, results provide relatively accurate picture about studied problem. Also, usage of the previously validated and widely used measurement tools allowed us to precisely compare the study results with those already reported. Therefore, we believe that the study, although not being the final word on a topic, will provide certain improvement in the body of knowledge and initiate the further research.

CONCLUSION

Study results provided no evidence about possible association between sport participation and single-type of SUM in older adolescents from southern Croatia. Most probably, while some factors may decrease the risk of smoking and harmful drinking, others may be observed as factors of increased risk of such behavior in this period of life. The "negative" influence of sport is particularly possible to occur taking into account that we observed the region where prevalence of alcohol drinking and cigarette smoking is generally alarming, and where are no clear social and/or cultural barriers against such type of SUM.

Although substance-specific analyses did not provide conclusive evidences about association between sport factors, smoking and drinking, the simultaneous drinking and smoking is evidently lower in adolescents who participate and compete in sports, than in their non-athletic peers. Since the participation in individual sports has stronger protective effect against multiple SUM than participation in team sports it is clear that sport-characteristics should be highlighted in further studies which will tend to explore the protective/risk effects of sport participation on different health-related issues.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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SITTING DUCKS: PHYSICAL ACTIVITY AND DIET-RELATED INTERVENTIONS IN THE "PERI-COVID-19" PERIOD

TELESNA DEJAVNOST IN PREHRANSKE SMERNICE V ČASU COVIDA-19

ABSTRACT

The global coronavirus disease 2019 (COVID-19) poses specific challenges for physically-active cohorts of people. Students, adults, and the elderly need to adapt and seek proper physical activity and diet-related interventions to use their spare time effectively and/or improve their health. Not surprisingly, the existing body of knowledge reveals a consensus on the importance of proper nutrition and physical activity in the so-called "peri-COVID-19" period (i.e., before, during, and after the coronavirus pandemic); however, we explain context-dependent considerations. Therefore, the present study provides a brief review of current knowledge of physical activity and nutrition and develops a three-stage conceptual model for context-based guidelines. The model pinpoints the relative importance of parameters of physical activity in three different periods. In addition, we provide illustrative examples of appropriate training regimens. Our findings complement the agenda for individuals willing to establish desired physical condition and nutrition after the pandemics. Finally, we reveal the supportive role of diet-related interventions and supplements in the peri-COVID-19 period.

Keywords: COVID-19, physical activity, nutrition, guidelines, model

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IZVLEČEK

Razsežnost koronavirusne bolezni (COVID-19) predstavlja specifične izzive za različne skupine aktivnih posameznikov. Študentje, odrasli in starejši odrasli se morajo prilagoditi in s prehranskimi intervencijami ter redno telesno dejavnostjo izkoristiti čas učinkovito ter ob tem izboljšati zdravje. Pretekle raziskave kažejo na vlogo oz. pomen ustrezne prehrane in telesne dejavnosti v obdobju pred, med in po COVIDU-19 ("peri-COVID-19"), vendar je potrebno ugotovitve relativizirati in opredeliti. Pričujoča študija zatorej ponuja kritičen pregled literature na področju relevantnih dejstev o telesni dejavnosti in prehrani ter razvije 3-stopenjski konceptualni model za boljše razumevanje smernic v celotnem obdobju COVIDA-19. Z modelom ponazorimo relativne razlike med posameznimi fazami in s primeri dodatno pojasnimo, kako ustrezno načrtovati prehrano in vadbo v t. i. peri-COVID-19 obdobju. Z našimi ugotovitvami in pregledom potencialne vloge prehranskih dopolnil lahko posamezniki bolje oblikujejo telesno pripravljenost in se predvidoma uspešneje vrnejo k zdravemu življenjskemu slogu po pandemiji koronavirusne bolezni.

Ključne besede: COVID-19, telesna dejavnost, prehrana, smernice, modeliranje

INTRODUCTION

Since antiquity, when Hippocrates warned that proper nutrition alone would not keep a person healthy, regular physical activity has been known to positively affect physical and mental health (Berryman, 2010). From the physiological perspective, any event that requires the consumption of energy as a result of skeletal muscle contraction is physical activity (Caspersen, Powell & Christenson, 1985). Physical activity is thus any activity that raises the heart rate and can be implemented in the form of sports, for instance walking to school or work, playing with friends, family, dancing, or other workouts (Roberts, Tynjala & Komkov, 2004). Physical activity positively impacts a person's development if it is frequent and of sufficient quality, intensity, and duration (Goh, Lim & Suzuki, 2019; Haskell et al., 2007).

Physical activity and nutrition improve physical health, well-being, quality of life, and cognitive performance (Arena et al., 2018; Hazzard et al., 2020; Kraemer, Ratamess & French, 2002; O'Connor, Paddon-Jones, Wright & Campbell, 2018; Powell & Pratt, 1996; Swift et al., 2013; Theodore et al., 2020). The technological and social developments of recent decades have led to major lifestyle changes (Ryden, 2015); compared to the generations of our parents or grandparents, to whom physical activity, from physical transport to hard work, was part of everyday life, the current environment not only reduces the need for such physical activity but also encourages sedentary behaviors and entices individuals into unhealthy dietary choices (Keim, Blanton & Kretsch, 2004; Owen, Sparling, Healy, Dunstan & Matthews, 2010). Consequently, people's energy expenditure has been gradually reducing (Hill, Wyatt, Reed & Peters, 2003; Tremblay, Colley, Saunders, Healy & Owen, 2010). The coronavirus pandemic inevitably increases sedentary lifestyle by establishing the need to quarantine individuals, and thus poses cumbersome challenges to designing physical activity appropriately (Khoramipour et al., 2020). More importantly, a growing body of evidence emphasizes the role of proper nutrition, medical support, and healthy lifestyles in pre-disease and during the period of infection to more effectively cope with COVID-19 (see, e.g., Aman & Masood, 2020; Jordan Ministry of Health, 2020; Khoramipour et al., 2020).

Much attention has been devoted to analyzing patients' fitness when hospitalized (or self-isolated) because of the global COVID-19 pandemic. To the best of our knowledge, the severity of the disease was linked to prior health-related issues such as pre-diabetes, prolonged hyperglycemia, type-2 diabetes, hypertension, obesity, and other chronic diseases (see, e.g., Brufsky, 2020; Surveillances, 2020). The avoidance of a sedentary lifestyle should be of key

importance for individuals in quarantine (Rynders, Blanc, DeJong, Bessesen & Bergouignan, 2018), especially as the growing body of evidence demonstrates the role of metabolic dysfunction and associated metabolic states to severe cases of COVID-19 (see, e.g., Targher et al., 2020). In addition, a sedentary lifestyle and poor diet choices are reliable predictors of weight gain (Booth, Rowlands & Dollman, 2015; Hruby et al., 2016; Rynders, Blanc, DeJong, Bessesen & Bergouignan, 2018; Sigmund et al., 2018), several forms of cancer (Gilchrist et al., 2020), chronic non-communicable diseases, including the risk of coronary heart disease (Batty & Lee, 2004), and COVID-19 susceptibility (Butler & Barrientos, 2020).

While the benefits of limiting sedentary behavior are intuitive, we address the ambiguities regarding the recommendations for coping with the sedentary lifestyle before, during, and after the coronavirus pandemic ("peri-COVID-19 period"). We differentiate between three time spans due to their inherent differences. The before stage is characterized by little to no barriers to being physically active and the probability of an average individual becoming infected with SARS-CoV-2 limited to zero. In the during stage, several limitations, such as mandatory staying at home or within one's county, exist and can prevent individuals from remaining as active as they previously were. In addition, the diet selection is expected to be poorer and lower, while the probability of an average individual to become infected rises considerably with a coronavirus pandemic. Drawing on the previous pandemics and anticipating and depicting near-future agenda, we consider the after stage as a period in which an average individual's physical activity (or condition), as well as the probability of becoming infected, is lower, while the barriers for physical activity are either non-existent or pose a little danger to preventing an individual from establishing and maintaining a level of physical activity similar to the one prior to the pandemic.

In the remainder of the study, we describe the existing body of knowledge to pinpoint potential differences in designing training regimens (e.g., moderate vs. vigorous bouts of exercise) and diet choices in the peri-COVID-19 period. By so doing, the aim of this study is thus three-fold. First, we review the literature on physical activity and general nutritional guidelines, emphasizing sedentary populations. Second, we contextualize the findings and develop a conceptual model to complement the existing guidelines concerning specific time-dependent interventions advised. Third, the current study discusses the potential to-be state after the coronavirus pandemics concerning physical activity and nutrition and provides a salient agenda for individuals whose goal is to increase activity and improve conditioning in the future.

THEORETICAL BACKGROUND

Physical fitness and physical activity

Physical fitness represents the level of physical ability that enables a person to operate independently and efficiently in everyday life, and it is closely related to health (Ortega, Ruiz, Castillo & Sjöström, 2008). Poor physical fitness has been associated with the risk of early cardiovascular death, which strongly suggests that physical fitness may modulate cardiovascular death risk (Engeseth et al., 2018). Physical inactivity is currently one of the most common causes of premature mortality (World Health Organization, 2020).

Evidence shows that even occasional high-intensity physical activity enhances immune responsiveness because it leads to increased antibacterial and antiviral immunity (Campbell & Turner, 2018). Research suggests that physical activity, which lowers systemic inflammatory activity and enhances aspects of immune function, leads to adjustments in the biomarkers of an aging immune system (Abramson & Vaccarino, 2002; Kasapis & Thompson, 2005). These changes could be interpreted as limiting or delaying immunological aging (Simpson, 2011; Simpson & Guy, 2010; Turner, 2016; Turner & Brum, 2017).

Research on proper (context-based) recommendations about physical activity during the coronavirus pandemic is scarce, although it is quite intuitive that the effects and measures implemented by governments worldwide to combat the COVID-19 will adversely impact the duration, intensity, and frequency of physical activity (Lippi, Henry & Sanchis-Gomar, 2020).

In the remainder of the chapter, Table 1 summarizes the available general guidelines concerning physical activity from the literature. Drawing on both the physical-activity and general nutritional guidelines, we then proceed to the development of a three-stage conceptual model.

Table 1. Excerpts of relevant general guidelines for peri-COVID-19 physical activity.

1.	Make physical activity a compulsory part of your daily schedule (Buchman et al., 2012; Church et al., 2011; Jurak et al., 2020; World Health Organization, 2010).
2.	Gradually work towards increased frequency, duration, and intensity (Hull, Loosemore & Schwellnus, 2020).
3.	Minimize sedentary time with short bouts of physical activity at home (Pinto, Dunstan, Owen, Bonfa & Gualano, 2020; Khoramipour et al., 2020; Warren et al., 2010).
4.	Prioritize adherence (the continuity and regularity) rather than the intensity of the physical activity (Ricci et al., 2020; Turner & Brum, 2017).

5.	Elderly people at greater risk of infection should perform light-intensity exercises to stimulate muscles and flex joints (World Health Organization, 2010), while the sedentary population, in general, should avoid exhausting exercise during pandemics (Shephard & Shek, 1994).
6.	The elderly should regularly perform suitable light-to-moderate intensity exercises for endurance, strength, balance, and flexibility (Buchman, Boyle, Yu Shah, Wilson & Bennett, 2012; Seguin & Nelson, 2003).
7.	Indoor physical activity should be preferred for those with hay fever (Jayawardena, Sooriyaarachchi, Chourdakis, Jeewandara & Ranasinghe, 2020).
8.	Physical activity (outdoors in compliance with physical distancing) is widely encouraged to battle the psychological effects of prolonged self-isolation (Jiménez-Pavón, Carbonell-Baeza & Lavie, 2020; Brooks et al., 2020).
9.	Any physical activity with the potential to transmit viruses such as SARS-CoV-2 during the pandemic should be adapted or avoided (Ricci et al., 2020).
10.	Avoid risk-prone and vigorous physical activity (i.e., exercise training performed at 7-9 times the intensity of being at rest) during the pandemics to prevent additional burdens on the health-care system (Bøyum, 1996; Toresdahl & Asif, 2020).

Nutrition and diet-related interventions

While different researchers, health representatives, and advisors in nutrition science generally agree on the importance of the quality of diet for general health, enhanced immunity, cognitive ability, physical performance, and the prevention of various diseases (Rizkalla, Bellisle & Slama, 2002; Ventura et al., 2009), consensus regarding a proper nutritional strategy remains elusive (Aragon et al., 2017). Nutrition plays an important role in an individual's fitness, especially in relation to concepts such as metabolic flexibility, glycemic control, and cholesterol levels, all known to be either related to several aspects of immune function or to more severe cases of COVID-19 (Butler & Barrientos, 2020; Brufsky, 2020; Hu, Chen, Wu, He & Ye, 2020; Targher et al., 2020).

Except for some unbiased and strategic views of the topic, it remains difficult to identify a proper nutritional plan. While the "nutritional conundrum" results from over-reliance on statistical significance, omitting context, or biased views (e.g., as a result of financial interests), it is inherently impossible to prepare a universally-applicable nutritional plan. More recently, the debates on diet choice revolve around its environmental impact in addition to health benefits (Aboussaleh, Capone & El Bilali, 2017). Unhealthy diets are not only more common worldwide but also contribute to the development of chronic diseases (see, e.g., Echouffo-Tcheugui &

Ahima, 2019). Since severe cases of COVID-19 are widely present in individuals with obesity, chronic diseases, or poor medical condition (see, e.g., Cai et al., 2020; Muniyappa & Gubbi, 2020; Robilotti et al., 2020), healthy diets should be of top priority during the coronavirus pandemic (see, e.g., Butler & Barrientos, 2020; Yousfi, Bragazzi, Briki, Zmijewski & Chamari, 2020). Table 2 below demonstrates some of the diet-related interventions with the potential to aid in fighting the coronavirus pandemic.

Table 2. Excerpts of relevant diet-related interventions for peri-COVID-19.

1.	Dietary adherence is a critical success factor for diet-related interventions and should be considered when adopting a nutritional plan (Gibson & Sainsbury, 2017; Greenland, 2019).
2.	Diet should promote lean-mass gain or weight loss (if applicable) to help individuals reach their desired body mass index (Kwok et al., 2020; Sattar et al., 2020).
3.	Nutritional plans primarily focused on weight loss should be driven by caloric surplus, whereas the plans aimed at lean-mass gain should focus on caloric surplus (Aragon et al., 2017; Strasser, Spreitzer & Haber, 2007)
4.	Various nutritional plans can promote health benefits and body composition if calorie intake, macronutrients, and micronutrients are properly managed (Aragon et al., 2017; Lange & Nakamura, 2020).
5.	Ensure glycemic control in infected patients or individuals with chronic diseases such as diabetes (Brufsky, 2020; Bode et al., 2020).
6.	In stressful and tedious situations, such as quarantine, choose food that promotes a desirable stress response (Muscogiuri, Barrea, Savastano & Colao, 2020; Yilmaz & Gökmen, 2020).
7.	Controversy remains regarding different and/or ideal nutritional strategies for enhancing immunity (Hoyles & Vulevic, 2008; Pae, Meydani & Wu, 2012)
8.	Healthy diet is widely encouraged to aid the fight against COVID-19 (Khoramipour et al., 2020; Calder, Carr, Gombart & Eggersdorfer, 2020)
9.	Avoid diets low in essential nutrients to prevent the development of chronic diseases and a subsequent increase in susceptibility to and severity of COVID-19 (Butler & Barrientos, 2020; Mattioli, Sciomer, Cocchi, Maffei & Gallina, 2020).
10.	To reap the benefits of diet-related interventions, additional lifestyle changes should be considered in a comprehensive approach (Fechner et al., 2020; Willett et al., 2006).

The concept of metabolic (in)flexibility has long been propagated by researchers for obesity and type 2 diabetes (Goodpaster & Sparks, 2017). Preventing "metabolic disease" (e.g.,

disorders disrupting normal metabolism) requires interventions for improving metabolic flexibility in skeletal muscles and adipose tissue. A metabolically-flexible individual can adjust to fuel selection and thus effectively utilize, transport, or store different available nutrients, primarily glucose and fatty acids (Smith, Soeters, Wüst & Houtkooper, 2018). Individuals improve metabolic flexibility by increasing physical activity and decreasing the amount of sedentary time (Rynders, Blanc, DeJong, Bessesen & Bergouignan, 2018), by adopting weight-loss diets (see, e.g., Coen et al., 2015), and interventions such as time-restricted feeding/intermittent fasting (Chaix, Zarrinpar, Miu & Panda, 2014).

When discussing controversial topics, such as cholesterol accumulation facilitating the human body's retaliation to infectious diseases (Ravnskov, 2003; Tall & Yvan-Charvet, 2015), it is important to determine whether such (or other) interventions have a positive "net effect" when considering the role of higher cholesterol levels' in the co-development of atherosclerosis and metabolic inflammation, for instance. Hence, the aforementioned diet-related considerations and the physical-activity guidelines establish the need for a proper and multi-faceted conceptual model of a peri-COVID-19 lifestyle.

DISCUSSION

Stage 1: Pre-disease

Although the pre-disease stage in general overlaps with normal conditions, pre-emptive measures are important to reduce susceptibility to and severity of COVID-19 during the pandemics. Physical activity may reduce inflammation by lowering M1 macrophages in visceral adipose tissue, decreasing the tissue's adipose volume. It promotes butyrate-producing members of the gut microbiota, contributes to the production of anti-inflammatory myokines, improves gut barrier functions, and decreases postprandial glycemic and lipidemic responses (Miles, Wilson & Yeoman, 2019)

Elevated levels of cardiorespiratory fitness and exercising at moderate to vigorous intensity can improve immune responses to vaccination, reduce chronic low-grade inflammation, and improve various immune markers in several diseases (da Silveira et al., 2020; Yıldızgören, 2020). Regular moderate to vigorous physical activity enhances immune function and reduces inflammation, and reduces the severity of infections. Moderate physical activity (i.e., exercise

training performed at 3-6 times the intensity of rest) can improve the common chronic conditions that increase the risk of severe COVID-19 (Fang, Wang, Tang & Selvin, 2020).

The nutritional plans of different cohorts of people probably differed remarkably in the pre-disease stage. From the standpoint of the sedentary population, we would suggest two interventions in the pre-disease stage. First, improve metabolic flexibility with, for instance, proper meal timing following the circadian rhythm (see, e.g., Ma et al., 2003; Moran-Ramos, Baez-Ruiz, Buijs & Escobar, 2016) and time-based distribution of a variety of macronutrients to increase the satiety effect (Smith-Ryan, Hirsch, Blue, Mock & Trexler, 2019).

Stage 2: Progression

As the spread of an infectious disease such as COVID-19 progresses, the appropriateness of vigorous and high-intensive exercise with its potential disadvantages for the immune function is questioned (Shephard & Shek, 1994). Among the negative implications of such exercise, the authors highlight impaired resistance of the immune system to acute infections. For individuals indirectly affected by COVID-19, legislation and its enforcement in the majority of countries prevented a range of indoor and outdoor sports activities, posing a threat to individuals' fitness levels (Jimenez-Pavon, Carbonell-Baeza & Lavie, 2020). Irrespective of physical-activity possibilities, we strongly advise quarantined individuals to minimize their sedentary time as much as possible, for instance, to prevent endothelial dysfunction (Kruse, Hughes, Benzo, Carr & Casey, 2018), among other reasons.

To counterbalance prolonged sedentary time (e.g., during the mandatory quarantine and/or remote work), we recommend any type of physical activity possible, considering the limitations during the pandemics and associated measures (Ricci et al., 2020). Furthermore, Prince, Saunders, Gresty, and Reid (2014) argue that increasing the duration of physical activity is a viable intervention to reduce sedentary time. Martin et al. (2015) emphasize the importance of "goal setting and self-monitoring" when individuals intend to reduce sedentary time and increase physical activity. For remote work, standing workstations (activity-permissive workstations) represent a promising solution to reduce sedentary time, while children can benefit from reducing screen time (Altenburg, Kist-van Holthe & Chinapaw, 2016; Neuhaus et al., 2014)

Healthy individuals can embark on exercise routines (moderate steady-state aerobic exercise, less than 60 min) that (in comparison to being inactive) are believed to stimulate the ongoing exchange and redeployment of distinct, highly active immune cell subtypes in peripheral tissues

via circulation (Ranasinghe, Ozemek & Arena, 2020). Both aerobic exercise and resistance training are known to reinforce immune function, which could be depressed due to the unfavorable effects of quarantine (Balchin, Linde, Blackhurst, Rauch & Schönbächler, 2016; Khoramipour et al., 2020). An aggregate number of up to 5-6 sessions of aerobic exercise and resistance training is suggested, while the individuals with triggered respiratory tract infection should limit their activity to respiratory muscle training (Liaw et al., 2020).

Adding some amounts of physical activity during COVID-19 is particularly important for people with additional risk factors who should remain active to engage with the mental and physical consequences and severity of COVID-19 (Jiménez-Pavón, Carbonell-Baeza & Lavie, 2020). Moderate physical activity is one of the best stress management methods because it prevents psychological disorders as a result of anxiety and depression, for instance (see, e.g., Khoramipour et al., 2020). Stress and distress create imbalances of cortisol that negatively affect immune function and inflammation. Moderate physical activity also aids in bringing cortisol into balance (Hojman, 2017).

Infected individuals suffer from muscle loss due to prolonged inactivity (English & Paddon-Jones, 2010). These individuals could potentially benefit from consuming leucine (English et al., 2016), β-hydroxy-β-methyl butyrate (Deutz et al., 2013), or essential amino acids, all in the form of a supplement (Cheng et al., 2018). While adding supplements such as vitamins C and D, zinc, melatonin, and omega-3 fatty acids to a healthy diet should be done with caution, a growing body of knowledge demonstrates the potential of various supplements in aiding a fight against COVID-19 (Meltzer et al., 2020; Martineau & Forouhi, 2020; Shakoor et al., 2020; Reiter, Abreu-Gonzalez, Marik & Dominguez-Rodriguez, 2020). Vitamin C is known to boost the immune system and for its antiviral properties (Arvinte, Singh & Marik, 2020), while vitamin D and omega-3 fatty acids are also believed to aid the immune systems of infected individuals (Khoramipour et al., 2020). However, individuals should be informed about the potential benefits and/or side effects (Arvinte, Singh & Marik, 2020; Bae & Kim, 2020).

Among the mid-crisis diet-related interventions, limiting sugar intake or even adopting low-carbohydrate high-fat (LCHF) diets have been suggested to alleviate metabolic disorders and lower body-fat levels (Li, Liu, Liu & Li, 2020; World Health Organization, 2020). A recent paper published in Frontiers in Public Health (Maffetone & Laursen, 2020) sheds light on the role of an LCHF diet in "promoting a positive immune response against influenza virus infection." A growing body of evidence has further fueled the debate on the use of the LCHF

diet as a diet-related intervention, specifically the importance of high HDL and LDL cholesterol levels in battling infection (see, e.g., Fan et al., 2020; Schoenfeld, 2012). The sharp decrease in cholesterol levels is caused by impaired oxidation reactions (Fan et al., 2020).

The consumption of various fatty acids (e.g., from grass-fed butter, coconut oil, nuts, etc.) could maintain adequate levels and ratios of LDL and HDL cholesterol and reduce cardiovascular-disease risk; however, the research results remain inconclusive (Hayes, 2002; Forouhi et al., 2018). The most salient reason for adopting an LCHF diet during the progression stage lies in its ability to decrease remarkably the so-called respiratory quotient (RQ), which signals which macronutrients are being (primarily) metabolized on the cellular level. Relying primarily on fat for fuel generates less carbon dioxide (to oxygen consumed) and hence offers a viable intervention when the aim is to reduce the burden and time concerning artificial ventilation (Al-Saady, Blackmore & Bennett, 1989).

Stage 3: Recovery

While it remains difficult to avoid prolonged sedentary time and to increase physical inactivity to some extent in the progression stage, either due to confinement policies and/or infection itself, hazards such as physical inactivity should be addressed proactively in the recovery stage to off-set the inevitable negative corollaries, such as higher levels of adiposity (Qin et al., 2018).

Physical activity in the recovery phase is important for enhancing the components of physical fitness (muscular strength, cardiorespiratory fitness, coordination-agility). It is directly associated with the physiological functions of the primary bodily systems (circulatory, respiratory, muscular, nervous, and skeletal systems) and indirectly implicated in the proper functioning of other systems (immune, endocrine, digestive, or renal systems) (Fletcher et al., 2018; Lavie, Ozemek, Carbone, Katzmarzyk & Blair, 2019; Ozemek, Lavie & Rognmo, 2019). Importantly, individuals should be careful to gradually increase the duration and intensity before commencing with vigorous exercise. A possibility of other health-related issues exists when returning to vigorous exercise too soon before a full recovery after a respiratory tract infection (Hull, Loosemore & Schwellnus, 2020).

During the progression stage, individuals suffer from a reduction in various components of physical fitness; therefore, multicomponent training with aerobic, resistance, balance, coordination, and mobility-training exercises would be appropriate for senior adults (Jiménez-Pavón, Carbonell-Baeza & Lavie, 2020). In addition to the modalities of the exercise program, the focus for everyone should be on workout frequency, volume, and intensity. By adjusting

these variables and performing new types of exercise, patients who have recovered but suffered muscle loss should adopt exercise training that promotes skeletal muscle hypertrophy (Damas, Libardi & Ugrinowitsch, 2018; Schoenfeld, 2012).

For individuals who want to regain lost lean mass during prolonged physical inactivity or hospitalization, a combination of carbohydrate- and protein-rich post-workout meals is recommended (Sousa, Teixeira & Soares, 2014). While the consumption of antioxidants and/or anti-inflammatory nutrients is desirable (Sousa, Teixeira & Soares, 2014), the research on consuming those from nutritional supplements remains ambiguous but promising (Pastor & Tur, 2020). In addition, there are some concerns about antioxidants from nutritional supplements interfering with a natural pathway mechanism activated after a muscle-building training exercise. Due to its myoprotective ability, the promotion of muscle strength, and ability to facilitate glycogen resynthesis, we also suggest the intermittent ingestion of creatine (e.g., doses of up to 20g for several days) (Roberts et al. , 2016). To further facilitate recovery (e.g., glycogen resynthesizes) after an exhaustive training exercise and ameliorate delayed-onset muscle soreness, the ingestion of approximately 3mg of caffeine/kg of body weight is suggested (Caldwell et al., 2017; Pedersen et al., 2008).

Ultimately, the diet-related interventions in the recovery stage should consider three focal points; first, the adopted diet should promote (long-term) adherence for an individual. Second, it should be tailored according to an individual's needs (e.g., contingent upon the somatotype and metabolic (in)flexibility) and goals (e.g., enhancing physical performance). Third, the targeted body composition can be achieved with a wide range of dietary approaches, primarily differing in caloric surplus (lean-mass gain) or deficit (weight-loss strategies). However, focusing on food choices that promote satiety and increasing the protein intake while increasing physical activity in the recovery stage are both widely recommended (Aragon et al., 2017). In addition to diet-related interventions and physical activity, regimes such as calorie restriction and time-restricted feeding show potential benefits for health-related markers, to prevent the development of chronic disease and to slow aging, and even to enhance physical performance (de Cabo & Mattson, 2019; Pons et al., 2018). In Table 3, we conceptualize these findings with a more nuanced view contingent on the aspect and stage of the peri-COVID-19 period. The conceptual model can be used to understand better or administer diet-related interventions and physical activity to various cohorts of individuals who aim to avoid sedentary behavior and engage in active lifestyles in different stages of pandemics.

Table 3. The conceptual model of physical activity and nutrition in peri-COVID-19.

Aspect/Stage	Pre-disease	Progression	Recovery
Physical activity	Improve metabolic flexibility and glycemic control (if applicable). Moderate-intensity and vigorous aerobic exercise and resistance training. Physical activity should target lean-mass gain or fat-mass loss.	Healthy individuals should practice moderate-intensity exercise of all types. Infected individuals should proceed with respiratory-muscles exercises. Individual workouts to be preferred to avoid virus transmission.	Gradually increase duration and intensity (of aerobic and resistance) training. Individuals recovering after the infection should regain lean mass and prioritize resistance training. Overweight individuals should design physical activity considering calorie-deficit nutritional plan.
Diet-related interventions	Improve metabolic flexibility and glycemic control (if applicable). Nutritional plan should promote reaching desired BMI. A range of nutritional plans will help individuals reach similar goals. The goal should be lean-mass gain or fat-mass loss.	The consumption of micronutrient-dense food should be preferred. Tailored interventions, such as low-carbohydrate diets, might be beneficial. Decrease the rate of lean-mass drop. Nutritional supplements exhibiting potential to aid.	Nutrient-dense and lean-mass-promoting food for severe cases of COVID-19 who suffered muscle loss. Weight-loss primarily driven by a calorie deficit for overweight individuals. Satiety effect of food and protein intake should be acknowledged in designing one's nutritional plan. Supplements can promote recovery.
Sedentary behavior	Reduction of sedentary time should be of key importance in all stages.		

CONCLUSION

The present study conceptualizes the peri-COVID-19 period and, drawing on a range of seminal papers and the vast majority of relevant recent research publications about physical activity and nutrition, provides context-specific recommendations for the inevitably increasing number of people with sedentary behavior during the coronavirus pandemic. Acknowledging controversy on various nutrition and sports science topics, we steer away from over-specifications to a more strategic view that demonstrates which guidelines and interventions should be prioritized and further tailored to one's specific needs. More importantly, we emphasize the need to adjust those guidelines and interventions with respect to individuals' conditions and stage of the peri-COVID-19 period.

Our main findings suggest the relative importance of physical activity, which should be moderate-to-vigorous before the infection, mitigated in intensity and duration during the

pandemic or even omitted when infected, and aimed at ameliorating the negative corollaries of quarantine interventions after "flattening the curve" and moving beyond the pandemics limitations in the recovery stage. Furthermore, in the pursuit of a nutritional strategy before, during, and after the coronavirus pandemic, our paper suggests considering diet-related interventions that focus on glycemic control, cholesterol levels, and metabolic (inflexibility) in every stage (Cucuzzella, 2020; Cucuzzella, Tondt, Dockter, Saslow & Wood, 2017), yet with varying degrees of relative importance. While metabolic flexibility should undoubtedly be achieved before the presence of an infectious disease, glycemic control, and increasing cholesterol levels tend to be of key concern during the pandemics itself and in the recovery stage (for patients, particularly). Finally, we briefly mention the promising aid of supplements; future research should thoroughly investigate the potentially beneficial role of supplements to fight COVID-19.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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USE OF BALANCE EXERCISES FOR DYNAMIC STABILITY IN BASKETBALL INJURIES

UPORABA RAVNOTEŽNIH VAJ ZA DINAMIČNO STABILNOST PRI KOŠARKARSKIH POŠKODBAH

ABSTRACT

Basketball is a very popular team sport that is played around the world with a high prevalence of lower limb injuries. Therefore, we have decided to test the effect of balance exercises on the dynamic stability of the lower limbs. We performed dynamic balance testing on a 30-member group of young basketball players of the same average age, playing the cadet competition of the Slovak Championships - West Region. The control group consisted of 16 basketball players. For testing, we have chosen a test for the dynamic stability – Y balance test (YBT). Testing of the dynamic stability of the lower limbs with hands placed freely next to the body in the intervention group was statistically significant ($p < 0.05$). We have also noticed statistically significant improvement in the intervention group ($p<0.05$). Balance exercises have been associated with improved dynamic stability in young basketball players.

Keywords: Y balance test, dynamic stability, basketball, balance exercises

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IZVLEČEK

Košarka je zelo priljubljen moštveni šport celega sveta in je igra z visoko pojavnostjo poškodb spodnjih okončin. V pričujoči študiji smo se odločili preizkusiti učinek vaj ravnotežja na dinamično stabilnost spodnjih okončin. V vzorec smo zajeli 30 mladih košarkarjev podobne starosti. Izvedli smo testiranje dinamičnega ravnotežja na ekipi, ki je igrala kadetsko tekmo slovaškega državnega prvenstva - zahodna regija. Kontrolno skupino je sestavljalo 16 košarkarjev. Za testiranje smo izbrali test dinamične stabilnosti - preskus ravnotežja Y (YBT). Testiranje dinamične stabilnosti spodnjih okončin z rokami, ki so bile prosto nameščene ob telesu v intervencijski skupini, je bilo statistično značilno ($p < 0,05$). V intervencijski skupini smo opazili tudi statistično značilno izboljšanje ($p < 0,05$) dinamičnega ravnotežja. Ugotovili smo, da so vaje ravnotežja značilno povezane z izboljšano dinamično stabilnostjo mladih košarkarjev.

Ključne besede: Y ravnotežni test, dinamična stabilnost, košarka, ravnotežne vaje

INTRODUCTION

Basketball is a very popular team sport that is played all over the world. Nowadays, professional basketball has become a physical sport characterized by high dynamic activity (1) and intense body contact. The game is characterized by frequent interruptions, jumping, challenging one-on-one situations, rapid changes of direction combined with challenging technique and aspects of coordination such as catching, throwing, passing and dribbling (2). It is constantly evolving into a larger physical game in which body contacts are expected and accepted. Most injuries in basketball affect the lower limbs. Basketball requires a high level of motor skills and special skills (3), as well as a high level of movement control, muscle coordination, gentle differentiation, fast cooperation in combinations and many other factors (4,5). In addition, basketball develops a number of will skills, psychological resilience and social cohesion. Characteristic abilities for basketball are dribling, shooting, jumps, rebounds and defense. Game skills are interrupted by pauses when alternating or interrupting the game. Very typical for this sport is the fluctuating intensity of the load. The characteristic of muscular activity in basketball is dynamic, but sometimes there are also short-term static contractions. Kinematic analysis has shown that a player runs an average of 3500 to 4000 meters in a match, jumps 15 to 41 times, passes approximately 30 times, shoots 12 times, changes direction up to 640 times and speeds up to 440 times (6). This intesity is significantly modified considering the age, gender and performance.

According to Garbenytė - Apoinskene (2), the effectiveness of proprioceptive (neuromuscular) training in reducing the incidence of certain types of sports injuries among adolescents and young adult athletes during sports activities such as basketball, is high. Young experienced athletes must be trained carefully in order to avoid excessive stress that can affect them physically and mentally.

Musculoskeletal disorders are potential problem for basketball players (7,8,9,10). The main imbalances include core system (11,12). The incidence of injuries is much higher than in other non-contact sports. According to a retrospective analysis of data collected during the 17 seasons of the American National Basketball Association, most injuries affect the lower limbs (13). Neuromuscular asymmetry of the lower limbs is associated with high risk of injury (14). Asymmetries of the lower limbs in terms of strength, coordination and postural control, occur more in female athletes than in male athletes. The higher incidence of sportswomen’s injuries

is associated with neuromuscular factors, including the overall dominance of one leg over the other (15–17).

The main theory of balance exercises is to minimize the support base and to induce a state of "balancing", which leads to a coordinated engagement of muscle loops, and this ensures that we achieve targeted movements or maintain a relatively unstable position without developing maximum strength (18). During exercise on unstable platforms, a force acts on the articulation from several sides with a intensity constantly changing. Balance training specifically employs muscles in an agonistic-antagonistic position. The point is to create a situation in which an individual finds himself in a game situation or in everyday life.

Due to the high prevalence of injuries in basketball, we have decided to test the effect of balance exercises on improving dynamic stability.

The aim of the study was to create a unit of balance exercises, appply it in the training process and to verify the influence of balance exercises on the value of dynamic stability measured by the y balance test of basketball players.

H1: We assume that the impact of regular balance exercises will improve the dynamic stability of the intervention group of basketball players over a period of three months.

H2: We assume that after a period of 12 weeks, there will be no statistically significant changes in the final testing of the control group of basketball players compared to the initial testing.

H3: We assume a positive effect on the level of dynamic postural control in the final testing after completing the balance unit in the intervention group in comparison with the control group of basketball players.

METHODS

The main method of data processing was research, which includes monitoring the impact of the application of balance exercises. The intervention in the form of a balance program included exercises to prevent injuries and strengthen the core system muscles.

Example of one training unit focused on balance exercises realized in the intervention group of basketball players in Nitra

1. Female push ups with hands on a balance pad

2. Alternating jumps to the barefoot lunge

3. Dynamic plank with lower limb attraction

4. Squats on one lower limb holding the TRX

5. Support the kneeling on four

6. Side plank

7. Squats against the wall with a fit ball behind your back

8. Dynamic plank alternately from bent to protruding upper limbs

9. Bridge

10. Support on the barefoot with turning of the torso with medicimbal (kettlebell)

11. Pushing the fit ball

12. Strengthening the thigh muscles with a miniband around the ankles.

13. Exercises on the principle of dynamic neuromuscular stabilization

The sample characteristics

We performed dynamic balance testing on a 30-member group of young basketball players of approximately the same average age, who are involved in the cadet competition of the Slovak Championships - West Region. The control group consisted of 16 basketball players who play for a basketball club in Trnava. At the time of the research, this group did not participate in balance exercises aimed at injury prevention under our supervision. The intervention group consisted of 14 probands - players of the youth basketball team in Nitra. They performed the balance program under our supervision. We examined all the basketball players before the start of the training unit. The first testing of basketball players took place in September 2019 in the gym in Trnava while the second group test took place in Nitra sports hall. During the input and output measurements, we tried to maintain the same conditions. We carried out the final testing in both groups of basketball players after 3 months. Each player had their own form, where we recorded the obtained results of input and output measurements.

Table 1. Basic somatic characteristics of the control group of probands.

	Age	Height (cm)	Weight (kg)	BMI	Length Of limbs (cm)
Arithmetic average	14,30	167,90	61,90	22,00	89,10
Median	14,00	168,75	61,00	89,50	21,70
Modus	14,00	-	60,00	92,00	-
Direct. deviation	0,77	5,44	7,33	4,15	2,74

Table 2. Basic somatic characteristics of the intervention group of probands.

	Age	Height (cm)	Weight (kg)	BMI	Length of lower limbs (cm)
Arithmetic average	14,79	171,61	62,29	21,21	89,00
Median	15,00	169,00	61,50	20,44	88,50
Modus	14,00	167,00	55,00	23,03	92,00
Direct. deviation	0,80	6,36	8,57	2,75	4,47

Description of the intervention group

The research was carried out with 14 cadets aged 14 - 16 years in the sport hall from September 2019. The players train 4-5 times a week for 90 minutes. Last season, several players overcame more serious but also less serious injuries. Three players from the team had sprains of the right ankle joint, one of them also had a fracture of femur on the right lower limb. Furthermore, one player of the team had a fracture of calf bone in the left lower limb, another torn ligament in the right ankle joint and one of them distension of ligaments in the left knee. All players formed one intervention set, which we tested for 3 months. None of the players have not done balance exercises before this research. We exercise with the players twice a week before the training unit for 20-30 minutes. The balance exercise training was happening during the season from mid-September to the second half of December. Afterwards we carried the final testing.

Methods

The dynamic stability test chosen - Y balance test (YBT) - was used for testing. Input and output measurement took place at the beginning of training units so that basketball players were not tired and their performance was not affected by negative events from previous activities.

YBT is a simple but reliable test of dynamic postural control that requires athlete to balance on one leg with maximum reach of the opposite limb in three separate directions. Therefore, this test measures the strength, stability and balance of the athlete in different directions. It has been developed to standardize the modified Star Excursion Balance Test (SEBT), to improve its practicality, and even it has become a popular test. YBT is a measurement of dynamic balance and is used to assess performance, identify chronic instability of the ankles, and to identify athletes at higher risk of lower limb injury (14). The YBT consists of a standing platform on which three rods are slid in the anterior, posteromedial and posterolateral directions. The rear bars were located 135 degrees from the front bar and the angle between the rear bars was 45 degrees. The distance in centimeters is marked on the bars and the exact achieved distance is determined by a sliding indicator placed on the bars (19).

Description of testing by YBT

YBT was performed using a standardized test protocol that has proved to be reliable. Subjects were familiar with testing procedures. The tested player stands with one foot on the test pad with toes behind the red starting line. The other foot moves the pointer slid on the wooden stick as smoothly as possible in the three directions. The tested player starts testing on the dominant standing leg, the right and left legs reach the distance by three attempts in the forward direction (anterior) with the hands sideways and return to the starting position. After completing three successful attempts, player exchanges the standing leg for the left one and performs three valid attempts in the same direction with the right leg. As soon as the test subject makes three successful attempts, the procedure is also repeated in the following posteromedial and posterolateral direction with three attempts for each direction with the same leg placement order (20). The achieved distance should be recorded to the nearest 0.5 cm. The rest time between trials is approximately 20 seconds, which is the time to record data and return the pointer to its original position. After completing the test with the hands sideways, the tested person repeats the test with the hands free next to the body, while the test procedure remains the same. We have recorded the distance made by each valid attempt by the test player so that we could calculate the composite score YBT. In each test, the achieved distance has been recorded with

an accuracy of 0.5 cm, and the longest distance achieved from three valid trials in that direction has been used for analysis.

The test was performed in the following order:

1. Right anterior

2. Left anterior

3. Right posteromedial

4. Left posteromedial

5. Right posterolateral

6. Left posterolateral

Invalid attempt: the tested unit cannot touch the floor with his foot before returning to the starting position, as any loss of balance is considered an unsuccessful attempt. However, as soon as the test person returns to the starting position, can place his foot down behind the central test pad. Also, the player cannot place his foot on the range indicator to gain support during the attempt - he must push the range indicator with the red target area. The athlete must keep his foot in contact with the target pointer until he reaches the point. In order to achieve better performance, the foot must not be rested on or kicked.

Valid attempt: We evaluate the attempt when test person returns to the starting position without violating rules on the validity of the experiment.mentioned above.

After completing the test and recording all the performances of the test subjects, we have calculated the performance scores of the YBT athletes using the following equations or all of the following equations:

Composite score (%): (sum of three directions of reach) / (3 x limb length) x 100

The length of the limbs is measured from the spina iliaca of the superior anterior to the medial malleolus. The asymmetry achieved has been calculated by the absolute difference in the maximum range distance between the right and left side. We have suggested asymmetry greater than 4 cm during YBT has been proposed to predict which individuals are at risk of lower limb injury (21).

Statistical analysis

Based on the analytical functions of Microsoft Excel, testing with hands placed freely next to the body in the intervention group has shown to be statistically significant with a value of α - 0.05. Hypothesis H1 has been confirmed, therefore we assume that the impact of regular balance exercises in the intervention group of basketball players will improve the dynamic stability over a period of three months (Table 3). To verify the hypothesis, a parametric test has been selected - a two-sample t-test with equality of variances based on the F-test for variance.

RESULTS

Based on this, the established hypotheses could be confirmed or rejected. To confirm or to negate hypotheses, we have used a two-sample F-test for variance and a two-sample t-test with equality and inequality of variances. The test results have been processed using Microsoft Excel and SPSS statistics. We have used the arithmetic average, mode, median, min, max, variance and standard deviation. Subsequently, the YBT test results are compared from the input and output tests. The significance of the differences has been determined at the α -0.05 level of statistical significance.

Table 3. Composite scores of the intervention group with hands placed freely next to the body, significance of changes and statistical characteristics.

	n	***x̄***	***sd***	***x_m***	***mod(x)***	***max.***	***min.***	***p***	***t***
Right side input	14	98,77	5,86	98,84	100	109,74	89,77	0,0089	2,06
Right side output	14	101,35	6,89	101,8	-	116,3	90,04		
Left side input	14	99,41	6,65	99,81	-	109,47	87,06	0,0041	2,06
Left sidde output	14	104,06	5,93	103,92	-	115,93	91,95		

Legend: n – amount of probands, x̄ - arithmetic average, sd – directional deviation, xm - median, mod(x) - mode, max. – max. rate , min. – min. Rate, p – value of statistical significance, t – test standard.

F However, hypothesis H2 has been rejected, as we assumed that after a period of 12 weeks, there would be no statistically significant changes in the initial testing of the control group of basketball players compared to the initial testing (Table 4). A two-tailed t-test with equality of variances have been used.

Table 4. Composite scores of the control group with hands placed freely next to the body, significance of changes and statistical characteristics.

	n	$\bar{x}$	*sd*	x_m	*mod(x)*	*max.*	*min.*	*p*	*t*
Right side input	16	97	5,54	95,91	89,96	108,14	89,96	0,00044	2,04
Right side output	16	101,55	5,46	103,66	105,07	110,47	92,16		
Left side ínput	16	98,5	4,62	97,53	-	106,83	92,11	0,0020	2,05
Left side output	16	102,03	5,94	102,21	-	110,73	88,89		

Legend: n – amount of probands, x̄ - arithmetic average, sd – directional deviation, xm - median, mod(x) - mode, max. – max. rate , min. – min. Rate, p – value of statistical significance, t – test standard.

Comparison of intervention and control group

Table 5 Comparison of output testing composite score results with hands placed freely next to the body.

	Intervention group Right side	**Control group Right side**	**Intervention group Left side**	**Control group Left side**
Str. value	101,35	101,55	104,06	102,03
Spread	47,45	29,83	35,14	35,29
Observation	14	16	14	16
Common spread	38,01			
Hyp. difference of str. values	0		0	
Difference	28		27	
t Stat	-0,09		0,93	
p	0,93		0,36	
t	2,05		2,05	

Legend: t stat – test statistic value, p – importance statistic value, t – test standard.

We can see the difference between the final testing of the intervention and control group with hands placed freely, in the fact that we could not prove under the given conditions that it is statistically significant. We have used a two-tailed t-test with equality of variance for the right lower limb and with uneven variance for the left lower limb. Therefore, hypothesis H3 has been rejected. In comparison with the control group of basketball players we have assumed a positive

effect on the level of dynamic postural control in the final testing of the intervention group after completing the balance unit.

Table 6. Comparison of the composite score of the right lower limb.

Intervention group		
PDK	P	t
Input hands sideways Input hands free	0,03	2,06
Control group		
Input hands sideways Input hands free	0,03	2,05
Output hands sideways Output hands free	0,01	2,04

Legenda: p – importance statistic value, t – test standard.

In Table 4, the comparison of the initial/input measurement with the hands placed sideways and the hand handled freely to the right lower limb in the intervention and control groups has been statistically significant at the level of statistical significance α - 0.05. When comparing the output testing with the hands of the side and the free right lower limb, there has been statistically significant change in the intervention group but there has been no statistically significant changes when comparing the output of the control group with the hands placed sideways and free.

Table.7 Comparison of the composite score of the left lower limb.

Intervention group		
L'DK	p	t
Output hands sideways Output hands free	0,01	2,06
Control group		
Input hands sideways Input hands free	0,01	2,05
Output hands sideways Output hands free	0,01	2,04

Legenda: p – importance statistic value, t – test standard.

DISCUSSION

Performing successful basketball actions requires more than just physical skills, such as sprint, strength or ability to change direction but also dynamic stability or postural control. Postural control is important for specific sport exercises, and postural control deficits are associated with a higher risk of falls and injuries. There is a risk factor of injuries for young athletes, and changes in postural control may be related to the occurrence of ankle injuries in high school basketball players. In addition to ankle injuries, anterior cruciate ligament injuries are also common. According to Nessler (22), both professional and recreational athletes between the ages of 15 and 25 are at greatest risk of injury. Basketball is also one of the sports with a high risk of injuries, but a larger percentage of injuries are non-contact, and therefore we can eliminate them with a suitable prevention program included in training at a young age.

The main method of testing was the Y balance test in which we tested an intervention and control group of basketball players aged 13 to 16 years. According to Garbenytė - Apolinskienė (2), it is the age at which basic functional movement patterns are extremely important for athlete‘s development and injury prevention.

The aim of our study was to determine the effect of balance exercises as injury prevention on a selected group of basketball players. For testing of dynamic postural control and strength, we have chosen the Y balance test also used to identify athletes‘ risk of injury. After the initial testing, we have created balance exercises to prevent injuries and strengthen core system, which we then included in the 3 months training process. An intervention group of basketball players -2 times a week for 20-30 minutes before the training unit. First of all, we practised the correct stereotype of breathing in basketball players stabilizing function of the diaphragm through dynamic neuromuscular stabilization (DNS) techniques according to Kolář (23), we performed exercises according to the movement pattern in various basic and modified positions. Gradually, we have increased the difficulty of the exercise, we have supplemented and modified some exercises to avoid stereotypes and we have added more demanding balance aids. The players had been performing this exercise for 12 weeks under our supervision. None of the players regularly have done balance exercises before this research. Several players from the team have overcome several serious but also less serious injuries in the previous season. After performing the final testing, which we have carried out after less than three months, we can see from the tables and graphs that there has been an improvement in dynamic stability in the intervention group and during this period only 3 players out of a total of 14 basketball players

have overcome easier outbursts. The dynamic stability has also improved in the control group of basketball players, with whom we have not carried out a balance program. We could have probably expected better results after a longer period of application of the balance program, which are among the compensatory exercises.

Measurement took place in the gym and sport hall of the operating basketball teams. A selected intervention group of players has performed a program of balance exercises twice in a week before the actual training for three months under our supervision. The research has proved the confirmation of only one hypothesis, hypothesis H1. We have confirmed the improvement of dynamic stability due to regular balance exercises in the intervention group of basketball players over a period of three months. We have rejected hypothesis H2, as we have assumed that there would be no statistically significant changes in intervention and control group. This can also be explained by the effect of the training itself on the y balance test values. Concerning the difference between the output testing of the intervention and control group with hands placed freely under the given conditions, we could not prove that it is statistically significant, and therefore we have rejected hypothesis H3, where we have assumed a positive effect on the level of dynamic postural control in output testing after the balance unit in intervention group compared to the control group of basketball players. Although the comparison of the intervention and control groups have not proved to be statistically significant, nevertheless, by analyzing the values obtained and the results obtained, we have proved that the balance exercise has an effect on improving dynamic stability and strength. Because when comparing the results of input and output testing, we can state that after the application of the intervention program of balance exercises, there has been an improvement in dynamic stability. Most of the players in the intervention group have experienced positive changes after completing the exercise. We are aware that success and technical level of dynamic are influenced by several factors and the possibility of including balance exercises in training is wide.

The results of a study by Boccolini (24) have shown that performing a 30-minute balance training twice a week for 12 weeks causes a significant improvement in early balance and vertical jump, both in the bipedal and monopedal positions. For this reason, in addition to being a valid training procedure for preventing injuries in basketball, balance training using unstable surfaces is an effective training method to improve dynamic stability and vertical jump. According to Boccolini et al. it is a very effective training method that every basketball coach should consider.

CONCLUSION

Balance exercises for basketball players have been linked with improved dynamic stability for young basketball players.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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DOES LINEAR ACCELERATION IMPACT AGILITY, VO2MAX, 30 METER SPEED AND STANDING LONG JUMP IN AMATEUR SOCCER PLAYERS?

ALI LINEARNO POSPEŠEVANJE VPLIVA NA OKRETNOST, MAKSIMALNI PRIVZEM KISIKA, ŠPRINT IN SKOK V DALJINO Z MESTA PRI NOGOMETAŠIH NEPROFESIONALCIH?

ABSTRACT

Agility and acceleration are known as high speed actions and impact soccer performance. Soccer players need MaxVO2 and standing long-jump to make high - speed actions during soccer match. The purpose of this study was to examine the prediction of the effect of acceleration on agility, endurance, long jump and 30 m-speed. Total 21 amateur male soccer players (mean ± SD: age = 20.29±1.82 yr, height = 1.81±0.37 m, and body weight = 72.10±3.71 kg) volunteered to participate in the study. Acceleration performance (10 m), sprint (30 m), agility (zigzag test), endurance (Yo-Yo intermittent recovery test 1), and jumping ability (standing long jump) were tested. Acceleration predicts MaxVO2 by 19.8 %, agility by 49.9 %, and 30 m-speed by 32.9 %. On the other hand, there is not relationship between acceleration and standing long jump. If we consider that there is a decrease in agility and subsequent increase in football players' sudden change of direction, we see that acceleration explains the decrease and increase in agility rate at the best level. It is thought that acceleration does not affect the long jump by stopping, as footballers are exposed to vertical jump rather than horizontal jump. To improve agility and speed performance, football coaches can design combined acceleration based training.

Keywords: change of direction, endurance, football, horizontal jumping

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IZVLEČEK

Okretnost in pospeševanje sta hitri dejanji, ki pomembno vplivata na nogometno igro. Nogometaši morajo dobro skočiti v daljino in morajo imeti visoko kapaciteto maksimalnega privzema kisika, da bi lahko med nogometno igro kvalitetno izvajali hitra nogometna dejanja. Namen pričujoče študije je bil preučiti napoved učinka pospeševanja nogometaša na okretnost, vzdržljivost, skok v daljino in hitrost teka na 30m. V raziskavi je sodelovalo 21 amaterskih nogometašev (starost = 20,29 ± 1,82 leta, višina = 1,81 ± 0,37 m in telesna teža = 72,10 ± 3,71 kg). Testirali smo pospeške (10 m), šprinte (30 m), okretnost (cik-cak test), vzdržljivost (Yo-Yo intermitent recovery test 1) in skakalno sposobnost (skok v daljino z mesta). Ugotovili smo, da pospešek napoveduje maksimlani privzem kisika za 19,8%, okretnost za 49,9% in hitrost teka na 30 m za 32,9%. Ugotovili smo, da ne obstajajo značilne povezave med pospešekom in skokom v daljino z mesta. Če pomislimo, da pride do zmanjšanja gibljivosti in posledičnega povečanja nenadne spremembe smeri nogometašev, opažamo, da pospešek značilno pojasnjuje tako zmanjšanje kot povečanje stopnje gibljivosti. Pospešek na zaustavitev ne vpliva na skok v daljino, saj so nogometaši bolj izpostavljeni navpičnemu kot vodoravnemu skoku. Za izboljšanje okretnosti in hitrosti nogometašev priporočamo nogometnim trenerjem oblikovanje kombiniranega nogometnega treninga, ki temelji na pospeševanju.

Ključne besede: sprememba smeri, vzdržljivost, nogomet, vodoravni skok

INTRODUCTION

Up to now, the standing long-jump, agility, acceleration, and MaxVO2 have been adopted by a variety of sports branches, both professional and amateur, to evaluate athletic success. Although coaches have examined and debated, what has not been considered is the standing long-jump, acceleration, endurance, and agility influence each other (Little & Williams, 2005; Dragijsky et al., 2017). Although coaches continually seek out new techniques and strategies to develop and test athletic performance, it is important for coaches to be aware of differential effects of various types of athletic performance on standing long-jump, acceleration, endurance, and agility performance. For this reason, several authors have suggested that the capacity to cope with high-intensity intermittent exercise is important for physical performance in soccer (Wragg et al., 2000).

High-speed actions during soccer competition can be categorized into those requiring maximal speed, acceleration and agility. Acceleration is the rate of change of velocity that allows a player to reach maximum velocity in a minimum amount of time. Maximum speed is the maximal velocity at which a player can sprint. Agility does not have a global definition, but is often recognized as the ability to change direction and start and stop quickly (Gambetta, 1996). Some common physiological determinants of agility performance as for acceleration and maximum speed, such as fiber type proportion, may lead to the assumption that these three qualities are highly related. Moreover, aerobic capacity has beneficial effects on parameters such as total time spent on high intensity activities during the game, agility, acceleration, jumping, number of sprints and the number of contacts with the ball during the match (Little & Williams, 2005).

Acceleration is a significant feature of game-deciding situations in the various codes of soccer. The different types of horizontal jumps - a standing long jump, standing five-jumps, and standing ten-jumps were correlated differently with time and stride characteristics (stride numbers, length, and frequency) across 10 m initial acceleration, 30 m secondary acceleration, and the entire 100 m sprint, regardless of the level of sprint performance (Maćkała et al., 2015). In previous a study, the best indicator of sprint performance appears to be the magnitude of the initial acceleration and velocity (9.1- to 18.3-m interval) and the maintenance of velocity throughout the sprint, independent of sprint distance (Brechue et al., 2010). In previous studies, the acceleration and sprint performance of soccer players was evaluated using distances of 10 m (Mendez-Villanueva et al., 2011) and 30 m (Taskin, 2008).

The majority of studies which assess all-round fitness in soccer players use a test battery largely consisting of field-based protocols to measure jumping ability, linear speed, agility and aerobic endurance. Thus, the purpose of this study was to examine the prediction of the effect of acceleration on agility, endurance, long jump and 30 m-speed.

METHODS

Participants

Total 21 amateur male soccer players (mean ± SD: age = 20.29±1.82 yr, height = 1.81±0.37 m, and body weight = 72.10±3.71 kg) volunteered to participate in the study. These soccer players are playing for same soccer club in the first amateur league of Turkey. Soccer players were trained by their coach at 1.5 hours 5 days and played one football match during a week. The body height of each soccer player was measured by generally accepted methods accurate to the nearest 0.1 cm. weight was determined using an electronic scale as accuracy-0.05 kg. This was followed by the administration of standing Long Jump, zigzag Agility Test, acceleration and maximum running speed, and Yo-Yo intermittent recovery tests. Standing long jump, zigzag Agility Test, acceleration and maximum running speed tests was applied on same day with a 10-minute interval and each test was applied twice, with a 3-minute interval, and the best result was recorded. However, Yo-Yo intermittent recovery test carried out else a day after 24 hours from other tests. Soccer players were instructed as to the proper preparation prior to measurement. Soccer players signed an informed consent document according to the Helsinki Declaration.

Acceleration and maximum running speed

The running speed and acceleration of players was determined using a 30-m sprint effort with dual-beam electronic timing gates (Smart Speed Performance Equipment) with split times at 10 m for acceleration as previously used by Wilson et al. (1993) (Okur et al., 2019) and 30 m for speed as previously reported (Little & Williams, 2005). Time was measured to the nearest 0.01 s. Players were instructed to run as quickly as possible over the 30-m distance from a standing start (crouched start positioned 0.5 m behind the timing lights) and run with the signal of light in start gate. Soccer players performed two trials with at least 3 min of rest between them. The best performance of the two tests was used for analysis.

Zigzag Agility Test

Agility was tested using a zigzag course consisting of four 5-m sections set out at 100◦ angles. This zigzag test was chosen because it required the acceleration, deceleration, and balance control facets of agility, and the familiarity of the subjects with the test and its relative simplicity also meant that learning effects would be minimal (Little & Williams, 2005).

Standing Long Jump

All subjects were instructed to perform a long jump from a standing position. Standardized instructions were given to subjects that permitted them to begin the jump with bent knees and swing their arms to assist in the jump. A line drawn on a hard surface served as the starting line. The length of the jump was determined using a tape measure, which was affixed to the floor. Each subject was given 3 trials, and the distance of the best jump was measured, to the nearest 1 cm, from the line to the point where the heel closest to the starting line landed. If the subject fell backward, the distance where the body part closest to the starting line touched the ground was measured as the jump's length. Each subject performed 3 jumps, whether or not a subject fell backward during an attempt. The longest jump was used as the test score (Almuzaini & Fleck, 2008).

Yo-Yo intermittent recovery test

Soccer players completed Yo-YoIR1 (Krustrup et al., 2003). The test was completed on days without wind. Air temperature ranged from 19 to 24C. The test consisted of 20-m shuttle runs performed at increasing velocities with 10 s of active recovery (consisting of 2x5 m of jogging) between runs until exhaustion. Yo-YoIR1 began at a speed of 10 km h-1. Audio cues for Yo-YoIR1 was recorded on a CD and broadcasted using a portable CD player. The end of the test was considered when the participant twice failed to reach the front line in time (objective evaluation) or he felt unable to complete another shuttle at the dictated speed (subjective evaluation). The total distance covered during Yo-YoIR1 was considered as the test 'score'. Before test, subjects performed a warm-up consisting of 5 min of low-intensity running followed by the first four running bouts in the test. All players were familiarized with the test procedures since the test form part of their usual fitness assessment program (Rapinini et al., 2010).

The calculation of maximum oxygen uptake was performed using the following formula:

YoYoIR1: MaxVO2 (mL/min/kg) = IR1 distance (m) × 0.0084 + 36.4 (Bangsbo et al., 2008).

Statistical analysis

SPSS 22 IBM statistical package program was used for data analysis. The data obtained were summarized as mean and standard deviation. The normal distribution of the data was tested by One - Sample Kolmogorov Smirnov test. In order to investigate the effect of acceleration on MaxVO2, agility, standing long jump, and 30 m-speed performance it was tested by linear regression analysis from parametric tests. In this study, the level of error was accepted as 0.05.

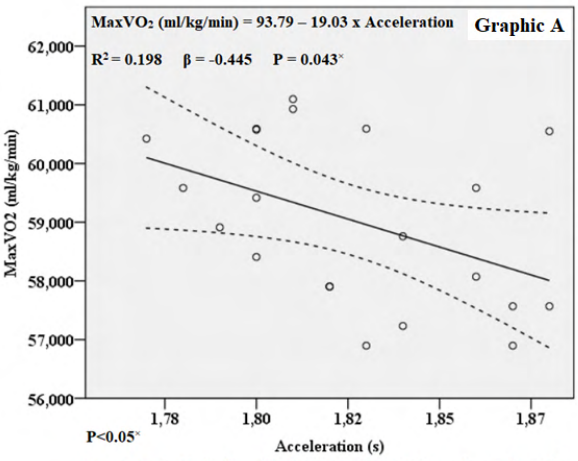
RESULTS

Table 1. Mean and standard deviation of the variables related to soccer players.

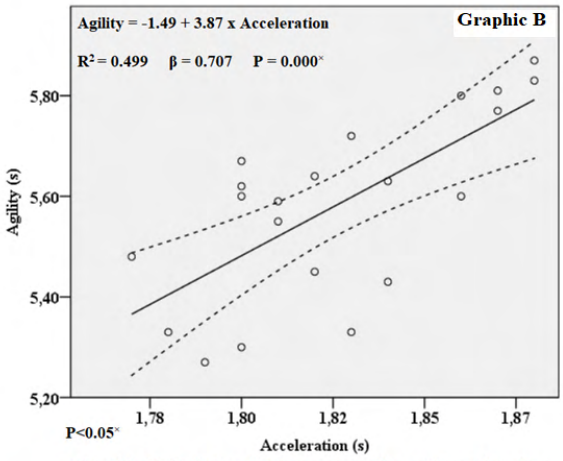
Variables	Mean±SD (N=21)
Age (years)	20.29±1.82
Weight (kg)	72.10±3.71
Height (m)	1.81±0.37
Linear acceleration (s)	1.83±0.03
30 m speed (s)	4.27±0.06
Yo Yo IR1 running distance (m)	2692.05±170.09
MaxVO2 (ml/kg/min)	59.023±1.426
Agility (s)	5.59±0.18
Standing long jump (m)	2.39±0.11

The mean (SD) age was 20.29±1.82 years, weight was 72.10±3.71kg, height was 1.81±0.37, Linear acceleration was 1.83±0.03 sec, 30 m speed was 4.27±0.06 sec, Yo Yo IR1 running distance was 2692.05±170.09 m, VO2Max was 59.023±1.426 ml/kg/min, agility was 5.59±0.18 sec, and standing long jump was 2.39±0.11 m for the 21 soccer players (Please see Table 1).

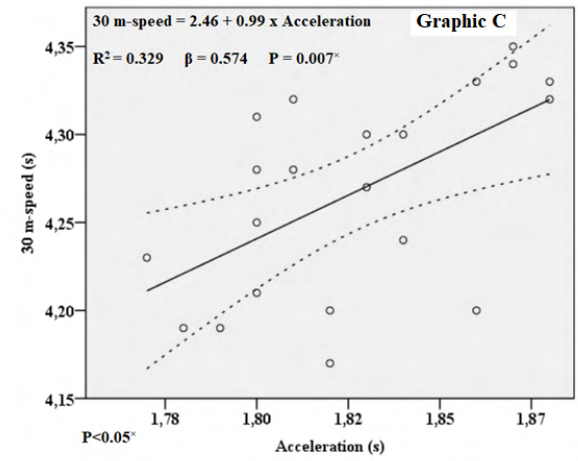
Figure 1. Relationship between acceleration and MaxVO2, agility, 30 m speed, standing long jump.



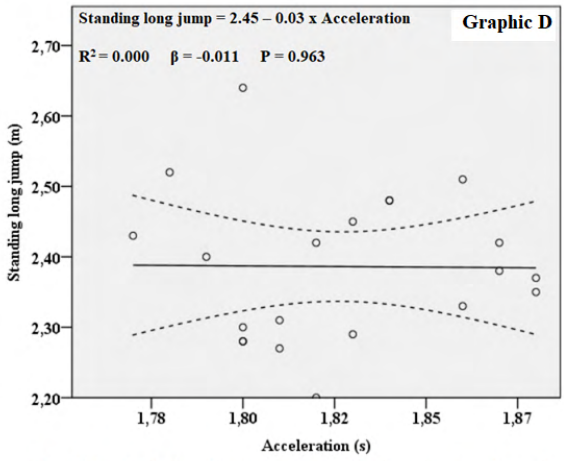
Graphic A. Relationship between $MaxVO_2$ and acceleration



Graphic B. Relationship between agility and acceleration



Graphic C. Relationship between 30 m-speed and acceleration



Graphic D. Relationship between standing long jump and acceleration

Acceleration predicts MaxVO2 by 19.8 % (Graphic A), agility by 49.9 % (Graphic B), and 30 m-speed by 32.9 % (Graphic C). One unit change in acceleration affects MaxVO2 performance by 19.03 percent, agility by 3.87 percent, and 30 m-speed 0.99 percent. There is positive relationship between acceleration with agility and 30 m-speed (Graphic B and C). Additionally, there is negative relationship between acceleration and MaxVO2 (Graphic A). On the other hand, there is not relationship between acceleration and standing long jump (Graphic D).

DISCUSSION

This study investigated the prediction of the effect of acceleration on agility, endurance, long jump and 30 m-speed for amateur soccer players. It was hypothesized that players who were

exposed to a lot of movement to other players' movements during a match (i.e., the agility, acceleration, sprint, jumping). After the player starts moving in the match, a sudden change in movement speed occurs. How does this change in speed (i.e., acceleration) affect other performance parameters (i.e., the agility, endurance, speed, jumping)? The performances on the 10-m test for acceleration, the flying 30-m test for maximum speed, Yo Yo IR1 test for endurance, and the zigzag test for agility were all correlated at levels of statistical significance ($p<0.05$). On the other hand, there is not relationship between acceleration and standing long jump. The coefficients of determination show that acceleration predicts endurance by 19.8 %, agility by 49.9 %, and 30 m-speed by 32.9 %.

Acceleration, as indicated by 10 m sprint times is proven to be a relevant measure in soccer, having been shown to distinguishing between amateur and professional players (Cometti et al., 2001). Relationships between repeated-sprint ability and other fundamental fitness tests (acceleration, agility, explosive power, and aerobic conditioning), vary substantially through the age groups of U11 to U18 in highly trained youth soccer players (Spencer et al., 2011). The increased velocity of the game may be attributed to interplay of influences. It has been proposed that speed and agility are two performance characteristics that positively correlate with the intensity of the game (Buttifant et al., 1999).

A previous study comprised 106 professional soccer players who were assessed for 10-m sprint (acceleration), flying 20-m sprint (maximum speed), and zigzag agility performance. Although performances in the three tests were all significantly correlated ($p<0.0005$), coefficients of determination (r2) between the tests were just 39, 12, and 21% for acceleration and maximum speed, acceleration and agility, and maximum speed and agility, respectively (Little & Williams, 2005). In a study, during the 36.6-m sprint, acceleration increased and peaked at 9.1 m and was maintained at the 18.3-m interval, decreased to a negative value at 27.4-m, but increased to a low positive value at 36.6-m. Velocity increased at 9.1 m and peaked at 18.4 m. acceleration and velocity at the 9.1 and 18.3-m intervals were significantly negatively correlated with sprint interval times and the final 36.6-m sprint time. It has been found that there is a positive relationship between standing long jump and acceleration (9.1 m) (Brechue et al., 2010). The magnitude of the correlation coefficients among the three motor abilities (jumping, acceleration, and agility) extracted was $r<0.56$ (Los Arcos et al., 2017).

A previous examined the specific strength and power characteristics that correlate with greater performance on the 40-yard dash in elite collegiate football players preparing for the National

Football League Scouting Combine. There was a significant negative correlation ($r = -0.894$; $n = 14$, $p < 0.05$) between acceleration and standing long jump. Also, there was a significant positive correlation ($r = 0.930$; $n = 14$; $p < 0.05$) between acceleration and speed (O'Brien, 2009). Besides, Wisloff et al. (2004) determined that jumping height of elite soccer players measured in conjunction with a force platform significantly correlates with the 10 m sprint ($r = .72$, $p < .001$) and 30 m sprint ($r = .68$, $p < .001$). Else a study found the standing long jump exercise is a significant contributor ($p < .05$) to female and male acceleration, and male maximum velocity (Settle, 2010). In a previous study, it is found that there is relationship between acceleration and maximal jump squat which requires maximum concentric power (Sleivert & Taingahue, 2004).

YoYoIR results significantly correlates ($p<0.05$) with 10 m (acceleration) and 30 m sprint times, ball-shooting speed, and vertical jump height (Wong et al., 2010). In a study, it was found that soccer players with enhanced acceleration ability had shown better performance in maximal aerobic speed which is associate with MaxVO2 (Nikolaidis et al, 2015). However, according to results of another study, there was no significant correlation between acceleration and aerobic power (İdrizovic & Raickovic, 2013).

Our study has some limitation. First we have amateur soccer players as study population, because only one amateur club allowed for tests. Another limitation is the choice to evaluation the some motor and physiological parameters. However, performance in soccer includes technical, tactical and psychological components. In limitation of the present study was the absence of more physiological assessments to better understand the acceleration induced adaptations in amateur soccer players.

CONCLUSION

In conclusion, acceleration predicts the most agility and at least predicts MaxVO2. On the other hand, it is seen that acceleration does not predict standing long jump. If we consider that there is a decrease in agility and subsequent increase in football players' sudden change of direction, we see that acceleration explains the decrease and increase in agility rate at the best level. It is thought that acceleration does not affect the long jump by stopping, as footballers are exposed to vertical jump rather than horizontal jump. To improve agility and speed performance, football coaches can design combined acceleration based training.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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DIFFERENCES IN BODY COMPOSITION WITH WATER POLO NATIONAL TEAMS PLAYERS PARTICIPATED IN THE WORLD CHAMPIONSHIP

RAZLIKE V SESTAVI TELESA RAZLIČNIH DRŽAV UDELEŽENIH NA SVETOVNEM PRVENSTVU V VATERPOLU

ABSTRACT

This research aimed to determine the differences between the junior (U20) water polo players of national teams of Serbia, Montenegro, and Australia in the anthropometric characteristics and body composition. The first sub-sample of the subjects consisted of 15 water polo players of the Serbian national team, the vice-champions of the FINA World Men's Junior Water Polo Championship in Kuwait 2019. The second sub-sample consisted of 18 water polo players of the Montenegrin national team, who occupied the sixth position and the last sub-sample of the examinees consisted of 13 water polo players of the Australian national team, who occupied the eleventh position on the championship. The players were tested at the final preparations just before the World Championship. Anthropometric characteristics and body composition were evaluated using a battery of 11 tests: body height, body weight, triceps skinfold, biceps skinfold, skinfold of the back, abdominal skinfold, upper-leg skinfold, lower leg skinfold, body mass index, fat percentage, and muscle mass. The results of the ANOVA displayed that the water polo players of the three national teams do not have statistically significant differences in the variables for assessing anthropometric characteristics and body composition. The results obtained in this research showed average team values for the estimated variables of water polo players of the three national teams (U20) who participated in the World Championship. That can serve as model parameters for all teams who want to participate in U20 water polo World Championship. Differences in classification among water polo players may be related to the motor abilities, technical and tactical parameters as their anthropometric parameters were found to be similar.

Keywords: junior water polo players; body composition of water polo players, anthropometric characteristics of water polo players, Serbian water polo, Montenegrin water polo

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IZVLEČEK

Cilj raziskave je bil ugotoviti razlike v antropometričnih značilnostih in sestavi telesa med mlajšimi (U20) vaterpolisti reprezentanc Srbije, Črne gorein Avstralije. V študijo smo zajeli tri podvzorce. Prvi podvzorec je sestavljalo 15 vaterpolisov srbske reprezentance, ki so bili podprvaki svetovnega moškega mladinskega prvenstva v vaterpolu v Kuvajtu 2019. Drugi podvzorec je sestavljalo 18 vaterpolistov črnogorske reprezentance, ki je zasedla šesto mesto; zadnji podvzorec preizkušenih pa je sestavljalo 13 vaterpolistov avstralske reprezentance, ki so na prvenstvu zasedli enajsto mesto. Igralci so bili testirani na zadnjih pripravah tik pred svetovnim prvenstvom. Antropometrične značilnosti in sestavo telesa smo ovrednotili z baterijo 11 testov: telesna višina, telesna teža, triceps kože, biceps kože, kožna guba hrbta, kožna guba trebuha, kožna guba kvadricepsa, kožna guba meč, indeks telesne mase, odstotek maščobe in odstotek mišične mase. Analiza variance je pokazala, da vaterpolisti treh reprezentanc nimajo statistično pomembnih razlik v spremenljivkah za ocenjevanje antropometričnih značilnosti in sestave telesa. Rezultati pridobljeni v tej raziskavi lahko služijo kot vzorčni parameter vsem ekipam, ki želijo sodelovati na svetovnem prvenstvu v vaterpolu do 20 let. Razlike v razvrstitvi med igralci vaterpola so lahko povezani z motoričnimi sposobnostmi ter tehničnimi in taktičnimi parametri, saj so bili njihovi antropometrični parametri zelo podobni.

Ključne besede: mlajši vaterpolisti; telesna sestava vaterpolistov, antropometrične značilnosti vaterpolistov, srbski vaterpolo, črnogorski vaterpolo

INTRODUCTION

Water polo is a popular sport worldwide. It is a highly dynamic and fast team game that, with its richness of movement, belongs to the category of polystructural sport games. Water polo is a sport characterized by numerous and various complex and dynamic kinesiological activities, which are then characterized by either cyclical or acyclical movement. It is contact sport (Cecchi, Monroe, Fote, Small, & Hicks, 2019), characterized by different swimming intensities, duelling, acceleration and deceleration (Gardasevic, Akpinar, Popovic, & Bjelica, 2019). In water polo, top results can be achieved only under conditions of a well-programmed training process. High quality management of the training process depends on knowing the structure of certain anthropological capabilities and water polo players' characteristics, as well as their development. Findings regarding anthropometric characteristics and body composition are of crucial importance for complex sports, such as water polo. The anthropometric space is defined by the longitudinal dimension of the skeleton, the transversal dimensionality of the skeleton, and the mass and volume of the body. The purpose of knowing anthropometric characteristics is to improve skills in many sports (Gardasevic, & Bjelica, 2020; Masanovic, Corluka, & Milosevic, 2018). The anthropometric status of top-level athletes is relatively homogeneous, depending on the sport, and can be defined as a model of athletic achievement (Gardasevic et al., 2020). Research on anthropometric characteristics and body composition among athletes of different sports indicates that athletes of different sports have specific characteristics (Bjelica, Gardasevic, Vasiljevic, Jeleskovic, & Covic, 2019; Popovic, Akpinar, Jaksic, Matic, & Bjelica, 2013), mostly because size of those characteristics contributes a significant percentage of total variance associated with athletic success (Carvajal et al., 2012). Muscle mass improves performance in activities that require muscular strength and endurance, but also in those that require enviable aerobic ability (Rico-Sanz, 1998).

It is well known that water polo in Serbia, Montenegro, and Australia has a long tradition and the best results in international competitions, especially Serbia and Montenegro. Serbians and Montenegrins were the junior world champions several times, and Australians were vice-champions once. Serbia and Montenegro junior national teams are always top-ranked in Europe and the world.

It was expected that the national teams would continue with good results on the FINA World Men's Junior (U20) Water Polo Championship in Kuwait 12 - 20 December 2019, where twenty national teams participated. It is clear that these were the best players in Serbia, Montenegro

and Australia, at age 20, and that they had many years of quality training in order to qualify to wear a representative cap. It is well known in all sports and, therefore, in water polo that long-term and intensive training is one of the critical factors that enable athletes to reach and remain at the elite representative level (Gardasevic, Bjelica, & Vasiljevic, 2019). It became interesting for researchers to determine the models of anthropometric characteristics and body composition of the water polo players who play for these three national teams to determine the differences among them.

This research aimed to determine the anthropometric characteristics and body composition of junior (U20) water polo players of national teams of Serbia, Montenegro, and Australia, who participated on the FINA World Men's Water Polo Championship 2019 in Kuwait. The variables between these water polo players were compared, and the possible differences between them were determined.

METHODS

In terms of time constraint, the research is transversal, consisting of a one-off measurement of the corresponding body composition and anthropometric characteristics of junior (U20) water polo players.

Participants

A sample of the subjects consists of a total of 46 water polo players, divided into three sub-samples. The first sub-sample of the subjects consisted of 15 water polo players of the national team of Serbia of an average age of 18.40±1.12, the vice-champions on the FINA World Men's Junior Water Polo Championship 2019. The other sub-sample consisted of 18 water polo players of the national team of Montenegro of an average age of 18.44±0.98, who occupied the sixth position on the championship . The last sub-sample of the examinees consisted of 13 water polo players of the national team of Australia of an average age of 19.00±0.91, who occupied the eleventh position on the World Men's Junior Championship (Table 1).

Table 1. Final rankings (20.12.2019) at the FINA World Men's Junior Water Polo Championship in Kuwait 2019.

National teams	Place
Greece	1
Serbia	**2**
Italy	3
Croatia	4
Spain	5
Montenegro	**6**
USA	7
Japan	8
Hungary	9
Canada	10
Australia	**11**
New Zealand	12
Russia	13
South Africa	14
Egypt	15
China	16
Brazil	17
Uzbekistan	18
Iran	19
Kuwait	20

Players of the Montenegrin and Australian national teams were tested at the joint final preparations in Niksic (Montenegro), one week before the World Championship. Players of the Serbian national team were tested at the final preparations in Kragujevac (Serbia), two days before departure for the World Championship. Considering that they were in the final pre-championship preparations, the final list of players was not formed (possibility of injuries or illness are the reasons there are often surplus of players), that was the reason the number of players tested was different among teams. All participants signed the consent form approved by the Institutional Review Board of the University of Montenegro, which was in accordance

with the Declaration of Helsinki as amended by the World Medical Association Declaration of Helsinki (World Medical Association, 2013).

Sample of variables

Anthropometric research has been carried out with respect to the basic rules and principles related to the selection of measuring instruments and measurement techniques, standardized in accordance with the International Biological Program guidelines. For this study, eight anthropometric measures have been taken: body height, body weight, triceps skinfold, biceps skinfold, skinfold of the back, abdominal skinfold, upper leg skinfold and lower leg skinfold, and three body composition assessment variables: body mass index, fat percentage and muscle mass. An anthropometer, calliper, and measuring tape were used for anthropometric measurements. To evaluate the body composition and body weight, a Tanita body fat scale (model BC-418MA) was used. The scale is based on the principle of the indirect measurement of the body composition; a safe electrical signal is transmitted through the body via electrodes located in the standalone unit. The Tanita Scale enables athletes to closely monitor their body weight, body mass index, fat percentage, fat mass, muscle mass, bones mass, as well as segmental analysis of arms and legs.

Method of data processing

The data obtained through the research were processed using descriptive and comparative statistical procedures. For each variable, central and dispersion parameters have been processed. The significance of the differences between the water polo players of the three national teams in the anthropometric characteristics and variables for assessing body composition was determined by ANOVA, with statistical significance of $p<0.05$ using IBM SPSS Statistics 20.0

RESULTS AND DISCUSSION

The variables for assessing anthropometric characteristics and body composition of water polo players of Serbian, Montenegrin, and Australian national teams are shown in Table 2.

Table 2. Descriptive data and ANOVA of 46 water polo players, members of the three national teams.

Variables	Serbia	Montenegro	Australia	ANOVA	
	Mean ± Standard Deviation			F	Sig.
body height	192.12±5.49	189.60±6.89	191.27±5.52	.734	.486
body weight	90.29±8.52	88.69±11.72	89.06±8.15	.114	.892
triceps skinfold	6.54±2.24	7.85±2.38	8.88±3.20	2.884	.067
biceps skinfold	5.45±1.32	6.35±1.86	7.04±3.87	1.457	.244
skinfold of the back	11.90±4.16	12.11±3.31	11.73±3.54	.042	.959
abdominal skinfold	13.87±6.47	16.01±7.45	13.51±8.24	.544	.585
upper leg skinfold	13.03±3.74	13.21±4.25	11.79±4.16	.509	.605
lower leg skinfold	10.95±4.15	9.96±3.54	9.46±3.49	.592	.558
body mass index	24.50±2.54	24.59±2.20	24.35±1.98	.044	.957
fat percentage	12.69±3.89	13.13±4.39	11.31±4.03	.756	.476
muscle mass	44.51±3.23	43.47±4.75	44.61±3.26	.426	.656

Based on the central and dispersion parameters of the water polo players of Serbia, Montenegro, and Australia (Table 2), it can be stated that the values of all the variables are very similar to all water polo players of this three countries. There were no significant differences in variables among the water polo players of the three national teams.

This study aimed to determine the difference in the anthropometric characteristics and body composition of the junior (U20) water polo players of the Serbian national team, who won a silver medal at the FINA World Water Polo Championship in Kuwait 12-20 December 2019, the water polo players of the Montenegrin national team, who occupied the sixth position, and the water polo players of the Australian national team, who occupied the eleventh position at the Championship. The results were obtained using a battery of 11 tests in the area of anthropometric characteristics and body composition. By examining the basic descriptive statistical parameters, we have analysed the best selected junior age water polo players from these three countries. Similar results in their research were obtained by Kondric, Uljevic, Gabrilo, Kontić, and Sekulić (2012). They found some lower body height 186.92 cm, and lower body weight 84.31 kg, on the sample of 110 the best world water polo players comparing to water polo players from our research, but it was the age of 18 years when growth and development is not finished. Having that in mind, we can say that those of U20 reached similar results as water polo players who were subject of this research. Kondric et. al (2012) at their sample of water polo players found value of skinfold of the back 12.57 which is slightly higher

value of those found in this research. When we compare water polo players of these three national teams with some other sport players, for example football players of the same age (Gardasevic & Bjelica, 2020) we can notice differences in anthropometric characteristics and body composition, which speaks in favour of the specificity of each sport in terms of new variables. It can be noted that the water polo players are taller and have a lower body weight than U19 football players in Montenegro (body height=179.01 cm; body weight=69.58 kg) in Bosnia and Hercegovina (body height=180.99 cm; body weight=73.65 kg) or in Kosovo (body height=178.15 cm; body weight=70.34 kg) (Gardasevic & Bjelica, 2020). Difference in fat percentage is noticeable as well, with football players in Montenegro it is 9.88%, in Bosnia and Hercegovina 9.65% and in Kosovo it is 8.66% (Gardasevic & Bjelica, 2020). These are lower values comparing to water polo players of three national teams. However, muscle mass is more dominant with water polo players and it is in average 8-9 kg on a higher level than it is with football players from mentioned three countries from the research Gardasevic and Bjelica (2020).

It can be observed that the water polo players of three national teams are of the approximately similar mean values of the all variables analysed, which is not surprising because these are the three national teams of the same age, in countries where water polo is popular and in where water polo coaches are highly skilled. If we go with analysing the final achievements at the championship, then we could say that absence of these differences is a surprise. Nevertheless, a final result at some competition affect many other things as well, such as physical preparation, technical and tactical preparation psychological preparation, that all players are without injuries, without penalties, than good timing of form in the championship, etc.

U20 water polo players have years of training experience and spend many hours in the pool each week. The ANOVA results showed that the water polo players of three national teams do not differ significantly in the analysed variables,. For all variables, some values are higher for water polo players of the Serbian national team (body height, body weight, lower leg skinfold), some for those of the Montenegrin national team (skinfold of the back, abdominal skinfold, upper leg skinfold, body mass index, fat percentage) and some for those of the Australian national team (triceps skinfold, biceps skinfold, muscle mass), although, insignificantly for statistics. All of the abovementioned indicates that water polo players of the Serbian, Montenegrin, and Australian national teams have similar anthropometric parameters and body compositions. All of these players have long-term training before a greatest competitions and they are all top water polo players at the world level, so it is no surprise that there are no

differences in anthropometric characteristics and body composition between them. Due to their lifestyle (constant training and sports nutrition), all top athletes take care of body composition, this is confirmed in research Merchiori et al. (2018) where did not get differences in body weight and body composition in 13 water polo players after a three-month training program for the Olympic Games. By using the system of bioelectrical impedance for high-level athletes involved in long and intense training periods helps to evaluate the effects of training and to prevent any decrease in the performance level of body composition (Melchiorri et al., 2018).

Given that the concentration of the best water polo players U20 is at World Championship in Kuwait 2019, the assumption is that the mean values of the analysed variables of three national teams' water polo players should be the model values for all such clubs in the world (Table 3). Of course, it is clear that these are the team average values of analysed variables, that the different positions which water polo players cover as well as their differences in stated variables in relation to these positions were not taken into consideration.

Table 3. Descriptive data of all 46 water polo players.

Variables	**Mean ± Std. Dev.**
age	18.58±1.02
body height (cm)	190.89±6.06
body weight (kg)	89.31±9.63
triceps skinfold (mm)	7.71±2.70
biceps skinfold (mm)	6.25±2.49
skinfold of the back (mm)	11.93±3.59
abdominal skinfold (mm)	14.61±7.31
upper leg skinfold (mm)	12.75±4.02
lower leg skinfold (mm)	10.14±3.70
body mass index (kg/m^2)	24.49±2.21
fat percentage (%)	12.47±4.11
muscle mass (kg)	44.13±3.86

Based on the obtained results in this research, before the start of the World Championship, it could not be assumed which national team would achieve a better placement. The Kuwait Championships showed that they were the national teams in which the nuances decided the final standings. For example, the Serbian national team beat the Montenegrin national team in the quarterfinals with one goal difference in the last minute of the game, thus going into the medal fight. In the finals, the Serbian national team lost to the Greek national team by a small

result and thus won a silver medal. After the defeat of the Serbian national team, the Montenegrin national team fought for 5th to 8th place (winning sixth place). All this confirms that these are the best water polo players in the world under the age of 20, many of whom already play for the senior national teams.

All water polo players of the three national teams had similar levels of subcutaneous adipose tissue. Different authors state the importance of body fat as a positive fact in water polo (Platanou, 2005; Peric, Zenic, Mandic, Sekulic, & Sajber, 2012), however in other studies it is not confirmed (Vila, Manchado, Abraldes, & Ferragut, 2018), and many researches showed that it is disruptive factor for athletes (Masanovic, 2019; Milanovic, & Vuleta, 2013). Also, in previous studies of water polo players of this age, subcutaneous adipose tissue has been shown to be a disruptive factor in defence (Milanovic, & Vuleta, 2013). It is well known that a low fat percentage is desirable for high physical performance in all sports. Although not every body composition characteristic is expected to play a role in optimal performance in professional sport, lower levels of body fat (that are specific to each player) are desirable for optimal performance, as body mass must be moved against gravity (Rienzi, Drust, Reilly, Carter, & Martin, 2000; S.M. Gil, J. Gil, Ruiz, Irazusta, & Irazusta, 2007).

CONCLUSION

All the water polo players of the three national teams had similar muscle mass values; water polo is a strenuous sport that takes place in water and requires significant muscle mass. Body height is important for swimming, and long arms are important for kicks and defence; however, there were no statistically significant differences between the water polo players of the three national teams, which is perhaps surprising, considering that the Serbian national team played the final of the World U20 Championship, the Montenegrin national team dropped out in the quarter-final of the competition, and the Australian national team did not qualify for the quarter-final. The reason for the different placement may be found in the different levels of technical and tactical preparation, and functional and psychological preparation between water polo players of the three teams. Physical preparation at such championships is essential because it is done every day, and we have not analysed it. Experience in playing deciding matches at this level of competition can be the reason for different placement. The Serbian team has the most experience, the Montenegrin team has less experience, and the Australian team has the least experience.

The national water polo associations of Serbia, Montenegro, and Australia should turn to other research studies and check the functional-motoric status, psychological preparation as well as tactical training of their players, and analyse if there are differences at water polo players that influenced the result at this world championship, and whether there is room for improvement. The values obtained in this research can be useful for coaches of these national teams for making a comparison of their players with others and prepare their work in a way that enables the reduction of adverse parameters, and raise the beneficial ones to a higher level. That will surely make their water polo players even better and more successful. The results obtained in this research can serve as model parameters for the estimated variables for water polo players (U20) of all clubs in Serbia, Montenegro, and Australia, because the players that have been analysed were the best and the most successful water polo players in their countries, and participants in the World Championship in Kuwait 2019.

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Declaration of Conflicting Interests

All authors confirm - no potential conflict of interest exists for this study.

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Hasan Sözen

THE RELATIONSHIP BETWEEN ANAEROBIC POWER, REACTION TIME AND BODY COMPOSITION PARAMETERS OF YOUNG SOCCER PLAYERS

ODNOS MED ANAEROBNO MOČJO, REAKCIJSKIM ČASOM IN PARAMETRI SESTAVE TELESA MLADIH NOGOMETAŠEV

ABSTRACT

The anaerobic activities is frequently used in soccer including high intensity actions. The aim of this study was to examine relationships between anaerobic power, reaction times and body composition parameters of young soccer players. The twenty-seven amateur young soccer players (Age: 13.81±0.48 years, height: 166.74±6.16 cm, weight: 55.17±5.40 kg) were involved in study voluntarily. The Wingate anaerobic power test parameters (minimum power, mean power, peak power, fatigue index), dominant and non-dominant hand visual and auditory reaction times and body composition parameters (lean body mass, body fat mass and body fat percent) were examined. The statistical relationships among explored variables were determined by correlation analyze technique. The relationship between parameters was examined by Pearson's correlation coefficient. According to the results, it was found that lean body mass, anaerobic capacity and mean power parameters had a statistical positive correlations ($p < 0.05$). Also, it was found that body fat percent and body fat mass values had a negative correlation with minimum power values ($p<0.05$). There was no significant correlation between visual and auditory reaction time values with body composition and anaerobic power parameters. Consequently, it could be said that the relationship between lean body mass and body fat percent with some anaerobic power parameters could be arisen from similar mechanisms affecting related parameters. Also, it can be concluded that the reaction time parameter is not closely related to the body composition and anaerobic power parameters, as it is closer related to neural mechanisms than physical mechanisms.

Keywords: anaerobic, reaction, body composition, soccer, performance

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IZVLEČEK

Anaerobni trening se pogosto uporablja v nogometu. Cilj študije je bil preučiti razmerja med anaerobno močjo, reakcijskimi časi in parametri telesne sestave mladih nogometašev. Sedemindvajset amaterskih mladih nogometašev (starost: 13,81 ± 0,48 let, višina: 166,74 ± 6,16 cm, teža: 55,17 ± 5,40 kg) je bilo prostovoljno vključenih v študijo. Preučeni so bili parametri anaerobne moči (minimalna moč, povprečna moč, največja moč, indeks utrujenosti), prevladujoči in nedominantni časi vidnega in slušnega odziva roke ter parametri sestave telesa (mišična masa, maščobna masa in odstotek maščobne mase). Statistična razmerja med raziskanimi spremenljivkami so bila določena s tehniko korelacijske analize. Razmerje med parametri smo preučevali s Pearsonovim koeficientom korelacije. Glede na rezultate smo ugotovili, da so mišična masa, anaerobna zmogljivost in povprečni parametri moči značilno povezani ($p <0,05$). Ugotovili smo tudi, da so vrednosti odstotkov maščobne in telesne maščobe negativno povezane z najnižjimi vrednostmi moči ($p <0,05$). Med vrednostmi vizualnega in slušnega reakcijskega časa s telesno sestavo in anaerobnimi parametri moči nismo najdli značilnih korelacij. Sklepamo, da razmerje med mišično maso in odstotki telesne maščobe z nekaterimi anaerobnimi parametri moči izhaja iz podobnih mehanizmov, ki vplivajo na povezane parametre. Prav tako sklepamo, da parameter reakcijskega časa ni tesno povezan s telesno sestavo in parametri anaerobne moči, saj je tesneje povezan z nevronskimi kot fizičnimi mehanizmi.

Ključne besede: anaerobna, reakcija, sestava telesa, nogomet, zmogljivost

INTRODUCTION

Soccer is a sport that incorporates many physical activities. In soccer, endurance is an important performance characteristic as well as strength and power (Stølen, Chamari, Castagna & Wisløff, 2005). Players perform different technical and tactical actions during the game. In a soccer game, running is a dominant activity and sprint, jump, one-to-one contact and ball-kicking activities are important for a successful performance (Cometti, Maffiuletti, Pousson, Chatard & Maffulli, 2001). Also, the actions such as sprint, jump, one-to-one contact, diversion and ball-kicking are explosive and anaerobic activities. These high intensity activities have a key role on game result. High anaerobic power allows players to perform anaerobic activities frequently. Thus, high anaerobic power ability may improve match performance of players. During a 90-minute soccer game, players perform short and explosive activities with short rest intervals (Meckel, Machnai & Eliakim, 2009). These findings highlight the significance of improving anaerobic power in soccer.

Reaction time is an important performance component in physical activities that fast reaction to external stimulus is critical. Reaction time categorized as the visual and auditory reaction time depends on the speed of the connection between motor and sensory neurons (Ricotti, Rigosa, Niosi & Menciassi, 2013). Soccer players have to react quickly during positions with or without ball in game. The better visual and auditory reaction performance can give soccer players an advantage for successful execution of soccer specific actions during game. For performing the requirements of playing positions, players should use the visual and auditory reaction features effectively to observe their opponents and react to them quickly and to carry out necessary actions. It was found that professional and college adolescent soccer players have better complex reaction times than regional adolescent players (Hirose, 2011). This result shows the significance of reaction time and its association with performance in soccer.

Lean body mass positively affects sport performance. Jaric (2002) reports that body mass is closely related to muscle strength. Athletic performance in sports branches depends on body mass and composition. The muscle mass is an important factor affecting lean body mass and motor performance. It could be indicated that the muscle mass is effective on athletic performance in sports branches such as soccer that anaerobic power and motor skills are important. The aim of this study was to examine the relationships between anaerobic power, reaction time and body composition parameters of young soccer players.

METHODS

Participants

The study sample consisted of 27 young soccer players playing in the youth setup of amateur soccer teams (Age: 13.81 ± 0.48 years, training age: 6,14 ± 0,78, height: 166.74 ± 6.16 cm, body weight: 55.17 ± 5.40 kg). The study group was selected from players performing regularly three trainings per week for 1.5 hours in their teams. The players without any sports injury were involved in study. All tests were performed at the same hour of the day with a two-day interval. The study was carried out in accordance with the Helsinki Declaration. The all of players completed the informed consent form and participated in the study voluntarily.

Data Collection

Body Height Measurements

Body height was measured with 0.1 cm precision by a height measuring device (Holtain, Dyfed, England) at upright posture position with barefoot.

Body Weight and Body Composition Measurements

Body weight and lean body mass were measured by a bioimpedance body composition analyzer (BC-418MA, Tanita, Tokyo, Japan). Participants stepped on the analyzer barefoot and grasped the apparatus of device with their hands. The body composition analyzer measured automatically their lean body mass, body fat percentage and body fat mass values.

Measurement of Anaerobic Power Parameters

Anaerobic power parameters of players were measured using the Wingate anaerobic power test performed on a bicycle ergometer (Monark Ergomedic 894E, Monark, Sweden). The anaerobic power test consists of cycling with maximal effort during 30 seconds with a load of 7.5% of total body weight. Participants were informed about the test. Saddle height was adjusted to each participant. Participants were allowed to warm up for 5 min at 60 rpm on the bicycle ergometer with 50 watts of power. After the warm-up, a 5-minute rest period with active recovery exercises was performed and then test was started. Participants were verbally motivated to reach maximal pedaling and allowed to reach 120 rpm. Then, the load on the pan was automatically lowered by the ergometer. The anaerobic power test was terminated after participants maintained pedaling speed for 30 s. The relative (corresponding to the kilogram of body weight) and absolute values of anaerobic capacity (sum of 6 peak power values in each 5 seconds of

test), peak power (the highest of 6 peak power values in each 5 seconds of test), minimum power (the lowest of 6 peak power values in each 5 seconds of test) and mean power (mean of 6 peak power values in each 5 seconds of test) parameters were determined in watts using the software of the bicycle ergometer. Fatigue index indicating percentage decrease in power was also determined using the formula below (İnbar, 1986):

Fatigue Index (%): Maximum power – Minimum power / Maximum power x 100

In the Fatigue Index formula, the 30-sec test period is divided into 6 periods of 5 sec. The highest and lowest power values in any 5-sec period of test were determined as maximum and minimum power values, respectively.

Measurement of Reaction Time

Visual and auditory reaction times were calculated using a visual and auditory reaction measuring device (Moart, Lafayette Instrument, USA) measuring the times of reactions to visual and auditory signals. Participants were informed about the test and then the test was started. The participants touched the buttons on the device with the index fingers of their dominant and non-dominant hands as fast as possible when the visual and audio signals were randomly sent by the device. The visual and auditory reaction test was repeated 3 times for the dominant hand and non-dominant hand, respectively. The auditory reaction test was performed similarly after visual reaction test. Visual and auditory reaction times were determined in milliseconds by the device and converted to seconds. The mean of three test values was calculated as mean test score.

Statistical Analysis

The descriptive statistics of paramaters were presented as mean, standard deviation, minimum and maximum values. The statistical relationship between anaerobic power parameters, reaction time and body composition parameters was examined by correlation analysis. The Spearman and Pearson's correlation coefficients were used for analysis of relationship between variables in accordance with normal distribution of data. The statistic package program for Windows operating system (SPSS 22.0, SPSS Inc, Chicago, USA) was used for data analysis. The significance level of all analyzes was applied as $p< 0.05$.

RESULTS

Table 1. Descriptive Statistics of Anaerobic Power, Reaction Time and Body Composition Paramaters.

		n	x̄	SD	Min.	Max.
Anaerobic Power	Peak power (watt)	27	554.45	134.51	367.52	971.04
	Peak power (watt/kg)	27	10.07	2.34	7.02	19.42
	Anaerobic capacity (watt)	27	412.07	65.21	299.66	499.49
	Anaerobic capacity (watt/kg)	27	7.55	0.85	5.88	8.96
	Mean power (watt)	27	415.77	66.91	299.66	499.49
	Mean power (watt/kg)	27	7.55	0.85	5.88	8.96
	Minimum power (watt)	27	179.47	91.41	-25.99	326.29
	Minimum power (watt/kg)	27	3.31	1.69	-0.51	5.83
	Fatigue Index (%)	27	37.95	13.57	16.38	86.23
Reaction Time	Dominant hand visual reaction time (sec)	27	0.44	0.05	0.35	0.58
	Non-dominant hand visual reaction time (sec)	27	0.41	0.04	0.32	0.49
	Dominant hand auditory reaction time (sec)	27	0.42	0.05	0.33	0.54
	Non-dominant hand auditory reaction time (sec)	27	0.41	0.06	0.31	0.63
Body Composition	Body height (cm)	27	166.74	6.16	153.00	181.00
	Body weight (kg)	27	55.17	5.40	43.60	67.10
	Lean body mass (kg)	27	48.71	4.07	38.70	56.40
	Body fat (kg)	27	6.46	2.40	2.00	12.50
	Body fat percentage (%)	27	11.52	3.63	4.60	18.60

Table 2. Results of Correlation Analysis Between Anaerobic Power and Body Composition Variables.

		Body Height (cm)	Body Weight (kg)	Lean Body Mass (kg)	Body Fat Mass (kg)	Body Fat Percentage (%)
Peak power (watt/kg)	r	0.252	0.111	0.191	-0.074	-0.138
	p	,205	,581	,340	,714	,492
Anaerobic capacity (watt/kg)	r	0.330	0.291	0.413	-0.045	-0.158
	p	,093	,140	,032*	,824	,432
Mean power (watt/kg)	r	0.330	0.291	0.413	-0.045	-0.158
	p	,093	,140	,032*	,824	,432
Minimum power (watt/kg)	r	0.057	-0.159	0.033	-0.414	-0.432

	p	,778	,427	,871	,032*	,024*
Fatigue Index (%)	r	0.240	0.078	0.114	-0.019	-0.075
	p	,228	,700	,571	,926	,710

*p<0.05

Anaerobic capacity and mean power correlated positively with lean body mass while minimum power correlated negatively with body fat mass and body fat percentage (p<0.05). There was no statistical significant correlation between the other anaerobic power parameters and body composition parameters.

Table 3. Results of Correlation Analysis Between Anaerobic Power and Reaction Time Parameters.

		Dominant Hand Visual Reaction Time (sec)	**Non-dominant Hand Visual Reaction Time (sec)**	**Dominant Hand Auditory Reaction Time (sec)**	**Non-dominant Hand Auditory Reaction Time (sec)**
Peak power (watt/kg)	r	0.254	0.112	0.057	-0.366
	p	,201	,579	,778	,060
Anaerobic capacity (watt/kg)	r	0.240	-0.074	-0.181	-0.094
	p	,229	,713	,365	,642
Mean power (watt/kg)	r	0.240	-0.074	-0.181	-0.094
	p	,229	,713	,365	,642
Minimum power (watt/kg)	r	-0.026	-0.162	-0.233	-0.010
	p	,898	,419	,243	,962
Fatigue Index (%)	r	0.116	0.029	-0.006	-0.248
	p	,566	,886	,978	,212

There was no statistical significant relationship between anaerobic power and reaction time parameters of young soccer players (p>0.05). In other words, the anaerobic power parameters didn't correlate with the dominant and non-dominant visual and auditory reaction times.

Table 4. Results of Correlation Analysis Between Reaction Time and Body Composition Parameters.

		Body Height (cm)	**Body Weight (kg)**	**Lean Body Mass (kg)**	**Body Fat Mass (kg)**	**Body Fat Percentage (%)**
Dominant Hand	r	-0.151	0.235	0.140	0.290	0.270
Visual Reaction Time (sec)	p	,454	,239	,485	,142	,174
Non-dominant Hand	r	-0.251	0.005	-0.117	0.209	0.246
Visual Reaction Time (sec)	p	,207	,982	,561	,296	,216
Dominant Hand	r	-0.088	-0.284	-0.265	-0.189	-0.122
Auditory Reaction Time (sec)	p	,664	,152	,182	,344	,543
Non-dominant Hand	r	0.104	-0.045	-0.024	-0.062	-0.062
Auditory Reaction Time (sec)	p	,604	,822	,906	,758	,759

There was no statistical significant relationship between dominant and non-dominant hand visual and auditory reaction times and body composition parameters.

DISCUSSION

The anaerobic power performance is important in high intensity exercises. The anaerobic power parameters measured during Wingate test indicates anaerobic power and capacity of athletes. Therefore, a lot of studies were available in literature related to anaerobic power and capacity. The visual and auditory reaction time is indicator of neuromuscular performance in exercise. The reaction performance is effective on exercise performance as an element of neuromuscular system. There were a few studies adressed examine relationship between anaerobic power and body composition with reaction time in literature. The examination of relationship between body composition and anaerobic power with reaction time was aimed in this study.

Taheri and Arabameri (2012) reported that sleep deprivation did not affect peak power and mean power parameters. In other words, the authors found no difference in peak power and mean power parameters between sleep-deprived and non-sleep-deprived groups. However, it was reported that the two groups differed by reaction time in mentioned study. Sleep deprivation adversely affects attention and concentration in exercises that the central nervous system is very active. Therefore, it could be said that only the reaction time was differed

between the two groups. In our study, no correlation was found between visual and auditory reaction times with body composition and anaerobic power parameters (Table 3 and 4). Considering the activation of the central nervous system on reaction exercise, this result is consistent with findings reported by Taheri and Arabameri (2012).

Nikolaidis (2014) performed a study on female soccer players aged mean 21.7 years and reported that lean body mass and body fat mass parameters correlated highly with peak power and mean power parameters. Also, maximal power parameters were also correlated with lean body mass in mentioned study. Although our study group consisted of young male soccer players, we found similar results indicating that gender has no effect on the correlation between lean body mass and body fat mass with anaerobic power parameters.

Zagatto, Beck and Gobatto (2009) performed a study on 40 young military personnel and reported that 6x35 m repeated sprint test results had a correlation with mean power, peak power and fatigue index. Also, it was found moderately negative correlation between relative and absolute mean power parameters with 35 m. sprint time and between 200 m. sprint time and relative mean power in mentioned study. The repeated sprint test is an exercise based on anaerobic power and athletes with high anaerobic power have better sprint performance due to tolerance to fatigue. We found a correlation between lean body mass and some anaerobic power parameters (Table 2). It is known that lean body mass affects positively anaerobic and explosive exercises. It could be said that lean body mass of participants might have an effect on their anaerobic power parameters and sprint performance although it is not directly addressed in the study of Zagatto, Beck and Gobatto (2009).

Potteiger et al. (2010) performed a study on 21 young male ice hockey players and it was indicated that body fat percentage correlated moderately with some of the skating performance parameters and that skating speed was lower in athletes with a higher body fat percentage. The authors also reported that fast skating correlated moderately with fatigue index and relative peak power at Wingate anaerobic power test. Both ice skating and soccer involve short-term explosive activities, and require well developed anaerobic power abilities. The positive correlation between anaerobic capacity and mean power parameters and lean body mass in our study supports the findings of mentioned study (Table 2).

Nikolaidis (2012) performed a study on young male soccer players and reported that body mass index and body fat percentage correlated negatively with the Wingate test mean power. The findings of mentioned study support results of this study. Both studies found that muscle mass

had a positive effect on anaerobic performance. Nikolaidis and Ingebrigsten (2013) performed a study on young and adult handball players and reported that body mass index of adolescent players correlated negatively with active jumping and the Bosco test mean power and correlated positively with fatigue index. Body mass index values greater than ideal values may indicate high body fat percentage affecting negatively the performance of athletes in sports branches requiring anaerobic power. Handball involves anaerobic activities requiring explosive power. Considering that the activities requiring anaerobic power have an effect on performance in soccer, it may be said that the findings of Nikolaidis and Ingebrigsten (2013) are similar to the results of our research.

Sporiš, Jukić, Bok, Vuleta and Harasin (2011) performed a study on 40 maritime military personnel. According to results of mentioned study, it was indicated that body fat percentage correlated moderately and negatively with 5, 10, 20 m. sprint times, active and squat jumping, stride long jump and maximum oxygen consumption. The authors also reported that performance parameters correlated positively with ectomorphic and mesomorphic body type and correlated negatively with endomorphic body type. The positive correlation between lean body mass with anaerobic capacity and mean power parameters in our study (Table 2) is similar to results of their study. Considering that soldiers should have a certain level of physical fitness because of their profession, it might be said that results of mentioned study were similar to findings of our study performed on athletes. In mentioned study, the Wingate anaerobic power test was not performed but sprint and jumping tests requiring anaerobic power were performed. It might be said that the findings of the two studies were similar because of using similar tests requiring anaerobic power.

Nikolaidis et al. (2016) performed a study on soccer players aged mean 23.4 years. They reported that 20 m. sprint time correlated positively with body weight, lean body mass and body fat percentage and correlated negatively with squat and active jumping and Wingate test relative peak and mean power. The author also reported the relationship between lean body mass, body fat percentage, jumping and Wingate anaerobic power with 20 m. sprint performance requiring anaerobic power. This result indicates that low body fat percentage has a positive effect on activities requiring anaerobic power and it is consistent with results of actual study. Heller, Bunc, Buzek, Novotny and Psotta (1995) performed a study on 42 young male soccer players aged mean 16.3 years. The authors reported that lean body mass correlated positively with the Wingate test peak power, anaerobic capacity. It was seen that these findings showed similarity to findings of our study (Table 2).

Andrade et al. (2015) performed a study on 39 young soccer players aged mean16.5 years. The relationship between performance of 30 sec. treadmill anaerobic power test developed by Zemkova and Hamar (2004) and performance of 6x35 meters repeated sprint test used for indirect measurement of anaerobic power was researched in their study. It was reported a positive correlation between the repeated sprint test times and the relative and absolute mean power of the 30 sec. treadmill anaerobic power test in mentioned study. This result indicates that although the ambient conditions were different and the tests were applied in different ways, the physical fitness parameters of exercises requiring anaerobic power may be similar and may correlate with lean body mass and body fat percentage. The correlation between lean body mass and body fat percentage with some anaerobic power parameters was found in our study (Table 2) and this result supported indirectly the findings of Andrade et al. (2015).

Boone, Vaeyens, Steyaert, Bossche and Bourgois (2012) performed a study on 289 Belgian professional soccer players and examined their anthropometric, anaerobic and aerobic performance parameters according to playing positions. They reported that goalkeepers had a higher body fat percentage than other playing positions, higher squat jumping values than right and left fullbacks, and higher active jumping values than right and left fullbacks and midfielders. This result may show that body fat percentage does not have an effect on jumping activities requiring anaerobic power. However, it may be said that goalkeepers execute explosive activities requiring anaerobic power frequently and performance characteristics required for goalkeeping position are more spesific than other playing positions. Therefore, this result may not be consistent with the findings in the literature. The fact that players playing in other positions do not differ by body fat percentage in mentioned study supports this evaluation.

In our study, there was no significant correlation between visual and auditory reaction times with anaerobic power, lean body mass, body fat mass, body fat percentage (Table 3 and 4). The effect on visual and auditory reaction time of neuromuscular performance and central nervous system may have important effect on this result. Anaerobic power parameters indicate the ability to produce high muscle power and maintain it for a certain period of time. In this context, it can be said that the relationship between reaction time and anaerobic power and body composition parameters is not significant statistically because of the structural characteristics of activities. Penna, De Mello, Ferreira, Moraes and Da Costa (2015) divided 76 young male soccer players aged mean 13.36 years into two groups; (1) those born in the first and second quarters of the year and (2) those born in the third and fourth quarters of the year. In mentioned study, it was not found significant correlation between the birth period and the choice reaction

time parameter. The birth period is a maturation-related factor. However, birth periods of participants were close to each other in mentioned study and it might be reason of non-significant relationship between the period of birth and reaction time. In our study, it was found that body composition and anaerobic power parameters didn't correlate with reaction time parameters (Table 3 and 4). Body composition and anaerobic power parameters can be defined as maturation-related parameters. However, it was not available a finding regarding maturation in our study. Therefore, it might be concluded that the relationship between two studies was not clearly evaluated. Longitudinal studies should be carried out to reach correct findings on this topic.

Alanazi and Aouadi (2015) performed a study on male soccer players aged mean 24.04 years and reported that reaction time correlated positively with the 20 m. turning sprint and Illinois agility test results. It may be said that anaerobic power may also have an effect on agility according to results of mentioned study. In this aspect, the findings of the mentioned study are similar to those of our study. Karadağ and Kutlu (2006) found that male soccer players aged mean 22.9 years had better non-dominant-foot visual and auditory reaction times than sedentary people. The significant difference between non-dominant foot reaction times of soccer players and sedentary individuals may arise from positive effect of anaerobic and aerobic power exercises performed to soccer players.

Moradi and Esmaeilzadeh (2015) performed a study on a group aged mean 10.7 years and reported that reaction times measured using clinical equipment correlated negatively with body fat percentage and that 4x10 m. agility performence had an effect on clinical reaction times. Reddy, Eckner and Kutcher (2014) performed a study on athletes at different branches and reported that clinical reaction times did not differ according to exercise period. Triki et al. (2012) reported that soccer players aged 10-11 had a lower body fat percentage, higher relative power in squat and active jumping tests and similar relative anaerobic power in Wingate test when compared to judo athletes. These findings indicating positive effect on anaerobic power of low body fat percentage support results of our study. Studies in literature report different results on reaction time. However, the number of studies reporting accurate findings on the correlation between reaction time with body composition and anaerobic power parameters is limited.

CONCLUSION

The examination of relationships between anaerobic power and body composition and reaction time parameters was aimed in this study. The findings indicated that some of the anaerobic power parameters (anaerobic capacity, mean power and minimum power) correlated with lean body mass and body fat percentage although visual and auditory reaction times didn't correlate with body composition and anaerobic power parameters. Also, it was found that the high lean body mass and low body fat percentage affected positively anaerobic power. The results indicated that reaction time might not relate to anaerobic power and body composition parameters due to its neuromuscular characteristic.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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UPPER LIMB RELATED FACTORS IN DETERMINING POSTURAL CONTROL

DEJAVNIKI POVEZANI Z ZGORNJIMI OKONČINAMI, PRI DOLOČANJU POSTURALNE KONTROLE

ABSTRACT

Postural control is an outcome of complex interactions between many systems and structures to control body position in space. Appropriate postural control is necessary for the initiation and continuation of movements in different body parts, such as the upper limbs. Although the importance of maintaining postural control for movement is well recognized, its relationship with upper limb functions is unknown. The present study investigated the factors related to the upper limb in determining postural control in healthy young adults. We included 68 non-symptomatic individuals in this cross-sectional study. The static and dynamic postural stability and upper limb performance parameters of the participants were evaluated. Multiple Linear Regression analysis was performed to determine the independent determinants of postural control. According to the results of the analysis, Six Minute Peg Board Ring Test (6PBRT) explaining 11% of the variance was the independent determinant of static general stability index ($p < 0.05$). Nine-Hole Peg Test (9HPT) explaining 5.3% of the variance was the independent determinant of static anterior-posterior stability index ($p < 0.05$). The 6PBRT and Medicine Ball Chest Launch Test (MBCLT) explaining 16.5% of the variance were found as independent determinants of static medial-lateral stability index ($p < 0.05$). There was no significant relationship between dynamic stability indices and upper extremity functional parameters ($p > 0.05$). It was concluded that upper limb functions were a determinant of static postural control in non-symptomatic young adults.

Keywords: Upper Limb, Balance, Postural Control

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IZVLEČEK

Ravnotežje je rezultat zapletenih interakcij med številnimi sistemi in strukturami za nadzor položaja telesa. Za začetek in nadaljevanje gibov v različnih delih telesa, na primer v zgornjih okončinah, je potrebno ustrezno ravnotežje. Pomen ohranjanja ravnotežja je za gibanje dobro prepoznavno, njegov odnos s funkcijami zgornjih okončin pa še ni znan. V študijo smo preučevali dejavnike povezane z zgornjimi okončinami pri določanju kontrole telesa pri zdravih mladih odraslih. V presečno študijo smo vključili 68 oseb zdravih oseb. Ocenili smo statično in dinamično ravnotežje ter parametre delovanja zgornjih okončin udeležencev. Ugotovili smo, da šestminutni test obroča (6PBRT), ki je neodvisen dejavnik statičnega indeksa splošne stabilnosti ($p<0,05$) pojasnjuje 11% variance. Test z devetimi luknjami (9HPT), ki je neodvisen dejavnik statičnega indeksa stabilnosti ($p<0,05$), pojasnjuje 5,3% skupne variance. Testa 6PBRT in test met medicinke (MBCLT), pojasnjujeta 16,5% skupne variance ($p <0,05$). Med indeksi dinamične stabilnosti in funkcionalnimi parametri zgornjih okončin nismo našli pomembnih povezav ($p> 0,05$). Ugotovili smo, da so funkcije zgornjih okončin determinanta statičnega ravnotežja mlajših zdravih odraslih.

Ključne besede: zgornji udi, ravnotežje, posturalni nadzor

INTRODUCTION

Postural control is the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support (Horak, 1987). Postural control is an outcome of complex interactions between many systems and structures, especially the nervous and musculoskeletal systems, to control body position in space (Ivanenko & Gurfinkel, 2018). In maintaining postural control; sensory (vestibular, visual and proprioceptive systems), perceptual (nervous system), and motor processes (musculoskeletal system) play important roles (Massion, 1994). Pertinent postural control is required to produce and maintain body movements (Feldman, 2016). Although a movement may seem like a simple process, it emerges as a result of the complex integration of many structures and systems (Winter, 2009). Motor movements can be successfully performed by means of precise cooperation between the nervous system (both peripheral and central nervous system) and the musculoskeletal system (Alexander, DeLong, Crutcher, & Sciences, 1992; Winter, 2009). During movements, the body constantly adapts to postural changes; these adaptations are characterized by low amplitude and slow oscillating movements involving whole body (Newell & Pacheco, 2019).

Upper limb movements are basic motor abilities for all activities, especially for activities of daily living. Body segments are organized to adapt to changing conditions during various activities, such as holding an object, launching and catching a ball, dressing, and cooking (Rau, Disselhorst-Klug, & Schmidt, 2000). Besides cerebellum, cortex, subcortical structures and peripheral nerves, which are main regulators, postural muscles also play an important role in fulfilling upper limb functions (R. Lalonde & C. Strazielle, 2007). Before the movement is initiated, core muscles contract to provide the stabilization necessary for the movement (Larson & Brown, 2018). Prior to the movement, preparative postural arrangements contribute to the initiation and maintenance of the movement (Larson & Brown, 2018; Mesquita Montes et al., 2017). Therefore, any insufficiency in postural control leads to problems in initiating and maintaining movements (Emami, Yoosefinejad, & Razeghi, 2018).

The ability of the upper limbs to perform various tasks depends on their ability to work away from the trunk; an ability that is in close relationship with the stability of the scapulothoracic joint (Meadows, Raine, & Lynch-Ellerington, 2009; Raine et al., 2012). The scapular muscles must stabilize the scapulothoracic joint before any functional movement in the upper limb. Attached to the trunk through scapulothoracic joints, upper limbs can function more effectively in a better state of postural control (Mottram, 1997; Voight & Thomson, 2000). Therefore,

postural control is in a dynamic relationship with the upper limbs. This relationship between upper limb movements and postural control is based on neuronal connections (R. Lalonde & C. J. P. i. n. Strazielle, 2007; Schepens, Stapley, & Drew, 2008).

Knowing the determinants of postural control in relation with the independent upper extremity functions will assist with planning tailored rehabilitation programs to improve the independence level and performance of individuals, especially during activities of daily living. Although the impact of postural control to upper extremities movements is well recognized in research, it is yet unknown whether upper extremities movements are a determinant factor for postural control.

The aim of this study was to examine the relationship between postural control and upper limb functions and to determine whether these functions can be a determinant factor for postural control. It was hypothesized that upper extremity functions would be the determinant of postural control.

METHODS

Study Design and Participants

A total of 68 individuals (30 men, 38 women) were included in this cross-sectional study. Individuals over 18 years of age who had no known health and communication problems were included in the study. Individuals with neurological or orthopedic problems or cognitive impairments, those with a history of surgery in lower or upper limbs, and individuals with a history of malignancy were excluded. Ethics approval was obtained from the Clinical Research Ethics Committee of University (approval no. 2019-21/206). All participants signed an informed consent form.

Outcome Measures

The participants' demographic data, including age, height, body weight, and medical background were recorded.

Evaluating Postural Control

The participants' postural control was evaluated via Biodex Balance System (BBS, a commercially available balance device, Biodex Medical Systems, Shirley, NY, USA). BBS is a commonly used method to evaluate postural control (Arnold & Schmitz, 1998; Aydog,

Aydog, Çakci, & Doral, 2004). BBS consists of a mobile platform capable of tilting up to 20° in 360° range of motion. The platform provides objective evaluation data using a computerized software (Upper display module-firmware version 1.09, Lower control board-firmware version 1.03, Biodex Medical Systems). Postural control can be evaluated over different difficulty levels ranging from 1 (the hardest) to 12 (the easiest). Based on the relevant literature, in the present study, postural control was evaluated both dynamically and statically in three measurements. Higher scores in each index indicate poor postural control. With their feet shoulder-width apart, the participants were asked to stand upright on the BBS platform in a comfortable position and look ahead. Participants were trained about 1 minute to adapt to BBS to reduce learning effects. Each measurement lasted for 20 seconds with a 10-second rest interval between the measurements. To evaluate dynamic postural control 2 levels were used and the evaluations were made with eyes open. For each participant, general stability index, anteroposterior stability index and mediolateral stability index scores were recorded for both static and dynamic postural control (Akhbari, Salavati, Mohammadi, & Safavi-Farokhi, 2015; Arnold & Schmitz, 1998; Pickerill & Harter, 2011; Testerman, Griend, & international, 1999).

Evaluating Upper Limb Functions

Upper Limb Exercise Capacity: Six-Minute Pegboard Ring Test (6PBRT) was used and the evaluation was based on the protocol by Zhan et al, (Zhan et al., 2006). Higher scores indicate low upper extremity exercise capacity.

Evaluating Dexterity: Nine-Hole Peg Test (9HPT) was used to evaluate dexterity. The participants were asked to insert the pegs into the holes using their dominant hand. Time was recorded in seconds using a stopwatch (Poole et al., 2005). A high score in 9HPT indicates low dexterity.

Evaluating Functionality: Closed Kinetic Chain Upper Extremity Stabilization Test (CKCUES) was used for evaluating functionality. Since the participants were sedentary individuals, the modified push-up position was used as testing position. The evaluation consisted of counting how many times, in 15 seconds, each participant assuming the modified push-up position was able to touch his/her supporting hand with the swinging hand (de Oliveira et al., 2017). A high score in CKCUES indicates higher upper extremity functionality.

Evaluating Muscle Endurance: Muscle endurance was evaluated both statically and dynamically. The evaluation of static endurance consisted of recording the duration each participant was able to hold a training ball of 5 kilograms with the shoulder in 45° of flexion

and 45° of abduction. To evaluate dynamic endurance, the participants were asked to hold a training ball of 5 kilograms, lift it to 45° of flexion and 45° of abduction in their shoulder, and return to the initial position. The number of repetitions within 30 seconds was recorded as the test score. Both evaluations were made with the participant sitting on a chair. Higher scores indicate better muscle endurance.

Evaluating Upper Limb Muscle Power: Performed in standing position, Medicine Ball Chest Launch Test (MBCLT) was used to evaluate upper limb power. The participants were asked to hold a 2-kilogram med ball at their chest and then explosively throw the ball forward as far as they could. Each participant had 3 test throws and the best throw was recorded as the test score. Larger throw distance scores indicate greater upper extremity muscle power.

Evaluating Upper Limb Flexibility: Active Internal Rotation Test (IRT), Horizontal Adduction Test (HAT) and goniometric measurement methods were used for the evaluations. For IRT, the participants were asked to stand in an upright position and reach with their thumb to their back with shoulder adduction and internal rotation. The distance between the spinous process of the seventh cervical vertebra and the thumb was recorded in centimeters (Granata & Orishimo, 2001). For HAT, the participants were asked to actively move their arm from 90° of flexion to the maximum of horizontal adduction. Once at the final position, the distance between the lateral epicondyle and the opposite acromion was measured and recorded in centimeters (Kugler, Krüger-Franke, Reininger, Trouillier, & Rosemeyer, 1996). Low scores (smaller distances) indicate greater upper extremity flexibility. Goniometric evaluations consisted of measuring internal and external rotation range of motion of the shoulder joint.

Sample Size

To the best of our knowledge, no study in the literature has investigated whether upper limb can be a possible factor for static and dynamic balance measured using postural control index. However, a previous study has reported body weight as a significant predictor of postural stability ($R^2 = 0.10$, $p < 0.05$) [24]. Based on the results of that study, the minimum required sample size for a multiple regression analysis was calculated as 60 participants for the probability level of 0.05, ten predictors in the model, the anticipated effect size as 0.14, and the statistical power level as 80% using G*Power Software (Version 3.1.9.2, Düsseldorf University, Düsseldorf, Germany). Allowing for a 10% dropout rate, 67 subjects were recruited into the study.

Data Analysis

SPSS 22.0 for Windows was used to analyze the data. Visual (histogram) and analytical (Shapiro-Wilk test) methods were used to examine whether the data were normally distributed. Values are given as mean ± standard deviation. Since the data had normal distribution, Pearson Correlation analysis was used to investigate the correlation between variables. Correlation coefficients of > 0.5 were considered as strong, 0.3–0.5 as moderate, and 0.2–0.3 as weak correlations (Cohen, 1988). Multiple Linear Regression was used to determine the independent determinants of postural control. Significance level was set as $p < 0.05$.

RESULTS

Demographic data and evaluation parameters of the participants are given in Table 1.

Table 1. Demographic and clinical characteristics of the participants.

	Mean	Standard Deviation	Minimum	Maximum
Age (years)	21.19	1.56	18	25
Height(cm)	169.09	8.73	149	187
Weight(kg)	64.35	10.69	47	90
BMI (kg/m²)	22.80	2.50	18.44	29.39

A statistically significant negative moderate correlation was found between the 6PBRT score and static general stability index ($r = -0.352$, $p = 0.003$, Table 2). A positive weak correlation was found between static general stability index and 9HPT ($r = 0.289$, $p = 0.017$, Table 2). There was no significant relationship between static general stability index and upper limb functions ($p > 0.05$, Table 2). According to the results of Multiple Linear Regression analysis, the 6PBRT was found as an independent determinant of static general stability index explaining 11% of the variance ($p < 0.05$, Table 3).

Table 2. Correlation between postural control score score and other assessments.

		6PBRT	9HPT	CKCUES	SEC	DES	MBCLT	IRT	HAT	IRT	ER
SOS	**p**	-0,352**	0,289*	-0,150	-0,009	-0,197	-0,224	-0,027	-0,182	0,133	0,131
	r	0,003	0,017	0,223	0,943	0,106	0,067	0,824	0,138	0,280	0,285
SAPS	**p**	-0,214	0,258*	-0,113	0,017	-0,082	-0,058	0,023	-0,077	0,073	0,057
	r	0,080	0,034	0,359	0,890	0,505	0,641	0,852	0,534	0,556	0,642
SMLS	**p**	-0,321**	0,176	-0,159	0,013	-0,200	-0,252*	-0,061	-0,191	0,175	0,128
	r	0,008	0,151	0,195	0,917	0,102	0,038	0,622	0,119	0,152	0,297
DGS	**p**	-0,191	0,238	-0,127	0,056	-0,105	0,105	0,122	0,039	-0,051	-0,121
	r	0,118	0,051	0,300	0,650	0,393	0,393	0,321	0,749	0,679	0,327
DAPS	**p**	-0,199	0,207	-0,122	0,005	-0,105	0,043	0,128	0,035	-0,040	-0,126
	r	0,104	0,090	0,320	0,967	0,396	0,727	0,297	0,777	0,745	0,308
DMLS	**p**	-0,102	0,220	-0,111	0,099	-0,092	0,193	0,097	0,062	-0,055	-0,079
	r	0,408	0,072	0,369	0,420	0,454	0,114	0,433	0,613	0,657	0,520

SOS: Static Overall Stability Index, SAPS: Static Anterior/Posterior Stability Index, SMLS: Static Medial/Lateral Stability Index, DOS: Dynamic Overall Stability Index, DAPS: Dynamic Anterior/Posterior Stability Index, DMLS: Dynamic Medial/Lateral Stability Index, 6PBRT: 6-Minute Pegboard and Ring Test, 9HPT: Nine-Hole Peg Test, CKCUES: Closed Kinetic Chain Upper Extremity Stabilization Test, SEC: Static Endurance Score, DES: Dynamic Endurance Score, MBCLT: Medicine Ball Chest Launch Test, IRT: Active Internal Rotation Test, HAT: Horizontal Adduction Test, IR: Internal Rotation, ER : External Rotation

A positive weak correlation was found between static anterior-posterior stability index and 9HPT score ($r = 0.258$, $p = 0.034$, Table 2). There was no significant relationship between static anterior-posterior stability index and upper limb functions ($p > 0.05$, Table 2). According to the results of Multiple Linear Regression analysis, the 9HPT was found as an independent determinant of static anterior-posterior stability index explaining 5.3% of the variance ($p < 0.05$, Table 3).

There was a significant negative moderate correlation between static medial-lateral stability index and 6PBRT score ($r = -0.321$, $p = 0.008$, Table 2). A significant negative weak correlation was found between the static medial-lateral stability index and MBCLT score ($r = -0.252$, $p = 0.038$, Table 2). There was no significant relationship between static medial-lateral stability index and upper limb functions ($p > 0.05$, Table 2). According to the results of Multiple Linear Regression analysis, 6PBRT (score) and MBCLT (m) explaining 16.5% of the variance were found as independent determinants of static medial-lateral stability index ($p < 0.05$, Table 3).

There was no significant correlation between dynamic stability indices and upper limb functions (p> 0.05, Table 2).

Table 3. Stepwise multiple linear regression model of postural control.

	B	**SH**	**Beta**	**p**	**adjusted R^2**
			Determinants of Static Overall Stability Index		
Constant	2.825	0.588	-	<0.001	0.110
6PBRT (score)	-0.01	0.003	-0.352	0.003	
			Determinants of Static Anterior/Posterior Stability Index		
Constant	-0.641	0.592	-	0.283	0.053
9HPT (sn)	0.077	0.036	0.258	0.034	
			Determinants of Static Medial/Lateral Stability Index		
Constant	2.710	0.529	-	<0.001	
6PBRT (score)	-0.008	0.002	-0.358	0.002	0.165
MBCLT (m)	-0.001	<0.001	-0.297	0.010	

6PBRT: 6-Minute Pegboard and Ring Test, MBCLT: Medicine Ball Chest Launch Test,
9HPT: Nine-Hole Peg Test

DISCUSSION

Postural control is an output of the interaction between the nervous and musculoskeletal systems (Ivanenko & Gurfinkel, 2018). Through this interaction, the muscular system enables individuals to perform all their activities (Ivanenko & Gurfinkel, 2018). Upper limb functions form the basis for important motor skills, which are required for daily living. Studies on postural control mainly focus on activities such as gait and balance; yet, it is important to know the relationship between postural control and upper extremities, which play a prominent role in the performance of daily activities. Therefore, as the first study in the literature, we examined whether upper extremity functions are determinants of postural control. According to the results, upper extremity functions are indeed a determinant of static postural control. Our results also indicated that upper limb exercise capacity and dexterity were the determinants of general static postural control, dexterity was the determinant of static anterior-posterior postural control, and upper limb exercise capacity and upper limb power were the determinants of static medial-lateral postural control. In the relevant literature, the concepts of postural control and

postural stability are commonly used interchangeably. Postural control is defined as the ability to keep or regain the center of body mass over the base of support (Horak, 1987). Postural stability is the stable position of the body mass center within the base of support to maintain an upright posture (Westcott, Lowes, & Richardson, 1997) (Iqbal, 2011). These two definitions show how intertwined the two concepts are. In our study, the term 'postural control' is used as it is more comprehensive than 'postural stability'.

Core muscles are involved in maintaining postural control. These muscles have been shown to improve upper limb functions by increasing trunk stabilization. In their study, Miyake et al. reported that increased core endurance and trunk stabilization lead to improved upper extremity functions (increase in the Purdue Pegboard score) and daily living activities (Miyake, Kobayashi, Kelepecz, & Nakajima, 2013). A study investigating the relationship between dexterity and postural control in children between five and six years of age reported a relationship between dexterity and postural control (Rosenblum & Josman, 2003). In a study conducted on individuals with Parkinson, the relationship between dexterity and postural control differed according to age. While there was a relationship between dexterity and postural control in Parkinson patients over 65 years of age, no significant relationship was observed in patients below 65 years old [6]. Furthermore, a relationship is reported between hand functions and postural control in individuals over 65 years of age (Fatih et al.). In line with these studies, our results also revealed a significant relationship between manual skills and SOS and SAPS indices. Moreover, 9HPT was found to be the independent determinant of SAPS index explaining 5.3% of the variance, indicating that dexterity is a determining factor of postural control. Static postural control is the ability to control the center of mass within the base of support during normal posture (Shumway-Cook & Woollacott, 2007). Based on our results, we can assume that 9HPT can be a factor in determining static postural control as this test is performed in static sitting position. There is a need for future studies to further investigate this finding.

Upper limb exercise capacity is another important aspect in performing and maintaining upper limb functions. Unsupported upper limb movements are needed for most of the daily living activities (Takeda et al., 2013). To the best of our knowledge, our study is the first study in the literature that examines whether upper extremity exercise capacity is a determinant of postural control. Therefore, there is no study in the relevant literature to compare our results with. According to our results, there was a relationship between upper limb exercise capacity and SOS and SMLS indices. Moreover, 6PBRT was found to be an independent determinant of

static general stability and static medial-lateral stability indices. Hence, it is thought that increasing upper extremity exercise capacity can have a positive effect on static postural control. Further studies are needed to examine this relationship between upper limb exercise capacity and postural control, and to investigate evaluation and intervention approaches.

It has been reported in several studies that upper limbs are functionally involved in maintaining and restoring disturbed postural control (Marigold, Bethune, & Patla, 2003; Roos, McGuigan, Kerwin, Trewartha, & posture, 2008). According to Gracovetsky's spinal machine theorem, the abdominal oblique muscles work in coordination with other central column muscles to create kinetic and potential energy and generate a rotating torque. As a result of this rotator torque, spiral motion system is activated and many functional movements originating from the central column (such as walking and rolling) can be performed. Maximum force is created when the force generated from the trunk and lower limbs is combined -through the thoracolumbar fascia- with the force produced in the upper limbs. According to the researcher, during baseball ball launch, the appropriate trunk position required for the upper limb is maintained with the coactivation of bilateral hip adductors together with ipsilateral internal and contralateral external oblique abdominals (Marcus, 2010). This explains the relationship between upper extremity functions and trunk stabilization. Previous studies have reported significant correlations between trunk stabilization and upper limb power in different sports such as baseball, handball, and football (Lust, Sandrey, Bulger, & Wilder, 2009; Saeterbakken, Van den Tillaar, Seiler, & Research, 2011; Sharrock, Cropper, Mostad, Johnson, & Malone, 2011; Shinkle, Nesser, Demchak, McMannus, & Research, 2012). In their study on 35 athletes, Sharrock C et al. (Sharrock et al., 2011) investigated the relationship between trunk stabilization and upper limb power. The researchers used double leg jump test to evaluate trunk stabilization and Medicine Ball Chest Launch Test to evaluate upper limb power. They reported a significant relationship between trunk stabilization and upper limb power (Sharrock et al., 2011). In another study on 25 football players, Shinkle J. et al. (Shinkle et al., 2012) examined the relationship between trunk stabilization and upper limb functional performance. They reported a significant relationship between trunk stabilization and upper limb performance, and concluded that this relationship was important in transferring power to the upper limbs and generating force (Shinkle et al., 2012). In their study on functional reactions of the lower and upper limb muscles to postural changes, Mcllroy et al. used EMG to evaluate muscle functions. They examined the response of the posterior deltoid muscle to the disrupted postural control and observed that in case of any loss in postural control, posterior deltoid responded together

with the muscles of lower limbs. They also reported that when postural control is medio-laterally disrupted, the posterior deltoid muscle responded even more than the lower limbs (McIlroy & Maki, 1995). In the present study, a significant relationship was found between upper limb power and static medial-lateral stability index. Moreover, upper limb muscle power was found to be an independent determinant of static medial-lateral stability. In a study on elite volleyball players, no relationship was found between upper extremity functional performance and dynamic postural control (Kugler et al., 1996). Similarly, we found no significant relationship between upper extremity power and dynamic postural control parameters. This might be due to the MBCLT protocol that we used to evaluate upper extremity power. In our protocol, the participants were asked to launch the ball using only their upper extremities without any swing in their trunk. So, it is normal for the results to be related to static postural control.

Maintaining posture during voluntary movements and reactions against external forces in unexpected situations are considered as dynamic postural control (Shumway-Cook & Woollacott, 2007). Dynamic postural control is the state of realignment of the body or regaining balance after a fall. Dynamic postural control ensures the maintenance of postural control during activities in which the body is no longer in contact with the base of support, such as running and jumping (Travis, 1945). A study conducted with dancers found a relationship between shoulder flexibility and dynamic postural control. In our study, there was no significant relationship between upper limb functions and dynamic postural control. This might be due to the fact that all upper extremity function tests were performed in static positions such as sitting and standing. If tests involving more dynamic stability were used to evaluate upper extremity functions, the results could be different. Moreover, lower limb functions could be more effective in determining dynamic postural control. In this context, future studies are recommended to separately examine the effects of upper and lower limb functions on static and dynamic postural control.

The study has some limitations. Healthy individuals were included and evaluated in the present study. Including different specific populations could also yield useful results. Future studies may examine the relationship between upper limb functions and postural control in more specific groups.

CONCLUSION

The present study is the first in the literature to examine and identify the determinants of postural control in non-symptomatic young adults. According to the results, upper limb functions are an independent determinant of static postural control. It is recommended to include upper extremity exercises to the rehabilitation programs that aim to improve postural control.

Declaration of Conflicting Interests

No conflict of interest was reported.

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THE DUAL COMMITMENT OF STUDENT ATHLETES IN LOWER SECONDARY SCHOOLS IN FINLAND

DVOJNA KARIERA UČENCEV ŠPORTNIKOV VIŠJIH RAZREDOV OSNOVNIH ŠOL NA FINSKEM

ABSTRACT

Student athletes are expected to succeed simultaneously in school and sports. Research findings mainly come from upper secondary and university students, while research on younger adolescent student athletes has been largely overlooked. Drawing upon rich qualitative data derived from individual interviews with student athletes from grade eight (n = 15), teachers (n = 4), principals (n = 2), and nonparticipant observations (n = 7) at five schools, this study examines how young student athletes succeed in school and sports and in combining these two. The data was analysed using collaborative qualitative data analysis to find themes describing these student athletes. The main findings indicated that most student athletes had high ambitions and showed strong orientations in their school approaches. For some student athletes, the student and athlete roles conflicted, and they prioritized sports over educational success. A similar variation in student athletes' sport commitments was found: from having a goal to become a professional athlete to pursuing sport as a leisure activity. Student athletes in this study were in the beginning of a developmental dual career process, and they needed to be recognized as a heterogeneous group with individual pathways. Finally, the sport school provided more opportunities for practice and a flexibility in school-related issues. The findings indicated the demanding nature of the dual commitment of student athletes in lower secondary sport schools. Consequently, it is difficult to form a consistent picture that fit every context because the student athlete role is individual and to some extent conflicting.

Keywords: student athlete, dual career, sport and education, qualitative methods

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IZVLEČEK

Študentje športniki morajo kombinirati šolsko in športno kariero. Dosedanje ugotovitve raziskav v večini temeljijo na starejših mladostnikih in mlajših odraslih, medtem ko so bile raziskave o mlajših mladostniških športnikih v glavnem spregledane. Pričujoča študija temelji na bogatih kvalitativnih podatkih, pridobljenih na podlagi individualnih razgovorov z učenci športniki iz osmega razreda (n = 15), učitelji (n = 4), ravnatelji (n = 2) in ostalimi opazovanci (n = 7) petih osnovnih šol. Podatki so bili analizirani s pomočjo skupne kvalitativne analize podatkov z namenom opisa osnovnošolske populacije učencev športnikov. Glavne ugotovitve so pokazale, da je večina učencev športnikov imela visoke ambicije saj je pokazala močne usmeritve pri svojih šolskih pristopih. Pri nekaterih učencih smo ugotovili. Ugotovili smo, da imajo športniki različne cilje, med najpogostejšimi sta slednja: i) postati poklicni športnik; ii) ukvarjanje s športom kot prostočasno dejavnostjo. Učenci športniki v pričujoči študiji so sicer bili na začetku procesa razvoja dvojne kariere in jih je bilo treba prepoznati kot heterogeno skupino z različnimi interesi in potmi. Ugotovitve študije nakazujejo na dvomljive ugotovitve zato je posledično tudi težko oblikovati skladno sliko, ker je vloga učenca športnika individualna in do neke mere nasprotujoča si.

Ključne besede: učenec športnik, dvojna kariera, šport in izobraževanje, kvalitativne metode

INTRODUCTION

Sport associations and clubs have traditionally had the main responsibility for structuring competitions and sports in Europe. Nevertheless, during the past decade, European countries have strived to combine practice, sport competitions, and education (The EU Guidelines on Dual Careers of Athletes, 2012), which has enabled individuals to begin making dual careers. A dual career (DC) is defined as a career with a focus on sports and study or work (Ryba et al., 2015; Stambulova & Wylleman 2015). Sports and educational experiences are connected, which makes the transition natural for the athlete and therefore, they can combine their interests in an ideal manner (Tekavc et al., 2015).

DC research is a relatively new field that has gained momentum in the last 10–15 years (Guidotti et al., 2015; Stambulova & Wylleman, 2019). The research area emphasises athletes who combine sports and education in normal schools, sports classes, sports schools, or universities (Stambulova & Wylleman, 2015). European DC research show an emphasis on athletic career development (Stambulova et al., 2009; Wylleman et al., 2013), challenges and demands in combining sport with education (Christensen & Sørensen, 2009; Ryba et al., 2016), and risk and resilience factors related to the construction of DC pathways (Ryba et al., 2016). There has been research examining the possibilities of making a DC at the upper secondary school level (Baron-Thiene & Alfermann, 2015; Ryba et al., 2017) and at the university level (Brown et al., 2015; Fernandes et al., 2019; Lupo et al., 2017). However, to the best of our knowledge, there is no research about the opportunities for DC in lower secondary school.

Student athletes who have made DCs are more successful at the transition from sports to working life than athletes who focused solely on sports (Ryba et al., 2017; Stambulova et al., 2009; Torregrosa et al., 2015). Aquilina (2013) described the presence of an alternative focus as a relief from the pressures of sports that provides perspective to the student athlete. However, investing in a sports career and education is demanding, and studies show that it is difficult to achieve good results in sports and academic careers at the same time (O'Neill et al., 2013; Ryba et al., 2016). Some student athletes are struggling to find a proper balance between combining an athletic career with an academic or working career (Aquilina, 2013; Debois et al., 2015). In addition, their commitment and motivation towards athletics and education can vary greatly depending on gender, age, and level of competition (Miller et al., 2005).

Student athletes pursuing DCs indicated that they experience challenges, such as absences from exams or lectures, training and sport pressure, too little leisure time, and the loss of social life.

(Condello et al., 2019; Li & Sum, 2017; O'Neill et al., 2013; Romar, 2012). Moreover, student athletes who make DCs at the upper secondary school face the risks of athletic burnout and school burnout and, thus, increase the risk of work overload and injuries. (Sorkkila et al., 2020; Stambulova et al., 2015; Tekavc et al., 2015). Student athletes tend generally to perform as well or better academically as their nonathlete counterparts (Emrich et al., 2009), while in the American high school context, female student athletes outperform their peers (Miller et al., 2005). In addition, findings related to participation and success in school in Finland, show that almost 40% of student athletes studying at upper secondary sports schools would consider dropping out of studies if education would interfere with their pursuits for athletic success (Ryba et al., 2017). Furthermore, students reporting low engagement or unwillingness to invest in school run higher risks of dropout and academic ill-being (Li & Lerner, 2013).

Research findings from student athletes in upper secondary school and higher education show that achievement in one domain is often accomplished at the expense of the other domain (Aquilina, 2013; Christensen & Sørensen, 2009). The majority of student athletes perceive education as important to facilitate future study options (Romar, 2012; Ryba et al., 2016). Some student athletes feel that sports are only a hobby, which is why they also concentrate more on education. These student athletes believe they will benefit from the studies for the rest of their lives, while the sports are only temporary (Li & Sum, 2017). Student athletes considering that sports might not be their future professions have higher academic identities (Stambulova et al., 2015). Nevertheless, many student athletes report that they prioritise sports over their education (Christensen & Sørensen, 2009; Cosh & Tully, 2014; Harrison et al., 2020; Tekavc et al., 2015). This choice is even more evident in sports where the student athletes easily get income to practice their sports professionally (Stambulova et al., 2015).

While gender is generally an issue in sports, female elite athletes tend to value and invest more in academic careers than males do (Kerštajn & Topič, 2017; Ryba et al., 2016). Similarly, male athletes often have stronger sports identities than females do (Stephan & Brewer, 2007). Research also indicates that female athletes have higher aspirations for education than males do, and they have less motivation to pursue sports careers (Gaston-Gayles, 2005; Tekavc et al., 2015). Therefore, female athletes have a greater risk of ending the DCs, which means that they will give up education or sports (Baron-Thiene & Alfermann, 2015; Stambulova & Wylleman, 2019; Tekavc et al., 2015). In addition, female athletes more often than male athletes cannot live on sports and have to work for financial stability (Harrison et al., 2020; Stambulova &

Wylleman, 2019). Importantly, these DC research findings are mainly from upper secondary and university students, while research on younger adolescent student athletes is lacking.

Tekavc et al. (2015) also noted a difference in study motivation between team athletes and individual athletes pursuing DCs. Team athletes study less frequently at universities, while those who participate in individual sports often study at universities. However, Lupo et al. (2017) argued that there were no differences in study motivation between team and individual athletes; rather, the differences were individual and not sport specific.

Several researchers have noted the developmental perspective of a DC. Li and Sum (2017) defined the first stage of the DC experience as becoming an athlete with DC. During this stage, the security, alternative focus, or backup plan was evident, particularly how student athletes intended to deal with the challenges whilst preparing for the future life. Later, student athletes deal with sport and education transitions at different stages of their lifetimes, highlighting that the DC is fundamentally developmental in nature (Debois et al., 2015). Apparently, student athletes encounter many challenges, which occur at different layers in sports and education, thus they have to prioritize depending on life situations (Stambulova & Wylleman, 2019). Student athletes use this fluctuation in focus and prioritization as a temporary coping mechanism for periods of particularly high demand on time or energy (Cartigny et al., 2019; Guidotti et al., 2015; Li & Sum, 2017). However, studies have indicated that the DC demands faced by student athletes increased during more advanced levels of education (Cartigny et al., 2019, Harrison et al., 2020).

Although research describes student athletes as a heterogeneous group, each athlete has their own individual process with different changing motives and related identities impacting on the student athlete's development (Defruyt et al., 2020; Li & Sum, 2017). Drawing on previous studies (e.g., Aunola et al., 2018; Ryba et al., 2017; Stambulova et al., 2015) and their own interview data, Cartigny et al. (2019) presented a lifespan perspective of the student athlete experience by identifying three distinct student athlete pathways. One group of student athletes reflected a balance between sport and education, while another showed a sporting dominancy and a third group showed educational and/or vocational dominancy. Differences in identity development were linked to each pathway, suggesting that athletes construct their DCs from a young age, and these constructions impact the individual actions they take.

Given an increased focus and concerns about youth sports, it is important to understand how student athletes balance sports and education at different educational levels. As outlined by

Stambulova and Wylleman (2019), the DC literature has grown in Europe during the last decade. The review underlined a need for further exploration of student athletes at a primary school level, which means the time before the transition to upper secondary education. Therefore, the aim of this study was to examine student athletes' commitments to education and sports during lower secondary education.

METHODS

Context

Finnish comprehensive schools have long had an international status as relatively equal and providing uniform education for all students. The educational system consists of 9 years of compulsory basic schooling, starting at age 7 and ending at age 16. In primary school (Grades 1–6), classroom teachers are mostly responsible for giving instruction, whereas subject teachers primarily give instruction in lower secondary school (Grades 7–9). After comprehensive school, students choose between upper secondary (academic track) or vocational education. Currently, Finland has 15 sports upper-secondary schools, which supports the construction of a DC path by collaborating with sports clubs, national sports academies, and sports federations.

The present study is part of an ongoing DC research project that focuses on examining student athlete well-being throughout lower secondary school. At present, 19 lower secondary schools nationwide have been certified in accordance with the criteria established by the Finnish Olympic Committee to participate in a 3-year lower secondary sports schools pilot project (LSSSPP) during the academic years 2017–2020. The aim of the LSSSPP project was to promote young adolescent athletes' opportunities to pursue academic and athletic careers simultaneously through strengthening the collaboration between local lower secondary schools, the national network of sports academies, and local sports clubs. The LSSSPP schools are geographically representative of Finland, and student athletes form their own classes (about 25 student athletes in one group) within each school. The participating schools have committed themselves to making special arrangements for flexible solutions, so that student athletes can combine sports with education. In reality, this means schools provide 10 hours a week during school days for physical education or sports practice, as well as a 2-hr weekly "Develop as an Athlete" unit during the whole school year. In addition, admittance to the lower secondary sport classes is competitive. Thus, student athletes must display physical competence, and the most competent are selected through national physical aptitude tests.

Participants

We purposefully sampled five LSSSPP schools that were located close to or had good connections to the university, were willing to be observed during the school day, and represented schools with different sports focuses. The participants in the study were 15 student athletes (M = 14.5 years old) and six persons from the school staff (see Table 1). We based the inclusion of school staff on Harrison et al. (2020), who suggested it would enable an understanding of DCs within a broader context. We selected three student athletes purposefully from each school, following the criteria of having gender, team, and individual sport balances. In addition, two subject teachers, two physical education teachers, and two principals participated in the study, with at least one staff member being from each school. Prior to data collection, we obtained ethical approval from the Åbo Akademi University ethics committee. Additionally, parents to all student participants signed written informed consent forms.

Table 1. Student Athletes, School Staff, and Observations as Data Sources at Five Schools.

School	**Student Athlete**		**School Staff**		**Observation**
	Name	**Sport**	**Name**	**Position**	**Subject**
Björkby	Roland	Soccer	Victoria	Physical education	Finnish
	Jenny	Soccer			Physical education
	Gustav	Soccer			
Granby	Lisa	Swimming	Oskar	Physical education	Swimming
	Ulla	Swimming		Principal	Motor skills
	Christopher	Swimming	Emma		Mathematics
Lärkby	Lukas	Ice hockey	Sofia	Finnish	Motor skills
	Ulrika	Swimming			Finnish
	Mathilda	Figure skating			
Tallby	Lovisa	Synchronized swimming	Ben	Principal	
	Marika	Motocross			
	Jesper	Ice hockey			
Enby	Pelle	T&F/Basket	Ida	Home economics	Mathematics
	Måns	Floorball			Physical education
	Amanda	Team gymnastics			

Data Collection

We obtained qualitative data for this study via interviews and observations with field notes. We conducted the interviews at the end of the academic year, when student athletes had attended 2 years at an LSSSPP school. The first and fourth authors conducted the interviews in a quiet room in each school. We audio recorded and transcribed the interviews verbatim. We used semistructured individual interviews to gain insight into the student athletes' commitment to school and education. We developed a semistructured interview guide based on previous DC literature (e.g., Guidotti et al., 2015; Li & Sum, 2017; Stambulova & Wylleman, 2019), similar for student athletes and school staff, to ask in-depth questions tailored to the participants' experiences. For example, broad categories of questions were related to individual factors (e.g., How important is education? What are the good points or downsides of this LSSSPP school?) and institutional factors (e.g., How do schools support students in combining education and sports?). The lengths of interviews ranged from 14–28 min for student athletes and from 16–39 min for school staff.

The purpose of nonparticipant lesson observations was to provide us a chance to "live" the DC in LSSSPP schools and experience what actually takes place. Although unsystematic in nature, the observations were based loosely on Virtanen et al.'s (2019) study using the classroom assessment scoring system. During observations, the researchers took detailed field notes about teachers' instructional behaviour and interactions, peer interactions, and student task orientation. We observed mathematics, Finnish, physical education, motor skill practice, and swimming lessons (see Table 1), and the length of each lesson varied from 60–90 min. These observations provided glimpses into a DC school day, as seen through the lens of the researchers.

Data Analysis and Trustworthiness

We analysed the qualitative data by using a collaborative qualitative data analysis (Richards & Hemphill, 2018). The development of coding categories involved a repetitious process of exploring the interview and observational data. We defined the codes to reflect the issues and with reference to notions in the DC framework. We achieved consensus upon discussion of differences in coding and categorizing the themes. Thus, we generated the final codes and created a coding frame to define key themes, their definitions, and criteria for recognition in the coding for each data source (see Table 2).

Table 2. Thematic Analysis.

Main Themes	Area of Focus	Example of Raw Data
School commitment	High study ambitions	I would say it [school] is very important. At the moment, it is my highest priority.
	Future professional careers	I think it is quite important. I want to a certain high school because I want to study medicine.
	Success in school	Probably this class is by far better than the other classes, if we think of all students on average.
	Differences among student athletes	It is individual, and I would still say that most of our students make an effort in school beside their sport involvement.
	Gender-specific issues	The girls are definitely investing more in school, while the boys are investing more [in] sports.
Sport commitment	Strong commitment	Super important . . . I have such a dream that I would like to win a World Cup medal.
	Weaker commitment	I want, as I now have, a good basic fitness level and physical activity, to be out and to be with friends. I don't have any major goals to play in any one league.
	Competences for everyday life	It has of course taught me time management. You almost have to have a minute schedule for each day, so that you have time for everything.
A dual career	Combining sport and school	Probably both are equally important; if you don't become a professional athlete, you have to build another career.
	To train during the school day	A good point is that you have a lot of physical education and morning sessions, which you might not get from a normal school.
	Demanding amount of work	In my opinion, the biggest challenge is to cope [with the demands]. Our young athletes are under a great pressure.
	Adjustments in schooling	If you have long game trips, you can get extra time for homework or similar.

We took several steps during the research process to facilitate trustworthiness. First, we made the study procedure transparent to participating student athletes and school staff at the beginning of the study. The triangulation of data sources involved identification of similar data situated in the observations and interviews. We used researcher triangulation multiple times to make sense of and challenge emerging categories. We retained verbatim quotes from student athlete and school staff interviews and field notes to stay close to the data, and for the result text, we chose the best of the selected quotes, which were identified by participant pseudo name and sport or staff position.

RESULTS

After analysing the data, we identified three main themes related to school commitment, sport commitment, and a DC. These themes are apparent across all data.

School Commitment

A large proportion of student athletes have a stong commitment to school with high study ambitions. A strong commitment to school means that the students were interested in and goal-orientated with their schooling. We noticed that they thought further studies were important. Ulrika (Lärkby School, swimming) said, “I would say it [school] is very important. At the moment it is my highest priority, I want to invest in school so that I get into a high school and, after it, to a university.” In addition, the student athletes reflected that schooling was important for their future professional careers. According to Jenny (Björkby School, soccer), the school was very important for her future life, “I think it is quite important, I want to a certain high school because I want to study medicine [Faculty of Medicine].” In addition, Emma (Granby School, Principal) pointed out that several student athletes had a strong commitment to school, “They are very determined to attend school because they want to get into Mäkelärinne [a sport upper secondary school].” Subject teachers also noticed that student athletes had a strong commitment to school and high aspirations: “In my opinion, they invest and are academically ambitious. Clearly they are already talking about what high school they are aiming for” (Ida, Enby School, home economics teacher).

The majority of the student athletes were also successful in school, and they had high average grades in academic subjects. Most of them had an average of more than 9.0 on a scale from 4 to 10. Mathilda (Lärkby School, figure skating) said, “I am very satisfied ... 10.0 [average].” According to the school staff, there were differences between student athletes and regular students in school success, while there were no low-performing students in the sports classes. Ida (Enby School, home economics teacher) said, “Probably this class is by far better than the other classes, if we think of all students on average … and the really low achievers are missing from this class.” We also observed high efforts on school tasks: “there was a good working climate in the class and students were interested and asking questions” (field note, Granby School, mathematics).

The school staff recognized differences in the school commitment among student athletes, while some students were high performers in school and some did not invest as much. Ben (Tallby School, Principal) said, “It is individual, and I would still say that most of our students make an effort in school beside their sport involvement.” Ulla (Granby School, swimming) also said, “Now, I have invested even more in sports and less focus on school during this spring, given the summer and the upcoming big competitions.” Conversely, there were some student

athletes with no clear plans for the future. Måns (Enby School, floorball) mentioned, “I might go to high school, a sports high school. I do not know what high school I am applying for.”

Furthermore, the school staff saw gender-specific differences in the school commitment for the student athletes. Girls often invested more in school than boys did, while the boys focused more on sports. Victoria (Björkby School, physical education teacher) pointed out, “The girls are definitely investing more in school, while the boys are investing more [in] sports. Among the boys there are several who take the school with a heel kick.” Classroom observations (field note, Lärkby School, Finnish) showed that presentations from girl students were structured and well prepared, while two boys showed low efforts in their presentations. Similarly, “during the recess before an examination in mathematics, two girl students were reading the mathematics text book, while a group of five boy students were watching a video clip from their phones, although the text book was on the bench” (field note, Enby School, mathematics).

Sport Commitment

There was also a variation in student athletes’ sports commitment, with students showing a strong commitment to sports and students with weaker commitment to sports. A strong commitment to sports indicated student athletes who were greatly determined and interested in sports. Amanda (Enby School, squad gymnastics) mentioned, “Super important ... I have such a dream that I would like to win a World Cup medal.” The school staff also noticed that some student athletes were devoting a lot to sports. Sofia (Lärkby School, Finnish teacher) expressed, “Then, there are those who invest more in sport.” The investment and high ambitions were evident in Lukas’ (Lärkby School, ice hockey) goals, “Well ice hockey professional, that you would someday play as professional and get money for it and live on it. You should do what you like.” Similar high future goals in an individual sport were recognized by Lisa (Granby School, swimming), “I think it is important, I want to be successful in swimming and reach high ... at least I want to participate in international competitions.” This commitment also was noticed in observations from sport practice where “student athletes showed great interest and engagement in the passing drill” (field note, Björkby School, soccer practice) and “they were concentrated and did their best during all parts of the practice session. No disturbing or deviant behaviours occurred” (field note, Granby School, motor skill practice).

Despite student athletes with strong commitment to sports, there were student athletes with weaker commitment to sports. These students were not as ambitious; rather, they participated in sports because it was fun and to be physically active. Roland (Björkby School, football) said,

"I want, as I now have, a good basic fitness level and physical activity, to be out and to be with friends. I don't have any major goals to play in anyone league." Sport could also be a leisure activity and Jenny (Björkby School, football) said, "I have not ever aimed for the national team or so. Rather it has been a hobby ... I have no goals in that way. And I don't want to be a professional [player] as an adult." In this sense, for some student athletes, school was more important. Ulrika (Lärkby School, swimming) said,

It is a second priority, right after school. I always go to the practice sessions; I preferably do not miss any. I do the best I can. I'm not necessarily that competition oriented, and I do not want to reach as far as [someone] else. For example, it is enough for me that I can participate in my own age group national championships, and I don't have to win anything there. For me, I just want to do my own best so I can enjoy the practice, and it is the most important to me.

Although sports may be demanding, student athletes indicated that sports gave them competences for everyday life. Many student athletes felt they learned social competencies and collaboration with others, as Roland (Björkby School, football) noted, "Social skills, you get to know new people more easily." In addition, they had learned time management and daily planning with the help of sports, and Mathilda (Lärkby School, figure skating) mentioned, "It has of course taught me time management, you almost have to have a minute schedule for each day, so that you have time for everything." Several student athletes also had learned not to immediately give up facing challenges, as indicated when Pelle (Enby School, athletics / basketball) said, "Then, when it starts to feel heavy, and you start to fight, then you do not give up, but you continue."

A Dual Career

The student athletes considered it important to have dual careers: to combine sports and school. They noticed that something else, other than sports, was important in life. Therefore, school and studies were important as a backup if the professional sports career was not achieved. Jesper (Tallby School, ice hockey) said, "Probably both are equally important, if you don't become a professional athlete you have to build another career." Also, Lukas (Lärkby School, ice hockey) pointed out, "Although I dream of becoming a professional ice hockey player, it's still good to have a backup plan there, so the school should be well taken care of so you have something after the ice hockey in life too."

Participation in the DC project schools allowed student athletes to train during school hours, which meant the athletes had better opportunities to develop as athletes. Gustav (Björkby

School, football) said, “At least we have much better opportunities for all kinds of things and activities [sport practice] than what other classes have. We have the opportunity to train more.” Practice sessions during the school days were usually morning sessions, which allowed athletes to increase their training loads.

A good point is that you have a lot of physical education and morning sessions, which you might not get from a normal school. Then, bad things, or not, I do not know, but that you can get too much sport. (Marika, Tallby School, motocross)

Although the amount of work can be large by combining sport and school demands, it might not feel heavy for the athlete. This is because athletes enjoy practice and going to the practice sessions, which makes it less stressful.

It can be difficult to combine sport and school, I don’t question that, but it certainly varies a lot from person to person. But for me, it personally has not been demanding. Of course, it is sometimes very difficult and demanding, but usually it hasn’t been that demanding. Maybe it’s because I haven’t had to invest in the school so much anyway, but that may change. Nevertheless, in itself, swimming probably never feels stressful because it is fun. For that, you like it and you like going to practice, and it’s not hard to watch Netflix when you like it. (Ulla, Granby School, swimming)

Even though no student athletes considered the load to be a challenge, the school staff felt that the load could be demanding. This could, according to school staff, lead to an increased burnout risk and/or an early drop out of sports when the combination of sports and school is a burden, not just sports or school. Most stressful was that students were constantly expected to perform, in school and in sports, and the overall load was often high.

In my opinion, the biggest challenge is to cope [the demands]. Our young athletes are under a great pressure, and I think this pressure comes from three different directions: demanding homes, demanding coaches in the sports, and demanding school. Ranking these is difficult, at least for me. I believe that everyone puts the school in the first place, or do they. But a young athlete gets tired because of that too much is too much. (Oskar, Granby School, physical education teacher)

The DC can be demanding for these young student athletes; however, they appreciated the way school was adjusted for their needs. The student athletes felt that the teachers were more flexible with schooling and understood that student athletes were not always able to do all assignments

on time. Måns (Enby School, floorball) mentioned, "If you have long game trips, you can get extra time for homework or similar." Similarly, Ida (Enby School, home economics teacher) felt that the teachers tried to adjust "the amount of homework or the placement of exams, which would make it easier for students' day-to-day living, when they feel that everything is not piling up." The field notes (Enby School, mathematics) also indicated that seven students missed the mathematic examination due to a tournament; however, the teacher explained that they would do it the next day. Finally, practice sessions were included during the regular school day to provide time for sports and school. Lisa (Granby School, swimming) said, "The most positive is that the practice sessions are adapted so that there is time for both school and swimming; that's the most important thing in my opinion."

DISCUSSION

The purpose of this study was to examine student athletes' commitment to education and sports during lower secondary education in Finland. This study's results add new knowledge to the existing literature, as past researchers have focused primarily on DC experiences from upper secondary or university levels. The student athletes at the lower secondary level in Finland indicated that education was important for further studies and for future working careers. At this stage, student athletes may not know how ambitious their sports careers will be and, therefore, are compelled to invest equally in their education. The student athletes in our study were in the first phase of their DC experiences, described by Li and Sum (2017) as becoming an athlete with a DC. During the first phase, student athletes are concerned about security and show backup plans in dealing with the challenges, whilst preparing for their future lives. When the lower secondary student athlete then transfers to upper secondary and university studies, we might see a higher investment in sports, and education can then be neglected (Christensen & Sørensen, 2009; Cosh & Tully, 2014; Stambulova & Wylleman, 2019). Ryba et al. (2016) also noted that Finnish university student athletes showed a high sports identity. If the student athletes notice at any phase of the career that they have reached the highest level and probably will not become a professional or international athlete, they usually start to invest in studies or working life (Cartigny et al., 2019). Furthermore, sports and school can complement each other. These student athletes thought it might be good to have something else to think about, not just school or sports (Aquilina 2013; Defruyt et al., 2020). According to previous research (Baron-Thiene & Alfermann, 2015; Stambulova et al., 2015; Tekavc et al., 2015), it is easier to succeed

with a DC if individuals are allowed to express themselves in several different ways, not only through sports.

Student athletes in this study were successful in school. They performed well in school and had higher averages grades than other students had in the same school. In addition, there were few student athletes who were significant low performers in academic subjects. These results are consistent with those reported by Emrich et al. (2009) and Gaston-Gayles (2004), where student athletes usually had good grades because they had to perform well in school to get into university sports programs. However, our results are from lower secondary student athletes in Finland, while Gaston-Gayle's (2004) results were based on college student athletes in North America, which means we cannot draw a direct link to previous research. However, education is important in Finland, and Finnish students are doing well in international comparisons. Therefore, the strong commitment to school and success may also be because these student athletes want to ensure their acceptances to a specific upper secondary school and from there on to university and working life.

This study also indicated that there were gender-specific differences in education for lower secondary student athletes. Girls were often more determined with school, while boys were more focused on sports. This finding supports previous evidence, which indicates that girls have higher ambitions with education (Kerštajn & Topič, 2017; Ryba et al., 2016 Stephan & Brewer, 2007; Tekavc, et al., 2015). One explanation may be that girls are usually more determined and have clearer plans for the future than boys have. In addition, girls usually mature earlier than boys do, which means that girls usually know what they want with their lives at an earlier stage than boys know (Harrison et al., 2020; Patton et al., 2004). Additionally, a few student athletes indicated that sports were more important than education, and these were all boys from team sports. A possible explanation might be that sports commitment among team sports boys is higher than among girls. Male team athletes usually succeed better financially than individual or female team athletes (Stambulova & Wylleman, 2019; Tekavc et al., 2015). A connection between boys in team sports and a strong commitment to sports might be related to male team athletes having a much higher probability of being able to support themselves through sports than individual or women athletes have. In addition, while men's sports tend to have higher status than women's sports and media visibility is higher for men's sports (Stambulova & Wylleman, 2019), these differences can affect student athletes' commitment and opportunities to pursue professional sports careers.

In addition to these DC experiences, lower secondary student athletes considered that the overall load could be demanding, but the load was not a problem for most student athletes. On the other hand, school staff felt that the overall load was demanding and that this could lead to dropout and/or burnout. Other researchers (Sorkkila et al., 2020; Stambulova et al., 2015; Tekavc et al., 2015) revealed that student athletes making DCs are at risk of suffering athletic burnout or school burnout. However, these studies were based on student athletes from the upper secondary or university level. This means that the situation might be different during the beginning phase of a DC (Li & Sum, 2017), particularly when both Harrison et al. (2020) and Cartigny at al. (2019) reported that a DC became increasingly difficult to manage when the levels of education increased. Thus, a DC might be challenging, but their situation was clearly supported by individuals (teachers and coaches) who were willing to sustain both of their pursuits. In addition, the provided structure with practice sessions during the school day, a flexible schedule, and adjusted time arrangement for school tasks and examinations also helped the student athlete in combining sports and education (Harrison et al., 2020; O'Neill et al., 2013).

Noticeably, the demands student athletes encounter are challenging and require effort, time, and support to meet (Ryba et al., 2016). They have to prioritize and adjust their focus to balance sports and education to find an optimal solution (Stambulova & Wylleman, 2019). Student athletes in this study were in the beginning of a developmental DC process with not only a single event but also several educational and sport transitions at different stages during their lifetimes, which highlighted the importance of adopting a lifespan perspective when considering DC student athletes (Debois et al., 2015; Tekavc et al., 2015). As the diversity of these student athletes indicated, distinguishing between the different DC decisions that each one makes at different levels is important. Therefore, we need to recognise DC student athletes as a heterogeneous group with individual pathways (Li & Sum, 2017), where an individual student athlete could be placed anywhere from high to low commitment. Student athletes in this study showed similar pathways, as reported by Cartany et al. (2019): a DC pathway, a sporting pathway, and an educational pathway. Thus, this study was able to extend the DC findings from older student athletes to lower secondary students. Finally, these student athletes constructed their careers at a young age, and because fluctuation in focus, prioritization, and coping mechanisms will change during their coming years (Guidotti et al., 2015), estimating their future DC pathways is impossible.

Limitations and strengths

A limitation of this study is the generalisability, because the results are based on a small sample and only on the DC experiences in Finland. Studies in a different context may yield different findings. A second limitation is that this study did not emphasize the type of sports that the schools offered and in which the student athletes participated. To obtain an understanding of the developmental processes of the DC, future studies should include a longitudinal approach, with qualitative and quantitative measures, while focusing on the challenges and the well-being of student athletes. A notable strength of this study is that we included school staff and observations in capturing the processes of DCs for young student athletes, thus providing a basis for future research to assess the progression and success of a DC. Regardless of the limitations, this study substantiates previous findings in the literature that understand student athletes during DCs as a heterogeneous group with individual pathways and processes. Finally, this study presents novel and interesting findings, which provide a detailed insight into Finnish lower secondary student athletes' DCs and the experiences encountered in their schools. Importantly, this knowledge needs to inform the government and the sporting movement to outline, develop, and implement a DC program in close cooperation with local lower secondary schools.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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EXTERNAL FOCUS OF ATTENTION ENHANCES PRECISION IN RECREATIONAL ARCHERS

ZUNANJI FOKUS POZORNOSTI IZBOLJŠUJE NATANČNOST PRI REKREACIJSKEM LOKOSTRELSTVU

ABSTRACT

The studies confirm that instructions and feedback that induce external focus of attention (oriented on movement outcome) result with greater efficiency in motor performance and learning regarding internal focus of attention (oriented on bodily dimensions). Advantages and differences between external and internal focus of attention have been proved also in different levels of sport and recreational expertise. In this study, 10 recreational archers were tested in three different conditions: C1 - freely oriented focus of attention, C2 – internally oriented focus of attention, and C3 – externally oriented focus of attention. The subjects first undertook the C1 condition, and afterwards the next two conditions were randomly decided. According to the hypothesis, the main goal was to investigate the effect of external and internal focus of attention on precision of the shots. According to the results, in externally focused condition, recreational archers had better results than in other conditions with higher number of 9 points and lesser number of misses. Based on findings from this paper, adopting an external focus of attention should be beneficial for the shot precision, self-fulfillment and feelings of accomplishment in recreational archers.

Keywords: archery, constrained action hypothesis, shot accuracy

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IZVLEČEK

Raziskave potrjujejo, da imajo navodila in povratne informacije, ki sprožajo zunanji fokus pozornosti (usmerjen na rezultat gibanja), za posledico večjo učinkovitost motorične izvedbe in učenja v primerjavi z notranjim fokusom pozornosti (usmerjen na telesne mere). Prednosti in razlike med zunanjim in notranjim fokusom pozornosti so dokazane na različnih nivojih športne in rekreacijske sposobnosti. V tej raziskavi je bilo testiranih 10 rekreativnih lokostrelcev v treh različnih pogojih: C1 – prosto usmerjen fokus pozornosti, C2 – notranje usmerjen fokus pozornosti in C3 – zunanje usmerjen fokus pozornosti. Osebe so bile najprej testirane v C1 pogoju ciljanja, potem pa je bil vrstni red pogojev naključno izbran. Glavni cilj hipoteze je bil raziskati učinke zunanjega in notranjega fokusa pozornosti na natančnost zadetka. Rezultati so pokazali, da so imeli rekreativni lokostrelci ob zunanje usmerjenem fokusu pozornosti boljše rezultate kot v ostalih pogojih, večje število 9-ic in manj zgrešenih strelov.

Ključne besede: lokostrelstvo, hipoteza omejene aktivnosti, natančnost zadetka

INTRODUCTION

The kinesiological analysis of archery identifies a monostructural acyclic activity in which dominates relatively statical lower body posture and discrete active coordination of shoulder girdle and arms, divided into several phases or elements of technique (Mann and Littke, 1989; Vrbik, A., Bene and Vrbik, I., 2015). The elite performance of archery technique is characterized by the ability to repeatedly hit the same spot in the space (center of the target) in specific time with high accuracy and precision. In order to do so, an archer has to perfectly perform elements of technique by precise repetition of all kinematic parameters of chosen i.e. key body coordinates with the consequence of accurate and desired positioning of the arrows in the target. The key factors of success in archery imply general motor abilities such as strength, endurance, balance and flexibility (Acikada, Ertan and Tinazci, 2004), but also specific motor abilities characteristic for archery itself (intermuscular coordination, rhythm, timing and precision). Different psychological factors also play an important role, such as concentration, relaxation and different types of attention (Zeplin, Galli, Visek, Durham and Staples, 2014), accompanied by visual focus (Acikada et al., 2004; Lee, 2009). As in all master performances, weather it is about playing a piano or hitting a target, a mindful repetition is a prerequisite of skill acquisition and later excellence. Unfortunately, sometimes it means spending hours and hours of long practice trying to brush the specific element or movement to perfection. In the field of sport it is considered to be quite an usual request, but in the field of sport recreation rules are a bit different (Andrijašević, 2010). As a professional kinesiologist in sports recreation one faces relatively smaller exercise time on hand, but very soon high performance outcome wishes from the clients. In recreational archery very often anecdotal stories evidence statements from the people who “want to shoot just a little and see how it goes” to “I am not satisfied with today’s shooting because I cannot hit what I want” in only a few weeks of practice. Why is this so? Since archery is a static sport, in recreational users a general fitness is not highly important for successful beginning of the activity. As they progress in training and practice, they also progress in performance, but since archery is an activity which requires a lot of accurate body posture repetition, a certain discrepancy from the expected progress occurs. In this paper the intention was to address this problem and see if through different focus of attention during shooting execution, some changes in precision in recreational archers can occur. Different effects of external versus internal focus of attention have been explained with the constrained action hypothesis (Wulf, McNevin and Shea, 2001), which states that an internal focus on the body parts causes individuals to control their movements at a more

conscious level, while a focus on the movement effect promotes a more automatic mode of control. Consequently, individuals tend to constrain their motor system by interfering with automatic control mechanisms that have the capacity to control movements effectively and efficiently. During years of research, focus of attention was observed from different aspects and was characterized as associative (focused on body senses) or dissociative (blocking of senses created by physical labor), wide or narrow, and by direction (internal or external). Many researches in sport tried to investigate different focus of attention: in golf, basketball, baseball, tennis, darts, swimming, high jump, volleyball and in football (An, Wulf and Kim, 2013; Lohse, Jones, Healy and Sherwood, 2013). Advantages and differences of different focus of attention were proven in different levels of sports expertise (Wulf and Su, 2007; Memmert, 2009; Vickers, 2010; Neumann and Thomas, 2011; An et al., 2013), and also in retention and transfer (Carpenter, Lohse, Healy, Bourne and Clegg, 2013). The main purpose of this paper was to investigate if different focus of attention has any impact on precision in recreational archers during archery practice sessions.

METHODS

Participants

The subject sample was consisted of 10 recreational male archers, with average age 29.8 years, all without any attention disorders in their anamnesis. Subjects were training 2 times per week on average, and had no more than one year of shooting experience. All subjects gave their written consent for participation, and this particular survey was approved by Science and Ethical Commission on Faculty of Kinesiology in Zagreb.

Protocol

The sample of variables came out from observed characteristics of entities in different shooting conditions. Therefore, in order to estimate shooting precision, a measure of arrow distance from the center of the target face was used, shown as a number of points in a standard way of scoring. The experiment was made in standard conditions of indoor field set-up, target placed at 18m distance, and target face standard triple ϕ40mm, with center target face positioned at 1,30m. One target face consisted of 5 concentrically placed circles valued 10 to 6 from approved standard equipment. The experiment was divided in three separate measures for each subject. Every measurement consisted of warm up (3 ends x 3 arrows) and testing (10 ends x 3 arrows).

Estimated time of warm up and testing by subject was about 45 minutes. The testing consisted of three different shooting conditions: C1- free focus of attention, C2 – internal focus of attention and C3 – external focus of attention. All subjects were first measured in C1 condition and then in C2 or C3 by a random choice. According to World Archery rules and regulations, the allowed time for one end, consisted of three arrows, is 120 seconds. Every archer set his own rhythm and tempo in each end. Between ends, the estimated time for rest was that needed for the arrows to be picked up from target and results scored (approx. 90 sec.). In all three conditions, subjects were told to try to be as much precise as they can. In C1 condition subjects got no special instructions. In other two conditions, subjects were directed via verbal instructions on different aspects of shooting: C2 – coordinated arms movement and release (movement of the body parts – internal focus), and C3 – on center of the target (bull's eye) and arrow flight (movement effects – external focus of attention). Concretely, in C2, before every end (10 ends in sum), an archer received a following instruction: "Focus on movement of your arms and shoulders and smooth release. If you are restless and experience tremor in bull's eye try to fix it in a way to concentrate on better push – pull action and patiently waiting for a smooth surprising release. Try to be as precise as you can." In C3, archers received following instruction: "Focus on bull's eye and arrow flight. If you are restless and experience tremor in bull's eye try to fix it in a way to concentrate on your sight's pin and letting it melt with the center and on the follow-through and arrow flight. Try to be as precise as you can." (Lohse, Sherwood and Healy, 2010; Lohse et al. 2013). The praxis in social experiments often imply a manipulation check, which is an additional check consisted of qualitative data and provides a researcher certain proof that measured variables truly reflect observed characteristics (Peh, Chow and Davids, 2011; Abdollahipour, Psotta, Nieto, Rouzbahani, Nikdast and Bahram, 2014). In case of this experiment, after every end in C2 and C3 conditions, the subjects were asked if they complied to the condition instructions in order to interpret obtained data with maximum certainty. The subjects were clearly informed that their honest feedback is very important for the experiment, and were encouraged in sense of giving as straight answer as possible.

Statistical analysis

Central and dispersive parameters were calculated for all variables. Since there was a deviation from normal distribution, as a non-parametric alternative to one factor ANOVA for repeated measures, Friedman's test was used, along with Wilcoxon's test of ranks.

RESULTS

In every shooting condition recreational archers shot 300 arrows, i.e. 900 arrows in sum (3 conditions x 300 arrows). In control condition C1, from possible 3000 points, archers shot 1826, from which 38 6s', 53 7s', 59 8s', 55 9's and 26 10s'. 69 times archers missed the target (mod value). The average shot was 6.09±3.51SD. In internal shooting condition C2, archers shot 1798 points from which 27 6s', 46 7s', 67 8s', 52 9's and 31 10s'. 77 times archers missed the target (mod value). The average shot was 5.99±3.68SD. In external shooting condition C3, archers shot 1969 points from which 35 6s', 48 7s', 61 8s', 75 9's and 26 10s'. 55 times archers missed the target. The average shot was 6.56±3.31SD.

Table 1. Descriptive parameters and the results of the Friedman's ANOVA and Wilcoxon's test of ranks.

S.C.	N	POINTS	Mean and S.D.	NO.OF 10's	F.A.	W.T.
C1	300	1826	6.09 ± 3.51	26		C1:C2
						p = 0.920
C2	300	1798	5.99 ± 3.68	31	p = 0.038*	C1:C3
						p =0.023*
C3	300	1969	6.56 ± 3.31	26		C2:C3
						p =0.012*

SC – shooting condition, N – number of arrows per condition, POINTS – sum of points shot, Mean – mean of the points scored, S.D. – standard deviation of the points scored, No. of 10's – number of 10 points scored, F.A. – Friedman's Anova, W.T. – Wilcoxon test of rank, * - statistically significant difference.

Table 1. shows that the best results were obtained in C3 condition of shooting (external focus of attention), and the worst results in C2 (internal focus of attention). Friedman's Anova showed significant difference between different shooting conditions. Wilcoxon test of rank showed that significant differences were found between C1 and C3, and C2 and C3 shooting condition. In C3 shooting condition archers had the lowest number of misses (0 points), 22 less than in C2 shooting condition, and notably larger number of 9s' (C1:C2:C3 – 55, 52, 77), indicating better arrow grouping and better shot precision.

DISCUSSION

Precision is defined as a qualitative motor ability which allows one to hit a certain dinamic or static target at a given distance by throwing or aiming (Milanović, 1997). In archery, precise shot is a result of a meticulously accurate movement performance related with specific coordination based on kinesthetic information from the memory and receptors and perfect balance and harmony with the visual target (Milanović, 1997; Čižmek, 2007; Čižmek and Peršun, 2011; Vrbik et al., 2015). Archery is a precision sport, meaning that it is an absolute imperative to hit a center of the target as frequent and as accurate as possible (Podržaj, 1998; Frangilli V. and Frangilli M., 2005). In this experiment, external focus of attention contributed to better results and higher precision in compare to internal focus of attention or non-guided condition (no instruction on focus localization). In many studies which dealt with different focus of attention and its impact on precision, similar results were obtained. Wulf, Lauterbach and Toole (1999) observed two groups with two different intervention focus (external and internal) in golf. Better precision was noticed in both groups along the experiment duration, but significantly better, i.e. precise results had the external focus group. Better precision in external focus of attention over internal focus of attention was also noted in volleyball players during tennis serve (Wulf, McConnel, Gaertner and Schwartz, 2002). Similarly, Zachry, Wulf, Mercer and Bezodis (2005) tested precision in basketball players during free throw. The external focus group had better precision and more accomplished free throws then internal focus group. Although recreational archers have respectively smaller number of hours of practice and absolutely different initial drive to train in compare with expert archers, the nature of archery as a sport always makes one tend to be perfectly precise. Unlike expert archers who accomplish automated movement with more ease due to the significantly higher time engaged in the activity, along with the more perfected planning and programming of the training process, recreational archers due to their occasional participation in the activity tend to spend a lot of time thinking and analyzing their technical performance in order to be able to shoot and be satisfied with the shot. Therefore, thinking of bodily parts during shot execution and overtaking internal focus of attention is very common among recreational archers. Additionally, no significant differences in precision between control condition and internal focus condition were found. Something similar was observed in the experiment of Wulf and Su (2007), who noticed that although one would expect individuals to adopt the optimal focus of attention in a non-guided condition (control), studies have shown that when participants do not receive attentional focus instruction, their performance is typically similar to that seen under internal focus

condition and less effective than under external focus condition. This suggests that individuals tend to use lower than necessary level of control as they incline to be relatively cautious when confronted with a complex task.

Limitations and strengths

It is important to mention that this paper also has certain limitations. Higher number of subjects would definitely give more reliable results on the matter. Unfortunately, archery is a relatively small sport, and recreational subjects were not easy to find and measure. For future studies it would be interesting to find out at what point exactly after acquiring archery technique starts a beneficial time of overtaking external focus of attention in recreational archers, and the exact pace of distancing the focus of attention.

CONCLUSION

Wulf and Prinz (2001) referred to Bliss (1892-1893) and Boulder (1935) who investigated researches from the end of the 19th century which engaged in studying distracting nature of excessive attention of a well-rehearsed activity. In many cases it was confirmed that specifically oriented focus of attention can have an impact on individual's motor performance and learning (Wulf and Prinz, 2001; Wulf, 2013). This paper investigated the influence of different focus of attention in recreational archers, and its impact on shot precision. Recreational archers demonstrated better shot precision when adopting external focus of attention, which is coherent with previous research of focus of attention. These findings are important from the recreational point of view, especially for the practitioners who plan and program recreational activities. The whole meaning behind the external focus of attention lies in redirecting one's attention to as distal possible point in order to allow body dimensions to self-tune in an optimal manner with the highest possible outcome. This is also connected with the quiet eye period (Vickers, 2010), and both terms are associated with anecdotal evidence of the zone or the flow. Why is this important? The main purpose of recreational archery programs is to allow its consumers safe environment in which they can relax, adopt a calm breathing manner, stretch and strengthen their muscles in fluent and low impact mode and enjoy the true essence of archery, and that is to hit the targeted area with ease, provoking only good emotions and well-being. In order to do so, professional practitioners are frequently put in a position of balancing between insisting and "drilling" on movement technique and outcome result recognized in points shot, losing the core essence of recreation. Therefore, based on findings from this paper we would suggest adopting

internal focus of attention for the period of acquisition of the motor skills in early stages of motor learning, but afterwards, adopting an external focus of attention should be beneficial for the shot precision, self-fulfillment and feelings of accomplishment in recreational archers.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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Yasemin Arı

EFFECTS OF DIFFERENT STRETCHING METHODS ON SPEED, JUMP, FLEXIBILITY AND UPPER EXTREMITY PERFORMANCE IN WRESTLERS

UČINKI RAZLIČNIH RAZTEGOVALNIH METOD NA HITROST, SKOK, GIBLJIVOST IN UČINKOVITOST ZGORNJIH OKONČIN PRI ROKOBORCIH

ABSTRACT

The aim of this study is to investigate the acute effects of different stretching methods on acceleration, vertical jump (CMJ), flexibility and upper extremity performance of young wrestlers. 8 young female wrestlers (15.37 ± 1.06 years; 162.46 ± 4.12 cm and 57.47 ± 6.41 kg) participated in the study voluntarily. Stretching methods were divided into five groups: control (no stretching), static, dynamic, static + dynamic and dynamic + static. The findings showed faster speed performance after control ($p = .012$; $\eta2 = 0.57$), dynamic stretching ($p = .050$; $\eta2 = 1.11$) and static + dynamic combined stretching ($p = .043$; $\eta2 = 0.96$) compared to static stretching; and there is a statistically significant positive difference according to the test averages after dynamic stretching ($p = .050$; $\eta2 = 0.91$) compared to dynamic + static combined stretching ($p<0.05$). Vertical jump performance, according to the control warming up, a statistically significant difference has been found according to the test averages after dynamic stretching ($p = 041$; $\eta2 = 1.17$) and static + dynamic combined stretching ($p = .043$; $\eta2 = 1.07$). No difference was found in flexibility and medicine ball throwing performances according to different stretching protocols ($p>0.05$). It was determined that the acute effect of static stretching had a negative effect on acceleration performances and dynamic stretching caused an increase in jump performance. This study suggests that dynamic and static + dynamic stretching can be used in young wrestlers to provide better performance in acceleration and jumping skills during warm-up sessions.

Keywords: wrestling, speed, vertical jump, throwing medicine ball, stretching exercises

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IZVLEČEK

Cilj pričujoče študije je bil raziskati akutne učinke različnih metod raztezanja na pospešek, navpičen skok (CMJ), prilagodljivost in zmogljivost zgornjih okončin mladih rokobork. V študijo smo vključili 8 mladih rokobork (15,37 ± 1,06 let; 162,46 ± 4,12 cm in 57,47 ± 6,41 kg), ki je v študiji sodelovalo prostovoljno. Metode raztezanja so bile razdeljene v pet skupin: nadzor (brez raztezanja), statično raztezanje, dinamično raztezanje, statično + dinamično raztezanje in dinamično + statično raztezanje. Rezultati so pokazali hitrejše hitrostne lastnosti po metodi nadzora ($p = .012$; $\eta2 = 0.57$), dinamičnega raztezanja ($p = .050$; $\eta2 = 1.11$) in kombiniranega statičnega + dinamičnega raztezanje ($p = .043$; $\eta2 = 0.96$) v primerjavi s statičnim raztezanjem. Ugotovili smo, da obstaja statistično značilna pozitivna razlika glede na testna povprečja po dinamičnem raztezanju ($p = .050$; $\eta2 =0,91$) v primerjavi z dinamičnim + statičnim kombiniranim raztezanjem ($p <0,05$). Ugotovili smo značilne razlika med kontrolnim in testnim navpičnim skokom po dinamičnem raztezanju ($p = 041$; $\eta2 = 1,17$) in statičnim + dinamičnim kombiniranim raztezanju ($p = .043$; $\eta2 = 1,07$). Značilna razlika je bila ugotovljena tudi v prilagodljivosti in uspešnosti metanja medicinske žoge glede na različno raztezanje protokolov ($p> 0,05$), kjer smo ugotovili, da akutni učinek statičnega raztezanja negativno vpliva na pospeševanje izvedbe testa ter dinamično raztezanje značilno poveča uspešnost skoka. Študija nakazuje, da lahko kombinirano statično + dinamično raztezanje uporabimo pri mladih rokoborcih, da bi s tem zagotovili boljše rezultate med ogrevalnimi sejami.

Ključne besede: rokoborba, hitrost, vertikalni skok, metanje medicinske žoge, raztezne vaje

INTRODUCTION

Wrestling is one of the popular sports played at the Olympics (Arakawa et al., 2020). Wrestling is a sports discipline that places great demands on physical preparation for athletes with a total of 6 minutes (2 halves of 2 x 3 minutes) match time (Sterkowicz-Przybycień et al., 2011). In wrestling, strength, speed, technique and flexibility skills are required to pull, push, throw and lift the opponent, stop his/her attacks or establish superiority over the opponent (Polat et al., 2018). Therefore, the players must have high physiological and psychological characteristics in wrestling-specific performances such as aerobic-anaerobic performance, speed, flexibility, and strength of the upper-lower extremities (Mirzaei et al., 2009) in order to achieve the desired result in wrestling competitions (Baić et al., 2006; Ziyagil & Türkmen, 2017). Maximum effort is vital for success in the wrestling game as in many sports branches. For this reason, appropriate warm-up exercises are performed to prevent high-level performance and athletic injuries before sportive loads (Gelen et al., 2012).

Stretching exercises, which are used as part of warming up before physical effort are used to lengthen connective tissues and improve range of motion (ROM) (flexibility) around a joint (Amiri-Khorasani et al., 2010). Athletes use different warming methods such as static stretching, dynamic stretching, combined (static + dynamic or dynamic + static) stretching and proprioceptive neuromuscular facilitation (PNF) before physical activity (Polat et al., 2018; McMillian et al., 2006; Kilit et al., 2019; Amiri-Khorasani et al., 2016; Aydın et al., 2019). The target muscles or muscle groups are slowly extended to the stretch point and this position is held for a certain time during the static stretching exercise, which is one of the stretching exercise protocols (Costa et al., 2009). Static stretching performed at different periods before exercise and athletic performance is widely used in team and individual sports to increase the muscle performance of elite and amateur level athletes (Kilit et al., 2019). While in some studies, it has been reported that static stretching does not have a negative effect on performance (Behm & Chaouchi, 2011; Little & Williams, 2006; Samson et al., 2012), many studies have shown that static stretching method has caused a decrease in isometric (McHugh & Nesse, 2008) and isokinetic power output (Sekir et al., 2010) and it has also affected muscle performances such as sprint time (Amiri-Khorasani et al., 2016), jump height (Paradisis et al., 2014) and strength (Herda et al., 2008) adversely. Therefore, it was stated that dynamic stretching should be used instead of static stretching because of the performance decrease caused by static stretching (Amiri-Khorasani et al., 2016).

Dynamic exercises form the basis of sportive movements used in training or competitions. These exercises are based on plyometric movements for the lower and upper extremities, loaded resistance exercises or maximum voluntary contractions (Gelen et al., 2012). Faigenbaum et al. (2006) suggested that voluntary contractions from a low level to high intensity, such as dynamic warming, before performing an athletic activity will increase power generation and performance by activating nerve-muscle function. In some studies, it has been reported that dynamic stretching affects speed, agility (Amiri-Khorasani et al., 2016), vertical jump (Carvalho et al., 2012), medicine ball throwing (Herman & Smith, 2008) and other performances (McMillian et al., 2006) positively. It is recommended for the players to perform the static and dynamic stretching together for a better fit although the studies present the positive effects of dynamic stretching (Amiri-Khorasani et al., 2016). Additionally, it is observed that there are different outcomes when the effects of combined stretches on the performance of athletes are examined in different studies. (Amiri-Khorasani et al., 2010; Chaouachi et al., 2010; Amiri-Khorasani et al., 2016; Kilit et al., 2019).

Although there are few studies evaluating the acute effects of static and dynamic stretch on speed (Kilit et al., 2019), vertical jump (Carvalho et al., 2012), flexibility (Polat et al., 2018), and upper extremity performances (McMillian et al., 2006), to our knowledge, no research has been conducted on the acute effects of five different stretching exercise protocols (no stretching, SS, DS, CSD, CDS) on the speed, jump, flexibility and upper extremity performance of wrestling players. Based on some studies that reported a decrease in some performances after static stretching (Amiri-Khorasani et al., 2010; Amiri-Khorasani et al., 2016), it is assumed that there will be an acute decrease in performance responses and performing dynamic and combined stretching will increase the performance of athletes by performing static stretching exercises afterwards. Therefore, the purpose of this study is to compare the acute effects of different stretching methods on speed, jump, flexibility and upper extremity performances and to determine which of these stretching methods are more effective on the performance of young wrestlers.

METHODS

Participants

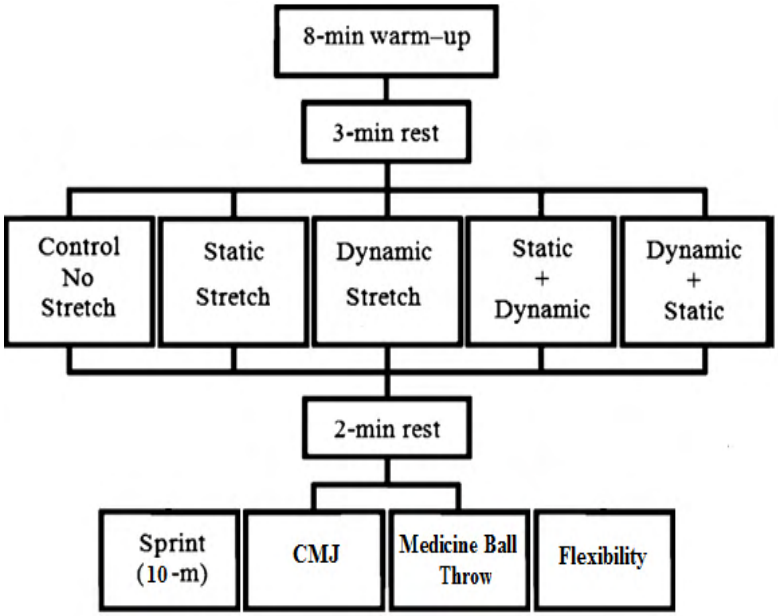
Eight women wrestlers (body height: 162.46 ± 4.12 cm; body mass: 57.47 ± 6.41 kg; age: 15.37 ± 1.06 years; BMI: 21.88 ± 2.66; body fat percentage: 21.42 ± 5.14; training experience: 4.62 ± 1.18 years) have participated voluntarily in this study. Data were collected during the pre-competitive season without any matches. The players have not been involved in any training or competition during the study. According to the inclusion criteria of the study, there should be no musculoskeletal injuries at least 6 months before the study, active participation in the trainings between 4 and 6 days a week and attendance in regular endurance, strength, sprint and wrestling special trainings for at least 2 years as training experience is required. All players and parents were briefed on the research procedures, requirements, benefits and risks before giving a written informed consent form before the test. The study was approved by the local university ethics committee (70400699 / 11.00-190066441).

Procedure

Anthropometric variables of each participant, including height (cm) and body weight (kg), were measured. Portable stadiometer (mesilife) was used for height measurement of wrestlers and electronic weighing machine (Tanita BC545N) was used for body weight measurement. The players were bare feet and wore shorts and T-shirts during measurement.

The current research protocol is adapted from studies conducted by Amiri-Khorasani et al (2016). All wrestlers participated in five stretching methods: control (no stretching), static stretching (SS), dynamic stretching (DS), static + dynamic (CSD), dynamic + static (CDS). The order of the performance tests for the players was randomly chosen with 48 hours of rest. The protocols are followed by each athlete's heart rate monitor (M400, Polar Electro Inc., Kempele, Finland), 8 minutes of general warm-up at a heart rate of 140 beats per minute, 3 minutes of rest, 30 seconds of stretching program for each muscle group (excluding stretch group), 2 minutes of rest followed by it consists of acceleration, vertical jump, flexibility and medicine ball throwing tests. Both static and dynamic stretching protocols have been adapted from the study of Herman & Smith (2008). The experimental procedure has been summarized in Figure 1. All measurements have been taken at the same time of the day (17.30-19.30) in the indoor sports hall.

Figure 1. Experimental design



10 m speed: The athletes were positioned 0.5 m from the starting point and started the tests when they felt ready. Time was recorded using the Microgate Witty photocell device. The timer was automatically activated when experimental subjects passed through the first gate, and their time was recorded at 10 m after passing the end gate (Gorostiaga et al., 2004).

Countermovement jump (CMJ): Participants were positioned within a specified area. A camera was placed right across the area to see the participant and the participant was asked to make an active jump, hands free. Jump was considered invalid when the knees were bent, the legs flexed at the hip, and was landed on or out of the marked field lines. The athletes made 3 jumps after sufficient rest and the best jump was recorded. The images were then transferred to the computer environment via SD card. The flight time of the participants was calculated using the Kinovea 0.8.15 program by looking at the transferred images. The jump heights of the participants whose flight times were determined were calculated by the formula (Markovic et al., 2004).

$$h = t_f^2 \cdot g^{-1} \cdot 8^{-1} \text{ (m)}$$

h = height g = 9.81m·s-^{2}t = flight time

Throwing medicine ball: The maximum distance that the participant could throw the medicine ball from the head to the back was recorded in centimeters. The ball was held while the heels were located on the measuring line and the elbows in a straight position. Legs and the body were in flexion position then, medicine ball was thrown backwards with full force with

extension movements. While hip, legs and the body performs the extension movements during shooting, flexion movement occurs in the shoulder part. The distance between the point where the medicine ball fell on the ground and the heel of the foot was calculated in meters (Stockbrugger & Haennel, 2001).

Sit and reach test: A standard sit and reach box was placed on the floor. A centimeter scale was placed on the top surface of the box. The athletes were seated on the ground with legs fully extended and placed the soles of their feet flat towards the end of the flex board. Participants stretched the measuring scale as far forward as possible with their arms, palms facing down, without bending their knees and they waited for 3 seconds where their fingers reached the farthest point (López-Miñarro & Rodríguez-García, 2010).

Warm-up and stretching protocols: Participants performed general warm-up by running at low to medium intensity to prepare for performance. All players were instructed to stretch for 30 seconds for each of the upper-lower extremity muscle groups during both static (overhead arm pull, rear lunge and reach, hamstring stretch, quadriceps stretch, posterior hip stretch, trunk flexion / extension stretch) and dynamic stretching (bend and reach, rear lunge and reach, power jump, prone row, windmill, diagonal lunge and reach). There was no resting period between the different stretching exercises. All stretching exercises were carried out by both legs with the help of an instructor. Dynamic stretching was performed slowly and continuously during the exercises. The number of combined stretching exercise (CSD or CDS) sets was reduced from 2 sets to 1 set for each muscle group of both legs in order to equalize the total stretching time. In the control group, the players rested after an 8-minute warm-up session.

Statistical analysis

All statistical analyzes were made using SPSS 18.0 version software. It was determined that all data did not indicate normal distribution. The effect of different stretching methods on speed, jump, flexibility and medicine ball throw was determined using Friedman analysis. The Wilcoxon Signed Rank Test was used to find the difference between the groups. Effect dimensions (Cohen's d) were calculated for the significance of the comparisons. Thresholds for effect size statistics are as follows: <0.20 = trivial, 0.20-0.59 small, 0.6-1.19 = moderate, 1.2-1.99 = large, ≥ 2.0 very large (Hopkins et al., 2009). Statistical significance level was set at $p<0.05$.

RESULTS

The average, minimum, maximum and quarterly values of the speed, vertical jump, flexibility and medicine ball throwing performances of different stretching methods of the athletes participating in the study have been given in Table 1. In view of the comparison of different stretching methods, while statistical difference has been determined in speed and vertical jump performance values ($p<0.05$), no statistically significant difference has been found in flexibility and medicine ball throwing performance values ($p>0.05$), (Table 1).

Table1. Friedman test results of acceleration, vertical jump, flexibility and medicine ball throw performance values of different stretching methods

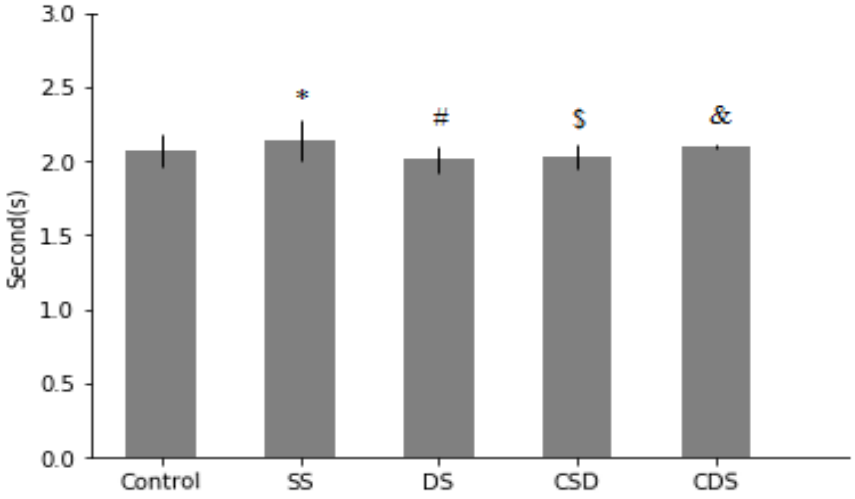
Performance Tests	Stretch Protocol	X±SS	Min.	Maks.	Percentiles			Chi-Square	p
					25th	50th (Median)	75th		
Acceleration	Control (No Stretch)	2.07±.11	1.89	2.28	2.00	2.06	2.14	12.51	.014*
	Static Stretching	2.14±.14	1.92	2.40	2.08	2.11	2.23		
	Dynamic Stretching	2.01±.09	1.84	2.12	1.93	2.04	2.08		
	Static+ Dynamic	2.03±.08	1.92	2.16	1.96	2.01	2.13		
	Dynamic+ Static	2.10±.01	2.00	2.29	2.00	2.07	2.19		
CMJ	Control (No Stretch)	25.13±.02	23.00	31.00	23.00	24.50	26.00	10.63	.031*
	Static Stretching	26.88±.03	23.00	34.00	23.75	26.00	29.75		
	Dynamic Stretching	28.13±.03	23.00	31.00	26.00	28.50	31.00		
	Static+ Dynamic	27.88±.03	23.00	34.00	26.00	26.00	31.00		
	Dynamic+ Static	26.25±.03	23.00	34.00	23.75	26.00	26.00		
Medicine ball throw	Control (No Stretch)	7.18±.91	5.78	8.98	6.65	7.19	7.53	9.30	.054
	Static Stretching	6.66±.84	5.48	7.85	5.80	6.80	7.35		
	Dynamic Stretching	6.46±.61	5.39	7.23	6.03	6.46	7.05		
	Static+ Dynamic	7.01±.95	5.61	8.54	6.21	6.89	7.77		
	Dynamic+ Static	7.01±.89	5.77	8.94	6.54	7.00	7.09		
Flexibility	Control (No Stretch)	32.11±6.89	23.00	40.90	24.97	32.90	38.32	9.34	.053
	Static Stretching	31.57±7.39	19.80	40.30	25.05	31.85	39.05		
	Dynamic Stretching	30.63±6.49	20.40	39.60	25.00	31.45	36.05		

Static+ Dynamic	32.53±6.89	23.30	40.90	25.07	33.40	39.15
Dynamic+ Static	30.88±6.92	21.80	39.50	23.37	32.50	37.22

*p<0.05

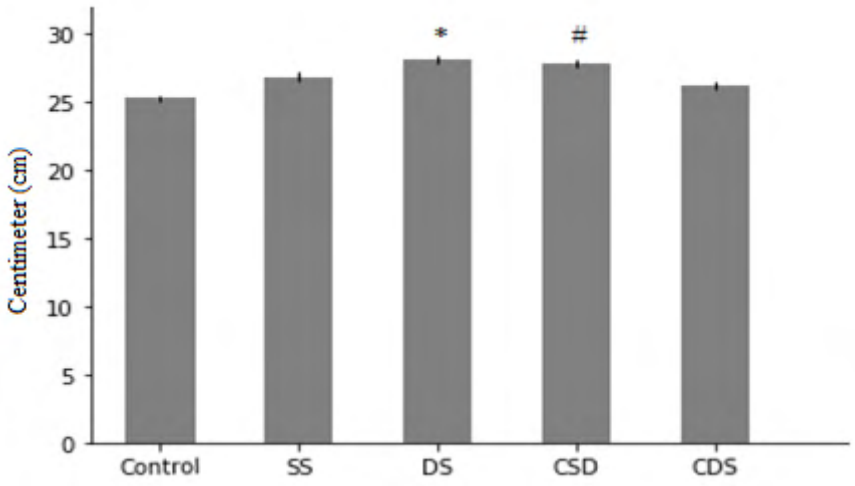
Considering the findings of the speed performance of different stretching methods in wrestlers, it has been determined that there is a faster speed performance after control (p = .012; η2 = 0.57, ‘‘small’’), dynamic stretching (p = .050; η2 = 1.11, ‘‘moderate’’) and static + dynamic combined stretching (p = .043; η2 = 0.96, ‘‘moderate’’) compared to static stretching; and there is a statistically significant difference according to the test averages after dynamic stretching (p = .050; η2 = 0.91, ‘‘moderate’’) compared to dynamic + static combined stretching (Figure 2), (p<0.05).

Figure 2. Wilcoxon Signed-Ranks Test results of the acceleration performance of different stretching methods. *No stretching - Static stretching; #Static stretching - Dynamic stretching; $Static stretching - CSD stretching; &Dynamic stretching - CDS stretching.



Considering the CMJ performance findings of different stretching methods, according to the control warming up, a statistically significant difference has been found according to the test averages after dynamic stretching (p = 041; η2 = 1.17, ‘‘moderate’’) and static + dynamic combined stretching (p = .043; η2 = 1.07, ‘‘moderate’’), (Figure 3), (p<0.05).

Figure 3. Wilcoxon Signed-Ranks Test Results of CMJ performances of different stretching methods. *No stretching - Dynamic stretching; #No stretching - CSD stretching.



DISCUSSION

As far as we know, the acute effect of the stretching method applied in this study on the performances of different sports players has been examined (Amiri-Khorasani et al., 2016; Aydın et al., 2019; Kilit et al., 2019), but this is the first study to examine the acute effects on the acceleration, flexibility, lower and upper extremity performances. Therefore, the aim of the study is to examine the acute effects of different stretching methods on acceleration, jumping, flexibility and upper extremity performances. It was determined in the research findings that the acute effect of static stretching had a negative effect on speed performance and dynamic stretching caused an increase in jump performance. On the other hand, there was no significant difference in performance between other protocols.

Wrestling is a sport with many performance dynamics. It is important to apply these dynamics at the maximum level and to be successful in training and competitions (Polat et al., 2008). Many studies have investigated the acute effect of dynamic or combined stretching, which are the recommended stretching methods to increase athletic performance responses (Little and Williams, 2006; Faigenbaum et al., 2006; Turki et al., 2012; Amiri-Khorasani et al., 2016; Kilit et al., 2019). In addition to these studies, in the study on wrestlers is consistent with most studies reporting that dynamic or combined stretching improves performance during sprint time (Turki et al., 2012; Amiri-Khorasani et al., 2016; Kilit et al., 2019). For example, Amiri-Khorasani et al. (2016) have shown that different stretching exercise protocols applied before exercise

performed better than the static and non-stretch protocols after dynamic and combined stretching. Little & Williams (2006) have stated that acute dynamic stretching improves the acceleration test performance of football players. However, there are also studies in the literature reporting that dynamic stretching has no effect on speed performance (Chaouachi et al., 2010). Polat et al. (2018) have found that acute applied ballistic warm-up does not show any difference in the speed performance of wrestlers. In addition, Schilling & Stone (2000) attributes that static stretching does not have a positive effect on linear running performance to the changes in the muscle-tendon unit as a result of static stretching. In this study, it can be said that the increase in muscle tension with static stretching decreases the performance values. As a result of the research, we can say that the hypothesis that the dynamic and combined dynamic stretching exercise protocol will positively affect the speed performance has been confirmed.

It has been stated that dynamic warming can increase power performance in addition to the changes in the relationship between warming and force velocity (McMillian et al., 2006). Many studies have shown that dynamic or combined stretching has a positive effect on power (Sekir et al., 2010) and jump (Carvalho et al., 2012) performances. Haghshenas et al. (2014) examined the acute effect of different stretching protocols on volleyball players and reported a significant increase in anaerobic power in favor of dynamic stretching when dynamic stretching and static stretching were compared. Behm & Chaouachi (2011) have concluded that dynamic stretching routines are the preferred method to improve explosive muscle contractions. Contrary to the current findings, some studies have reported that dynamic stretching does not improve short-term explosive performance (Jaggers et al., 2008; Samuel et al., 2008). Aydın et al. (2019) applied the same protocol with the different stretching exercises in this study and stated that there was no statistically significant difference in vertical jump performance values after the study. In addition, although some existing studies have not shown any side effects of static stretching (Samuel et al., 2008), others have stated that static stretching may adversely affect short-term maximum performance (Paradisis et al., 2014). It is thought that the inconsistencies in the findings of some existing studies with this study may be due to the age of the participants, training status, stretching time, volume, density or other factors used in current protocols.

The ability to generate or transfer explosive muscle power is a key element for the success of many athletic activities (Stockbrugger & Haennel, 2001). To the author's knowledge, only a few studies have examined the acute effects of different warm-up methods on upper extremity strength performance (Knudson et al., 2004; McMillian et al., 2006; Torres et al., 2008). In this study, it was determined that there was no statistically significant difference in medicine ball

throwing performance of different stretching exercises applied to wrestlers. Torres et al. (2008) examined the effect of upper body static stretching and dynamic stretching on upper body muscle performance in athletes and stated that there was no significant change in medicine ball throwing performance in athletes. In contrast to these studies, Mcmillian et al. (2006) have stated that there is a positive difference in the performance of throwing medicine balls in dynamic stretching exercises compared to static stretching. Herman & Smith (2008) applied a four-week dynamic and static warm-up program to wrestlers and reported an improvement in medicine ball throwing performance (4%) in favor of dynamic exercise at the end of four weeks. It is difficult to make a definitive judgment as to whether different stretching exercises affect performance with so few studies focusing on the upper body. Also, Torres et al. (2008) have stated that almost all studies in the literature focus on the effects of yawning on lower body neuromuscular performance.

Flexibility is included in athletes' training program as an important part of the warm-up procedure. However, it is not correct to limit performance only to flexibility (Polat et al., 2018). According to the current literature studies, it has been seen that different stretching protocols can affect the flexibility performance of athletes in different ways. For example, Tsolakis et al. (2010) have found no significant difference in flexibility performance after static or ballistic stretching of the lower extremities in international fencers. In addition, it was stated in another study similar to our study findings that there was no difference in sit and reach performance between static and dynamic exercises (Perrier et al., 2011). Contrary to the current findings, Polat et al. (2018) have found that ballistic warming applied to wrestlers increases their flexibility. Kumar & Chakrabarty (2010) have found that ballistic exercise significantly increases the flexibility of athletes' hamstring muscles compared to static exercise. In addition, there are a number of other studies reporting the superiority of static stretching for increasing static ROM in addition to the positive effects of dynamic stretching (Covert et al., 2010). Samson et al. (2012) reported that static stretching increased 2.8% in sitting and reaching range of motion (ROM) compared to dynamic stretching.

Although this is the first study to examine the acute effects of different stretching methods on acceleration, jump, flexibility and upper limb performances in young wrestlers, some limitations should be carefully noted before final conclusions are drawn. Firstly, it is small sample size given that they are young female wrestling players. Another limitation is that it did not analyze the chronic influence of wrestlers on their performance. However, an important

strength of this study is, short-term procedure was chosen to minimize any performance changes that could occur over a longer time period.

CONCLUSION

In conclusion, the acute effects of different stretching methods on acceleration, jumping, flexibility and upper extremity performances of young wrestlers were examined in this study. These research findings show that dynamic and combined (static + dynamic) stretching can increase speed and jump performance in young wrestlers. According to the study findings, coaches and sports scientists should consider choosing the stretching type after the warm-up session. In addition, dynamic and combined (static + dynamic) stretching should be done to increase the speed and jump performance of their players. Researches on athletic performance and sports branch performances of different stretching methods, athletes of different ages and performance levels are recommended in future studies.

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Conflicts of Interest

The author declare no conflict of interest.

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INFLUENCE OF 12-WEEK ARTISTIC GYMNASTICS TRAINING ON CHILDREN'S STRENGTH AND BALANCE PERFORMANCE

VPLIV 12-TEDENSKEGA TRENINGA ŠPORTNE GIMNASTIKE NA MOČ IN RAVNOTEŽJE OTROK

ABSTRACT

The purpose of the present study was to investigate the influence of 12-week artistic gymnastics training on children's strength and static balance performance. A total of 32 children attending gymnastic club for kids with mean age 6.09 ± 7.45 years; height 106.81 ± 5.47 cm, body weight 17.00 ± 2.72kg and body mass index (BMI) 14.98 ± 2.57 kg/m2 were included in the study. A training program with 270-minute intensity at a frequency of 3 days a week for 12 weeks has been implemented for all participants. Hand grip strength test, stretched arm hanging duration on high bar and stork balance test for dominant and non-dominant legs were applied to the participants. SPSS 21.0 statistical program was used in the statistical analysis of the data and the statistical significance level was accepted as $p<0.05$. As a result of the study, while a statistically significant difference has not been observed between Non-dominant leg stork balance pre-test and the post-test ($p=0.06>0.05$), a statistically significant difference was observed between the Dominant leg stork balance pre-test and the post-test ($p=0.00<0.05$). However, a significant difference was found between both hand grip strength pre-test and post-test ($p=0.00<0.05$) and stretched arm hanging duration on high bar pre-test and post-test ($p=0.00<0.05$). There was a statistically significant difference between the participant's pre-test sit and reach and the post-test ($p= 0.00<0.05$). It can be said with this study that 12-week artistic gymnastics training increased children's forearm flexor muscle isometric strength and balance performance.

Keywords: Artistic gymnastics; balance; forearm flexor muscle; strength

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IZVLEČEK

Namen pričujoče študije je bil raziskati vpliv 12-tedenskega treninga ritmične gimnastike na moč in statično ravnotežje otrok. V vzorec smo zajeli 32 otrok s povprečno starostjo 6,09 ± 7,45 let; višino 106,81 ± 5,47 cm, telesno težo 17,00 ± 2,72 kg in indeksom telesne mase (ITM) 14,98 ± 2,57 kg / m2. Za vse udeležence je bil izveden program usposabljanja, trajajoč 12 tednov, 270 minut tedensko in 3 krat tedensko. Za udeležence so bili uporabljeni preizkus moči oprijema roke, vesa v zgibi in Storkov test ravnotežja štorklje za dominantno in nedominantno nogo. Statistična analiza je bila narejena v programu SPSS 21.0, raven statistične pomembnosti pa smo določili pri $p<0,05$. Med pre-testom in post-testom nedominantne noge pri Storkovem testu nismo zaznali značilnih razlik ($p = 0,06> 0,05$), smo pa opazili statistično značilne razlike v pre- in post- testu: i) dominantne noge Storkovega testa ($p = 0,00 <0,05$); ii) moči oprijema roke ($p = 0,00 <0,05$) in iii) veso v zgibi na visokem drogu ($p = 0,00 <0,05$). Pričujoča študija dokazuje, da 12-tedenski trening ritmične gimnastike pozitivno vpliva na povečanje izometrične moči rok in statičnega ravnotežja otrok.

Ključne besede: ritmična gimnastika; ravnotežje; fleksorska mišica podlakti; moč

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INTRODUCTION

Artistic Gymnastics (AG) is a traditional sport that has been included in Olympic program since Athens Olympics in 1896 (Molinari et al., 2010). AG requires artistic and balance skills as well as explosive movements such as jumping, pulling, pushing and sprinting. Coordination skill is one of the motor skills that should be at a high level (Gardasevic, & Vasiljevic, 2017) These components operate various muscle groups bilaterally and in a coordinated manner for force generation (Kutac, Jurkova & Farana., 2019). Hand grip strength is a good indicator of total muscle strength, endurance, and overall strength of the body (Erdogan et al., 2016). It is basically based on the maximal isometric strength produced by the hand and forearm muscles (Karataş, 2017). "The ability to grip is made possible by the fact that the thumb can move opposite to the other fingers the fingers and thumb act as a versatile pair of pliers" (Krejač, K., Žvan, M., Peharec, S Milan., & 2020, Čoh, Milan). Thus, hand grip strength is highly important while hanging and rotating movement routines are performed in parallel bars (Savucu et al., 2018). For this reason, it is recommended to be used in various motor ability measurement test batteries recommended for children. High bar is one of the competition equipment used by male and female gymnasts to perform their movement routines. Routines performed on the high bar include forward and backward circular movements (swing / full giant), releasing the high bar and holding it again and finishing movement (Yeadon & Hilley, 2020).

Balance is the ability to remain stable with minimal sway on the support base of the center of gravity of the body (Akşit & Cırrık, 2017). Gymnasts need to increase especially their dynamic and static balance performances in order to perform the somersaults and acrobatic movements at different levels successfully. Just like taekwondo players landing during kicking (Ipekoglu et al., 2018), as the number of somersault increases, the angular momentum in the long axis will increase, making it difficult for the gymnast to maintain balance during landing (Suchilin & Arkaev, 2004). Therefore, performing different techniques in gymnastics training improves the ability to control the body position in the air during the somersault movements and the ability to stay in balance while landing. Gymnasts perform static skills such as handstands in a slow position, in a controlled manner, and after a swing. For this reason, AG requires both static and dynamic balance. In this study, it was hypothesized that 12-week gymnastics training would increase the strength of the forearm flexor muscles and static balance performance of children.

METHODS

Participants

Totally (n=32) children, including 20 girls and 12 boys with an average age of 6.09 ± 7.45 years, average height 106.81 ± 5.47 cm, body weight average 17.00 ± 2.72 kg, body mass index (BMI) 14.98 ± 2.57 kg / m^2 were included in the study. All children were allowed to carry out a test only once by being verbally informed about the test in advance. All participants were right-handed gymnasts. All participants were asked not to participate in any sports activity in the last 24 hours to avoid fatigue before the test. The feedback of the performance was reported to the participants during the test in order to achieve maximal effort. All participants were given detailed information about possible risks that might occur during training before the test and they were asked to read and sign an informed consent form. The families of the participants were given detailed information about the study and asked to sign the family consent form. Thus, attention was paid to conduct the research in accordance with the Declaration of Helsinki.

Experimental procedure

12-week Training Program

A training program specific to the beginner level of artistic gymnastics was carried out for a total of 270 minutes at a frequency of 3 days for 12-week. A training unit was determined as a total of 90 minutes, on Monday, Wednesday and Friday (see below). Special care was taken for each training unit to include learning new technical skills and repetition of old technical skills. They trained only calisthenics without using any additional weight in any training unit.

Table 1. Training unit chart

The number of training (days of week M-W-F)	Total training duration volume/intensity/ (min.)	Warm-up section (min.)	Main section (min.)	Cool-down section (min.)
3	270	20	55	15

Abbreviation: Min= minute, M=Monday, W=Wednesday, F=Friday.

Warm-Up Section

Participants were randomly divided into 3 groups after a 5-minute jogging run on a 12x12 floor implement and performed sequentially animal walks, tiger crawl, bear walk (stretched leg), caterpillar walk, crab walk, frog and rabbit jump, side swing leg, tuck jump, scissor leap,

galloping and wheel barrow walk movements with voice commands. Each animal movements were performed one repetition.

Main Section

This section included backward roll (10 repetition), backward and forward roll with straight leg (10 repetitions), backward and forward straddle roll (10 repetitions), scissor leap (2 rounds), handstand work on the wall (10 repetitions), cartwheel (10 repetitions), round off prior exercise (10 repetitions), backward roll on incline mat (repeated and with helper), intermittent isometric body hold training, repetition of old technical skills, flexibility specific for gymnastics (side split, center split, back and forward bridge/arch/back bend), movements to increase the range of motion of the shoulder joint on the wall bars and repetition of learned skills.

Cool Down Section

This section consisted of games specific to gymnastics after 3-5 minutes of slow pace run, back extension roll, lower extremity static stretching exercises; bilateral side split, isometric stretching exercises for upper extremities; as combined neck, shoulder, wrist, elbow, and combined stretching exercises; back arch exercises.

Data Collection

Handgrip Strength Test

Camry digital hand dynamometer (Model EH101) was used to evaluate the grip strength of the dominant hand. The participants were asked to sit on a chair and hold the elbow joint at a 90° angle. After the dynamometer was adjusted according to the hand size of the participants, they were asked to grasp with their maximum power for three seconds. The test was repeated twice, and the best degree was recorded as grip strength (Le & Shim, 2019).

Stretched/Straight Arm Hanging Duration on High Bar Test

This test was implemented in order to evaluate the continuity of the strength especially by contracting the forearm muscles in an isometric type against a stable resistance. (Berisha & Çilli, 2016). Validity and reliability of the test was carried out by Sleeper, Kenyon, & Casey, 2012. Participants waited with their arms stretched/staright and the body suspended on the high bar. The test was terminated with a movement in body position or arms. The test was repeated once and the hanging on the high bar time was recorded in seconds.

Standing Stork Balance Test

This test was used to measure the balance of participant while standing on one leg. Each participant placed one foot on the inside of the knee on the other leg for support, with bare feet, hands on waist. The stopwatch was started when the participant lifted one foot off the ground. The test was terminated by stopping the recorded time when one or both hands were separated from the waist or the position of the support leg changed (when it was moved). The test was repeated three times and the best result was recorded according to the rating score (Castillo-Rodriguez, Onetti-onetti, Sousa-Mendes & Chinchilla, 2020) (see below).

Table 2. Stork Balance Scoring

Rating	Score (sec.)
Excellent	> 50
Good	40 - 50
Average	25- 39
Fair	10 - 24
Poor < 10	< 10

*Sec = Second; https://www.topendsports.com/testing/tests/balance-stork.htm

Flexibility

Sit and reach (S&R) stand with 32 cm. height and 35 cm. length placed on a flat surface was used to determine the flexibility of the participants. Participants were asked to reach as far as possible on the S&R table on the floor without bending their knees with their feet with their legs extended and without shoes. The furthest distance between the middle fingers and the point corresponding to the soles was measured. After repeating the test twice, the longest distance reached was recorded as the best degree (Şahin et al., 2019).

Data Analysis

SPSS 21.0 statistical program (SPSS INC, Chicago IL) was used in the statistical analysis of the data and the statistical significance level was accepted as $p < 0.05$. Paired sample T-test was used to control some variables, while Kolmogrov-Smirnov test was used for normal distribution analysis. Results were interpreted with the help of Cohen's d effect size value. Cohen' s d effect size is small values between 0.20-0.50; 0.50-0.80; shows a medium effect of 0.80 and a larger level (Cohen, 1988).

RESULTS

Table 3. Descriptive statistics of the participants' physical characteristics (mean ± sd).

Variables	Minimum	Maximum	Mean ± Sd
Age (year)	4.5	7.5	6.09 ± 7.45
Height (cm)	96	118	106.81 ± 5.47
Weight (kg)	13.0	22.5	17.00 ± 2.72
BMI* (kg/m^2)	10.05	19.95	14.98 ± 2.57

*Body Mass Index

Descriptive statistical data of the participants are given in Table 3. The average age of 32 participants took part in the study has been defined as 6.09 ± 7.45; mean height 106.81 ± 5.47; mean body weight 17.00 ± 2.72 and the mean BMI 14.98 ± 2.57.

Table 4. Paired sample t-test of the hand grip strength pre-test and post-test test of the participants.

Variables	Mean± SD	t	p	Cohen's d
Handgrip Strength pre-test	0.91± 0.41	-12.59	.00	0.43
Handgrip Strength post-test				

($p < 0.05$)

There is a statistically significant difference in the handgrip strength of the participants between pre-test and post-test ($p = 0.00 < 0.05$). (Table 4.)

Table 5. Paired sample t-test of stretched/staright arm hanging duration on high bar pre-test and post-test of the participants.

Variables	Mean± SD	t	p	Cohen's d
Stretched/straight arm hanging duration on high bar Pre-test	-3.19 ± 1.44	-12.53	.00	0.41
Stretched/straight arm hanging duration on high bar Post-test				

($p < 0.05$)

There is a statistically significant difference in the stretched/staright arm hanging duration on high bar between pre-test and post-test ($p = 0.00 < 0.05$). (Table 5.)

Table 6. Paired sample t-test of the stork balance (DL) pre-test and post-test of the participants.

Variables	Mean± SD	t	p	Cohen's d
Stork balance Pre-test (DL) Stork balance Post-test (DL)	-6.23 ± 3.41	-10.31	.00	0.41

(p <0.05) DL = Dominant Leg

A statistically significant difference has been found between the (DL) Stork balance pre-test and post-test (DL) of the participants (p = 0.00 <0.05). (Table 6.)

Table 7. Paired sample t-test of the stork balance (N-DL) pre-test and post-test of the participants.

Variables	Mean± SD	t	p	Cohen's d
Pre-Stork balance test (N-DL) Post-Stork balance test (N-DL)	-0.74 ± 2.15	-1.95	.06	0.11

(p <0.05) N-DL = Non-Dominant Leg

There is no statistically significant difference between the participants pre-test stork balance test (N-DL) and post-test (N-DL) (p = 0.06> 0.05). (Table 7.)

Table 8. Paired sample t-test of the sit and reach pre-test and post-test of the participants.

Variables	Mean± SD	t	p	Cohen's d
Pre-test sit and reach Post-test sit and reach	-1.62 ± 0.85	-7.76	.00	0.53

(p <0.05)

There is a statistically significant difference between the sit and reach pre-test and post-test of the participants (p = 0.00 <0.05). (Table 8.)

DISCUSSION

In this study, the effect of 12 weeks of artistic gymnastics training on forearm flexor strength and static balance performance was examined.

According to the results of the study, a significant difference was found between both hand grip strength pre-test and post-test (p = 0.00 <0.05) and stretched arm hanging duration on high bar

pre-test and post-test ($p = 0.00 < 0.05$). The reason for this difference may be due to the increase in forearm flexor muscle strength in the practice of hanging and swinging movements in the high bar for 12 weeks. In other words, it can be explained by the adaptation of the participants to the applied gymnastics training. Similarly, Genc, Cigerci & Sever, 2019 found a significant difference in the hand grip strength data as a result of their study investigating the physical and physiological effects of 8-week core training on female handball players. Ziyagil et al., 1996 found a significant difference between 11-year-old sedentary children and the children engaged in sports in view of grip strength. Berisha & Çilli, 2016 observed that there is a positive linear relationship between the time of hanging with stretched arms and gymnastic technique scores of 15-16-year-old children. Bayraktar, 2005 found the grip strength of swimming athletes to be significant ($p < 0.001$) compared to gymnastics and athletics athletes. As a result of the study on the relationship between the hand grip strength of elite shooters and their shooting performance conducted by Erdogan et al., 2016 while there was a positive and significant relationship between female shooters dominant hand grip strength and their shooting scores, insignificant relationship was observed between male shooters dominant hand grip strength and their shooting scores. In the study conducted by Yasemin, Tunçel & Harbili, 2020 which they examined the relationship between upper extremity strength, anaerobic power, speed and agility in young handball players, they found a high level of positive correlation between anaerobic power and medicine throwing, dominant and non-dominant hand grip strength values.

The fingers are generally the main joint that generates force for hand grip strength. (B-Razak et al., 2018) Muscle strength and muscular endurance develop in childhood (Koçyiğit, Akın & Şentürk, 2020). Hence, the increase in hand grip strength can lead to more force generation in finger movement. Therefore, they are considered to be extremely important during the combination of movements in gymnastic equipment (the high bar and the asymmetric bar) where movements such as hanging and swing are frequently repeated. As the body passes through a hanged position, it is subjected to both its own weight and the force of constantly changing acceleration.

These forces can cause the athlete to fall from the apparatus quickly to the ground. The hand and forearm muscles must generate a significant amount of force in order to perform a continuous routines of movements in the apparatus (Ruiz et al., 2006). Based on this information, a successful performance, especially in some apparatus, regardless of age and gender, may require hand grip strength. In this study, it was observed that there was no statistically significant difference between N-DL stork balance pre-test and post-test, but there

was a statistically significant difference between DL Stork balance pre-test and post-test. It was expected that there was no statistically significant difference in N-DL. According to the study conducted by Granacher et al., 2011, children aged 6-7 years were given a 4-week balance exercise to evaluate the effect of balance, leg strength, and balance training, but no statistically significant improvement was observed. Gymnastics is a sport in which aesthetic values are at the forefront and at the same time it is necessary to maintain balance (Choen Whiting & Mclaine, 2002). In gymnastics, every maneuver (whether male or female) ends with a landing (Čuk & Marinšek, 2013).

The gymnast needs an extraordinary level of balance control especially during the competition (Moraru, Neculaeş, hodorcă, 2014). Accordingly, a significant amount of balance training should be practiced throughout the year in order to meet the balance requirement (Vuillerme et al., 2001). In addition, it is among the information in the literature that gymnastic exercises support strength development in children and thus have an effect on balance performance (Akın & Kesilmiş, 2020). The landing phase after the routines performed on both male and female gymnastics equipment should end with a perfect standing position. Otherwise, every deviation from the correct position is considered as a mistake and the necessary score deductions are made by the judge. (Xiao et al., 2017) Tanasă et al., 2020 found that gymnastics training improved balance capacity as a result of their study on the effects of gymnastics training on static balance in children aged 4 to 8 years. According to Daly, Bass & Finch, 2001 strength, which is among the basic motoric properties, has a significant effect on gymnastic performance. The improvement in different types of force especially in artistic gymnasts causes significant effects on the application of the movements performed on the floor, balance beam and vaulting table (Kankal, 2008). Evridiki, Aggeliki & Vassiliki, 2004 presented that the movement education program positively affected the jumping and dynamic balance performances of preschool children aged 4-6. In this study, a statistically significant difference was found between the S&R pre-test and the post-test of the participants. According to Aedo-Muñoz et al., 2019 flexibility is accepted by gymnasts and trainers as the most important physical parameter after strength in performing artistic gymnastic exercises with high technique and quality (Sterkowicz-Przybycień et al., 2019). In a study, it was observed that stretching and strength training specific to the lower extremity positively affected the lower extremity control of athletes (Sağiroğlu Kurt, Pekünlü & Özsu, 2017). However, no significant difference was found between the S&R pre-test and post-test test in the study that Nazari & Lim, 2019

investigated the effect of a 12-week core training program on the physical properties of rhythmic gymnastics.

CONCLUSION

The effect of 12-week artistic gymnastics training on children's strength balance performance was investigated in this study. The results show that artistic gymnastics training carried out at a frequency of 3 days a week for 12 weeks can be said to improve children's forearm flexor muscle strength and static balance performance. This situation may contribute to the performance to be demonstrated in future competitions. As a result, it is thought that the significant findings obtained will contribute to the literature. Almost all measures displayed significant main effect, small and medium (effect size) improvements for time (post-test > pre-test).

Declaration of Conflicting Interests

The author declare no conflict of interest.

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Neja Markelj

LETTER TO THE EDITOR: GREAT RESEARCH IDEAS FAIL BECAUSE OF WEAK EXPERIMENTAL DESIGN

PISMO UREDNIKU: DOBRA RAZISKOVALNA IDEJA PADE S SLABIM EKSPERIMENTALNIM NAČRTOM

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The manuscript contains only original material, has not been previously published, is not currently under consideration elsewhere, and will not be submitted elsewhere pending a final journal decision.

We read with great interest the findings of Demirci and Demirci (2018) on the article "The effects of game and physical activity lessons in children with learning disabilities". This study examined the effect of participation of students with learning disabilities (LD) in Game and Physical Activities (GPA) lessons on their academic achievement and exercise self-efficacy (SE) levels. The authors conducted a semi-experiment with physical activity (PA) intervention for 30 male students with LD. In addition to regular PE, the experimental group attended GPA five times per week for 40 minutes. The GPA followed the basic movement skills curriculum program written by Turkish Ministry of Education. The study found a significant decrease in body weight and body mass index (BMI) of the students in the experimental group and a large impact of GPA on their exercise SE and academic performance.

As previous studies have shown (e.g., Fedewa & Ahn, 2011), PA is as beneficial to academic achievement for children with LD - if not more so - than for children without such disabilities. Previous studies (e.g., Gore, 2006) have already found that SE predicts academic outcomes and have explored possible interventions to change SE beliefs in adults and children. The important contribution of this study is to explore how PA might change SE beliefs in children with LD.

Despite the good research idea and the importance of the objectives, the main shortcoming of the paper is the unclear organization of thoughts. The introduction of the paper is written in a confused way; therefore, it is difficult for the reader to understand what the main objectives are. Most of the ideas and research findings on which this study is based are described in the discussion section. The reader must first read the entire article to understand the basis of the research. To the best of our knowledge, we identified their implicit thesis; adapted and individualized activities and teacher instruction for students with LD during PE increases exercise self-efficacy, which increases overall self-efficacy, which contributes to academic success. However, the experimental design does not allow us to test that.

Despite its great potential, the experimental design is the weakest link of this study. Unfortunately, the description of the study protocol is inadequate to be replicated by other researchers. The authors failed to describe in detail the characteristics of the participants and the GPA program. First, we learn nothing about the nature of the participants' learning disabilities. There is a wide range of learning disabilities: from motor to cognitive to sensory; we believe that any experimental PA program would have different effects on the different types of disabilities. Second, the paper only describes the content of the GPA program and lacks description of objectives, methods, and adapted teacher instructions and exercises. The reader

cannot determine what makes the difference in teaching PE students with LD to achieve the desired goals.

Also, it is important to know if the participants attended a regular school or a special school for students with LD. Did the participants attend different schools or the same one? Did the participants in the experimental group attend GPA in their schools from their PE teachers or together after school from the same instructor? If the participants attended a special school for students with LD, then we assume that the PE teacher(s) already followed the adapted PE curriculum to some extent; on the other hand, the degree of inclusion of students with LD in regular PE depends mainly on the teacher's knowledge, skills, and willingness to individualize instruction and practice. We recommend the authors to explain these details and control the listed factors in the experimental design.

As we read the article further, we noticed several errors in the statistical reports. First, the authors state that the participants are 9-11 years old, while the descriptive statistics in Table 2 show that the mean age is 8.27 years for the control group and 8.33 years for the experimental group. Second, the authors failed to report results on the decrease in body weight and BMI for both groups, although they discuss this in the Discussion.

Third, we question the procedure of quantifying experimental effects, i.e., the calculation and presentation of Cohen's *d*. On the one hand, we recommend that the authors present the effect size with a confidence interval; on the other hand, the number of participants in both groups is too small to use Cohen's *d* as a correct measure. Cohen (1992, p. 156) writes: "In research planning, the investigator needs to know the N necessary to attain the desired power for the specified α and hypothesized *ES*. *N* increases with an increase in the power desired, a decrease in the *ES*, and a decrease in α. For statistical tests involving two or more groups, *N* as here defined is the necessary sample size for each group." He also points out that the only specification for power is .80 (i.e., $\beta = .20$; the probability of rejecting a false H0), which should make the number of participants in each group at specified $\alpha = .05$ at least 26, 64, and 393 if the expected effect size in the population is large, medium, or small, respectively. For smaller sample sizes (< 50), Cohen's *d* tends to inflate the results, and the upward bias is relatively large when sample sizes are less than 10 in each group (Nakagawa and Cuthill, 2007). There is a correction factor available that reduces the effect sizes by a few percentage points. Nevertheless, the authors did not use it.

The most important finding of the study is that participation in the GPA has a large impact on the development of exercise self-efficacy and academic performance in children with LD. However, the authors made an overly firm statement that children with high SE contribute to successful outcomes.

In summary, we agree with the authors that given the inherent academic difficulties of children with LD, PA should not be overlooked as an effective intervention to stimulate children's learning. We support the authors' initiative to raise awareness of the importance of individualizing the learning process in PE, especially for children with LD. However, it is crucial to present a more detailed experimental design and to reconsider the introduction of control variables.

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