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ORIGINAL SCIENTIFIC PAPER

Technical and tactical evaluation of ball possession in international youth water polo matches using the Team Sport Assessment Procedure (TSAP) instrument

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Abstract

In water polo, the playing style of a team is characterized by players' tactical behaviour. The purpose of this study was to provide an analysis of offensive actions, by means of the Team Sport Assessment Procedure (TSAP) of the first four youth national teams during the 20th FINA Junior Water Polo World Championships. Twenty-nine elite youth (U20) water polo matches, involving the national teams of Greece (n=7), Serbia (n=7), Italy (n=7) and Croatia (n=8) were selected for the analysis. The TSAP included: i) two indicators of gaining possession of the ball; ii) four indicators of disposing the ball. Using these indicators, the following indices of technical performance were computed: Volume of Play (VP), Efficiency Index (EI) and Performance Score (PS). The field was divided in twelve zones. The one-way ANOVA showed no significant differences between teams for all parameters (p>0.05), except that for Offensive Balls (OB) and Successful Shots (SS) occurred in specific zones of the field: for OB significant differences were found in zone 1 (p=.019), in zone 2 (p=.014) and in zone 5 (p=.007); for SS significant differences were found in zone 1 (p=.026) and in zone 2 (p=.008). The main reason of between-teams differences could be explained by the presence of a left-hand player in the game, and by the tactical behaviour of coaches and players. The TSAP instrument could offer productive feedback to coaches to perceive the different requirements of playing and to evaluate how players understand the game.

Keywords: *match analysis, offensive phase, performance index*

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EVALUATION OF BALL POSSESSION IN YOUTH WATER POLO
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Introduction

Water polo, which originated in the late 1800s, is one of the oldest team sports of the modern Olympic Games, being part of the Summer Olympics program since the second games, in 1900. Since 1973 the Federation Internationale De Natation (FINA) also organize the Men's World Championship, with the last edition (the 19th) held in Hungary (Budapest). This competition has been also extended to the youth categories, with the Men Water Polo World Junior Championships (currently named U20) played since 1981. The tournament consists of a preliminary group stage phase, with teams divided into two groups and playing once with each other, followed by a knockout phase (eight-, quarter-, semi-final, and finals). Despite the situational nature of water polo, like other team sports, makes difficult the game analyses in terms of replication (Lupo et al., 2010), in literature are present different types of investigation, including physiological characteristics (Botonis et al., 2019a; Smith, 1998), monitoring of training (Lupo et al., 2014a; Botonis et al., 2019b), as well as swimming capabilities (Dimitrić et al., 2022; Perazzetti et al., 2022). Regarding the technical and tactical aspects, specific studies have been provided involving men and women collegiate teams (Lupo et al., 2011), playing role efficacy (Botonis et al., 2018), game rules evolution (Borges-Hernández et al., 2022), different competitive levels (Lupo et al., 2012a), and influence of match outcome (Ruano et al., 2016). However, from our point of view, in water polo, the absence of a valid and reliable instrument to objectively assess the players' level of tactical awareness and game knowledge, to use on both match and training contexts, is responsible for the paucity of studies on these topics.

The Team Sport Assessment Procedure (TSAP) instrument has been used in both sport and physical education by students, teachers, coaches, and researchers (Grehaigne et al., 1997) to assess performance in games as the integration of tactical understanding, decision-making and skill performance. Its primary objective is to provide coaches with objective data on players' offensive performance in different invasion and net games, while avoiding standardized tests which do not provide tactical behaviours of players (Richard et al., 2002). Indeed, the basic idea of this procedure is to consider the players' and teams' specific behaviours during the game and to summarize the data collected either under the form of total occurrences or under the form of some performance index. For that reason, the TSAP method is focused on the offensive ball aspects of the game, assessing how a player or team gains the ball possessions, and how a player or team disposes the ball (Grehaigne et al., 1997). In current literature, studies regarding the use of TSAP instrument have been published in soccer (Blomqvist et al., 2005), basketball (Catarino et al., 2017), ice-hockey (Nadeau et al., 2008) and volleyball (Richard et al., 2002). However, in water polo, to the best of our knowledge, only one study was conducted using this instrument, showing how the TSAP could be a valid procedure to evaluate the performance of international youth teams during international water polo competitions (Perazzetti & Tessitore, 2021). Therefore, the present study aimed at providing the TSAP analysis of the last Men's Water Polo World Junior Championships organized by FINA and played in Kuwait at the end of the 2019, before the spread of coronavirus pandemic.

Methods

Twenty-nine matches of the 2019 FINA World Men's Junior Water Polo Championships (Kuwait City, Kuwait), involving the national teams of Greece (n=7), Serbia (n=7), Italy (n=7) and Croatia (n=8) were selected for the analysis. The TSAP instrument (Grehaigne et al., 1997) was used to assess Received Balls (RB) and Conquered Balls (CB) as variables for gaining possession of the ball; and Offensive Balls (OB); Successful Shots (SS), Neutral Balls (NB) and Lost Balls (LB), as variables for disposing of the ball. Then, the Volume of Play [VP: RB+CB], Efficiency Index [EI:(OB+SS)/(10+LB)] and Performance Score [PS:(VP/2)+(EI*10)] were calculated as performance indicators (Table1). The EI used in this study is the adapted version of Richard et al. (2000), which differs from the original version of Grehaigne et al. (1997; EI:(VP)/(10+LB)) and poses an emphasis on the ball possession management (i.e. pass or shoot on goal) (Light et al., 2008).

Table 1. TSAP Components in Water Polo*

GAINING POSSESSION OF THE BALL	
Receiving the ball (RB)	The player receives the ball from a partner and does not immediately lose control of it.
Conquering the ball (CB)	A player is considered having conquered the ball if he or she intercepted it, stole it from an opponent, or recaptured it after an unsuccessful shot on goal or after a near-loss to the other team.
DISPOSING OF THE BALL	
Playing a neutral ball (NB)	A routine pass to a partner or any pass which does not truly put the other team in jeopardy is considered a neutral ball.
Losing the ball (LB)	A player is considered having lost the ball when he or she loses it to the other team without having scored a goal (Shot, Passages, Lost Ball, Contrafoul).
Playing an offensive ball (OB)	An offensive ball is a pass to a partner which puts pressure on the other team and, most often, leads to a shot on goal (Assist, Offensive passages, Center Ball) or a gained exclusion with the ball in the hand
Executing a successful shot (SS)	A shot is considered successful when it scores or possession of the ball is retained by one's team (Goal and Shots)
PERFORMANCE INDICATORS	
Volume of Play (VP)	VP: RB+CB
Efficiency Index (EI)	EI: (OB+SS)/(10+LB)
Performance Score (PS)	PS: (VP/2)+(EI*10)

*Adapted from Grehaigne et al. (1997). Journal of teaching in Physical Education, 16(4), 500-516

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Through the LongoMatch Pro software (LongoMatch By Fluendo, Windows version 1.7) we customized a specific water polo dashboard to collect TSAP parameters during all ball possessions for each observed team. For the CB, LB, OB and SS parameters has also been provided an analysis of their frequency of occurrence in relation to the zone in which they took place. The field was divided in twelve zones according to the ususal classification used by water polo coaches and adopted in a previous study by Perazzetti and Tessitore (2021). In particular, the field was divided in a "defensive half" (DH) (left zones: -1 and -2; right zones: -4 and -5; and central zones: -3 and -6) and an "offensive half" (OH) (right zones: 1 and 2; left zones: 4 and 5; and central zones: 3 and 6) (Figure 1).

The Shapiro–Wilk test was applied to ascertain the normal distribution of data. Descriptive statistics of all TSAP parameters, including means and standard deviations, for Greek, Serbian, Italian and Croatian teams and pooled data were calculated. The one-way ANOVA was used to analyse differences between teams for all parameters and according to the zones of the field, while the independent t-Test with pooled data was used to analyse differences, for the same parameters, between tournament phases (preliminary round vs final round) (García-Marín et al., 2017) and match status in relation to the difference of number of goals scored by the two opponent teams [balanced (≤3 goals) vs unbalanced (>3 goals)] (Lupo et al., 2012b). A Pearson correlation was used to characterize the association between TSAP's parameters and total amount of gained exclusions, gained penalties, goals conceded, and goals scored. The correlation coefficients were defined as follows: small 0.1–0.3; moderate 0.3–0.5; strong 0.5–0.7; very strong 0.7–1.0 (Schober et al., 2018).

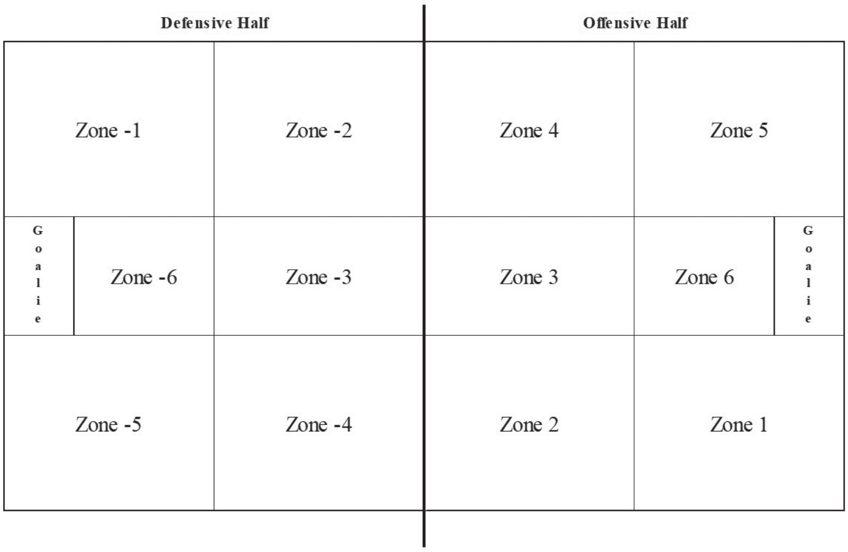

Figure 1. The division of the water polo field in twelve zones

The statistical analyses were conducted using the statistical package SPSS (version 20.00; Institute, Inc., Cary, NC), and the criterion for significance was set at a 0.05 alpha level.

Results

Table 2 shows the total amount of TSAP parameters of the 29 matches analysed, indicating minimum, maximum, mean and SDs.

Table 2. Total amount of TSAP parameters (29 matches) with pooled sample (Greece, Serbia, Italy and Croatia national teams)

	DESCRIPTIVE STATISTICS				
	Mean	SD	CV (%)	Min	Max
RB	197.7	34.6	17.5	126	257
CB	9.3	3.6	39.1	3	16
VP	207	33.4	16.1	142	269
NB	135.1	34.3	25.4	70	203
LB	22.7	5.9	26.1	9	33
OB	31.7	7.8	24.5	18	46
SS	17.5	6.2	35.6	7	32
EI	1.6	0.7	43.8	.7	3.5
PS	119.6	17	14.2	84	157.4
Goals Scored	13.1	6	45.3	4	27
Goals Conceded	7.2	3	41.9	2	15
Gained Exclusions	11	4.5	49.2	3	23

Note. RB= received balls; CB= conquered balls; VP= volume of play; NB= neutral balls; LB= lost balls; OB= offensive balls; SS= successful shots; EI= efficiency index; PS= performance score

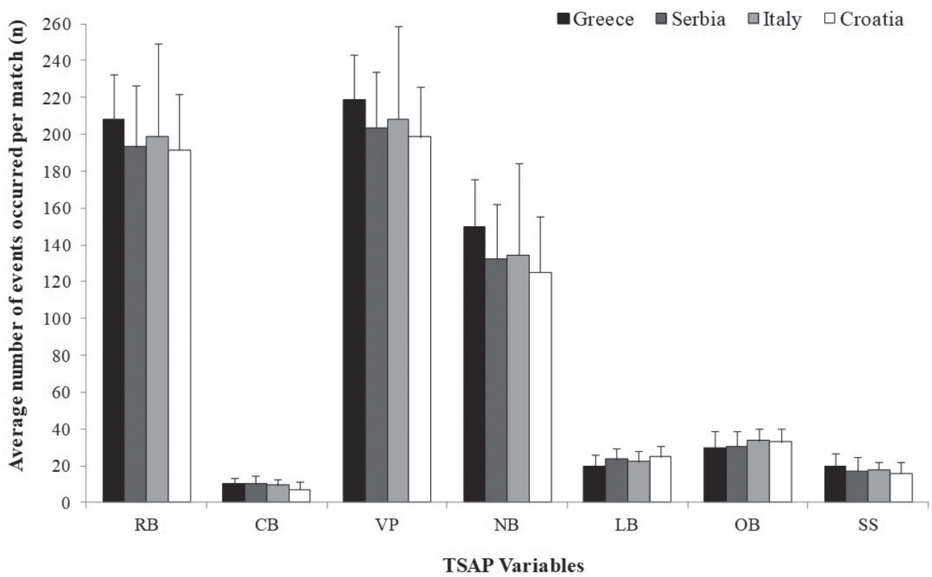

Figure 2. Comparison of the TSAP variables' mean values per match between national teams (Greece, Serbia, Italy and Croatia) (p>0.05); Note. RB= received balls; CB= conquered balls; VP= volume of play; NB= neutral balls; LB= lost balls; OB= offensive balls; SS= successful shots

Regardless the tournament phase, the one-way ANOVA showed no significant differences between national teams (Greek, Serbian, Italian and Croatian) for any of the TSAP parameters (Figure 2).

Through the analysis of the field zones, the pooled data showed that CB occurred more in the defensive half (n=270) of the field than in the offensive one (n=2). Contrariwise, the LB, OB and SS parameters have mainly occurred in the offensive half of the field (LB, n=647; OB, n=894; SS, n=495) compared to the defensive one (LB, n=11; OB, n=26; SS, n=13). Regarding the distribution of the zones of the field, for the defensive half zone -6 showed the highest number of CB occurred per match (n= 5±2), while for the offensive half zone 6 for LB (n=6±3), zone 2 for OB (n=7±3), and zone 6 for SS (n=6±4) showed the highest values. Instead, the one-way ANOVA showed significant differences (p<0.05) between the four teams for OB played in zone 1 (p=.019), in zone 2 (p=.014) and in zone 5 (p=.007) and for SS performed in zone 1 (p=.026) and in zone 2 (p=.008) (Table 3).

Table 3. Distribution of the frequency of occurance per match for the CB, LB, OB and SS parameters according to the zones of the field.

				DEFENSIVE HALF			
Parameters	Teams	Zone -1	Zone -2	Zone -3	Zone -4	Zone -5	Zone -6
CB	Greece	1.3±1.1	1.3±1.1	1.6±0.8	0.3±0.5	0.1±0.4	6.0±2.0
	Serbia	1.1±1.1	0.3±0.5	1.6±1.8	0.6±0.8	0.9±0.9	5.7±2.6
	Italy	0.8±0.7	1.0±1.0	1.9±1.7	0.4±0.8	0.1±0.4	5.3±2.3
	Croatia	0.7±1.0	0.9±0.8	0.7±1.0	0.1±0.4	0.7±0.9	4.0±2.6
				OFFENSIVE HALF			
Parameters	Teams	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
LB	Greece	2.3±2.0	2.9±1.9	5.7±2.8	3.0±1.6	2.6±1.4	3.4±2.4
	Serbia	2.4±1.6	5.3±2.4	5.1±2.6	3.9±2.4	1.6±1.7	4.7±1.9
	Italy	1.7±1.5	3.9±1.0	5.1±3.4	2.4±1.6	0.7±0.5	7.6±3.2
	Croatia	2.9±2.8	5.0±2.9	5.1±3.0	2.1±2.0	2.4±2.0	7.1±4.1
OB	Greece	4.7±1.7	4.9±2.4	7.3±1.9	3.6±2.8	3.6±2.4	5.3±4.1
	Serbia	3.9±2.4	8.7±2.9	6.4±3.3	3.3±3.2	1.9±1.7	4.0±1.5
	Italy	4.7±1.1	6.0±2.3	8.4±4.1	4.1±2.3	4.4±2.2	5.6±3.1
	Croatia	7.0±2.0	8.7±2.5	5.1±3.4	3.9±1.9	1.0±1.0	6.7±1.7
SS	Greece	1.1±1.0	1.7±1.6	5.0±2.8	2.6±1.1	2.1±1.7	6.9±3.0
	Serbia	1.4±0.9	3.3±1.5	4.4±2.4	1.1±0.7	2.4±1.7	4.1±3.2
	Italy	2.1±1.3	1.0±0.8	3.1±1.4	0.9±0.9	3.0±4.0	6.9±3.6
	Croatia	0.4±0.7	1.1±0.9	3.5±2.2	1.4±2.3	2.0±1.2	6.9±5.3

Note. CB= conquered balls; LB= lost balls; OB= offensive balls; SS= successful shots

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The analyses with pooled data (29 matches) by means of the independent t-Test showed significant differences between preliminary round (17 matches) and final round (12 matches) for CB (p=.038), LB (p=.048), OB (p=.013), SS (p=.000), EI (p=.002).

The difference of the number of goals scored by the two opponent teams per match showed that a margin of ≤3 goals (balanced) occurred in 11 matches (38%) while a margin >3 goals (unbalanced) occurred in 18 matches (62%). Regarding the analysis of match status in relation to the tournament phases, data showed that of the 11 balanced matches 18.2 % (n=2) and 88.6% (n=9) were registered during the preliminary and final phases, respectively; while of the 18 unbalanced matches 83.3% (n=15) and 16.7% (n=3) were registered during the preliminary and final phases, respectively. Moreover, the independent t-Test, showed a significant difference (p<0.05) between matches with balanced and unbalanced scores for RB (213±24 vs 188±37), CB (7±3 vs 10±4), NB (153±29 vs 124±33), LB (26±4 vs 20±6), SS (13±4 vs 20±6) and EI (1±0.5 vs 2±1), respectively.

The Pearson correlation with pooled data showed a positive very strong correlation between VP and NB (r=.957, p=.000) and a negative very strong correlation between LB and Goals Scored (r=-0.903, p= .000) (Figure 3). Strong correlations were also showed between OB and SS (r=.605, p=.001), Total Gained Exclusions and RB (r= 0.597, p= .001), CB and Goals Scored (r= 0.506, p=.005). Moderate correlation was found between Goals Conceded and LB (r=.387, p=.038), while negative moderate correlation was showed between NB and Goals Scored (r=.-496, p=.006).

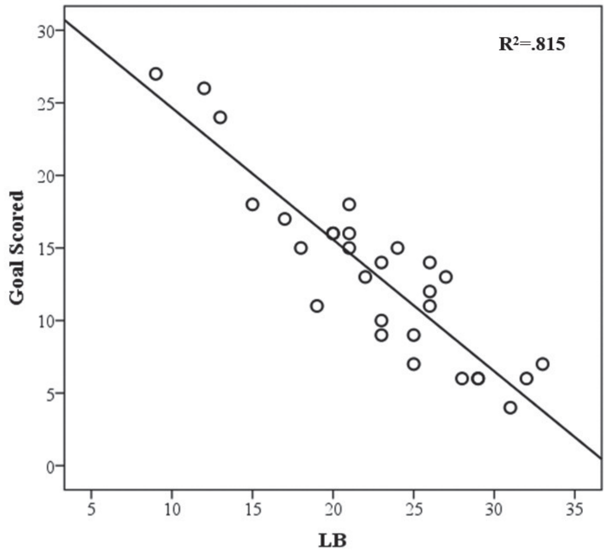

Figure 3. Pearson Correlation between LB and Goal scored (r=-.903); Note. LB= lost balls

Discussion

This study aimed to provide a technical and tactical analysis of offensive actions during international youth water polo competitions by means of the Team Sport Assessment Procedure instrument. The TSAP analysis has investigated the matches of the youth water polo national teams of Greece, Serbia, Italy and Croatia, which gained the first four placements at the 2019 FINA Men's Water Polo World Junior Championships (Kuwait City, Kuwait).

TSAP differences between teams and type of matches

The main findings showed that there were no significant differences between the four national teams for all TSAP parameters and indices. Nevertheless, the winner national team (Greece) showed higher mean scores per match for several parameters and indices (RB, n=208±24; CB, n=11±3; VP, n=219±24; SS, n=20±7; EI, n=2±1; PS, n=127±10) compared to the other three national teams. Furthermore, Greece showed the lowest score of LB per match (n=20±6), demonstrating a higher tactical awareness and ball possession ability compared to their opponents. The results of our winning team (Greek national team) confirm the findings of a previous study on elite and sub-elite men's water polo (Lupo et al., 2010), where the winning teams showed a higher duration of the even actions respect to the losing ones, speculating that winning teams were more able to maintain the ball possession and successively to defend their goal. When the analysis included the data distribution in relation to the different zones of the field, despite only OB and SS were significant, the four teams showed a different distribution of data. Such difference between the four national teams could be explained by the tactical behaviour of their coaches and the players' technical capabilities. In the World Junior Championships analysed in our study, the four national team coaches may have asked a different way to play NB and OB in relation to the gained position of their centre-forwards, and consequently according to the kind of defence adopted from each opponent teams. In fact, as suggested by Canossa et al. (2022), based on the new rules changes occurred at the international water polo level, a national team could adopt a more static or dynamic game that characterize its playing style. Therefore, these coaches' directions might have impacted on the distribution of the number of offensive passes in relation to the zone of the field influencing players' decision making and technical skills. In particular, the main reason of this difference between the four teams could be interpreted by the presence or not of a left-hand player in the game.

Anyway, considering the four national team pooled data, the zone -6 resulted to be the main position in which players conquered the possession of the ball (56% of the total

CB). Moreover, in zone 6, occurred the 26% of LB, as well as the 36% off SS, confirming this zone as the most dangerous position to score a goal in youth water polo matches, other than in senior elite level (Lupo et al., 2007). In addition, the 23% of OB took place in zone 2, demonstrating the relevance of this zone that is considered a 'play's construction' zone, where usually play 'perimetral' or 'wing' players. One of the main findings of this study, in line with previous ones (Lupo et al., 2012b), shows that the men's water polo matches of the World Junior Championships have mainly been characterized by the divergence between balanced (closed) and unbalanced games, as well as the comparison between preliminary and final rounds. Thus, it could be speculated that the game aspects of the youth elite men's water polo matches must be analyzed in relation to specific margins of results and the tournament phase (preliminary round or final round) and not only considering the winning or losing outcome.

TSAP parameters correlations

In terms of correlation, the results of this study suggest that for a team performing a higher value of VP doesn't mean to improve the possibility to score a goal compared to the opponent team. In fact, according to our results a higher value of VP improved only the number of NB, which were correlated with a decrease of the number of goals scored. Indeed, in youth water polo matches, the VP does not appear to be always a positive index, due to the strong correlation between RB and the total amount of gained exclusions occurring in a match. In fact, during a water polo match, it is widespread among coaches to ask their players not to rush to complete their attack and try to exchange the ball to find the best solution (Platanau & Varamenti, 2022). Furthermore, this aspect, could be explained by the fact that after an opponent exclusion (6 vs 5) players perform more passes, especially as NB, than during an even situation (6 vs 6). Our findings are in line with those of Platanau and Varamenti (2022), which demonstrated that the number of passes not always affect the scoring, especially in the power-play situations.

The results of our study, provide a useful indication for water polo coaches in terms of LB, showing how a higher number of LB decreases the number of goals scored and increases the number of goals conceded, confirming that the loss of ball possession might denote negative effects on the final outcome (Lupo et al., 2014b). Finally, our findings suggest that the number of CB and OB increase the number of goals scored, as in particular demonstrated by the Greece team (gold medal), which registered the highest values of TSAP parameters and indices between the four national teams.

Practical applications and future research perspectives

Based on our results, the use of TSAP instrument appears to produce an objective indication of teams' offensive performance in youth water polo matches. The findings from the analysis of the tournament could help to guide the training process along a championship or an entire season. In fact, this kind of monitorization could also offer productive feedback to coaches to perceive the different needs of playing, as well as to assess the way the players understand the game collectively or individually, for the purpose of adapt their planning and actions. Therefore, the coaching staff might use this information to establish common goals for trainings and matches of their teams. The coaches could have enough information to organize specific exercises, as small sided games, in their trainings to better reproduce the match situations (McCormick et al., 2012). Future directions of research could include individual scores and indexes of water polo players belonging the same team during a competitive season to see how all values changes according to the type of match and the period of the season.

Conflict of Interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

References

Blomqvist, M., Vänttinen, T., & Luhtanen, P. (2005). Assessment of secondary school students' decision-making and game-play ability in soccer. Physical Education and Sport Pedagogy, 10(2), 107-119. https://doi.org/10.1080/17408980500104992

Borges-Hernández, P. J., Argudo-Iturriaga, F. M., García-Marín, P., & Ruiz-Lara, E. (2022). Origin, evolution and influence on the game of water polo rules. Cultura, ciencia y deporte, 17(51). https://doi.org/10.12800/ccd.v17I51.1677

Botonis, P. G., Toubekis, A. G., & Platanou, T. I. (2018). Evaluation of physical fitness in water polo players according to playing level and positional role. Sports, 6(4), 157. https://doi.org/10.3390/sports6040157

Botonis, P. G., Toubekis, A. G., & Platanou, T. I. (2019a). Physiological and tactical on-court demands of water polo. The Journal of Strength & Conditioning Research, 33(11), 3188-3199. https://doi.org/10.1519/JSC.0000000000002680

Botonis, P. G., Toubekis, A. G., & Platanou, T. I. (2019b). Training loads, wellness and performance before and during tapering for a Water-Polo tournament. Journal of Human Kinetics, 66(1), 131-141. https://doi.org/10.2478/hukin-2018-0053

Canossa, S., Fernandes, R. J., Estriga, L., Abraldes, J. A., Lupo, C., & Garganta, J. M. (2022). Water Polo Offensive Methods after the 2018 FINA Rules Update. International Journal of Environmental Research and Public Health, 19(5), 2568. https://doi.org/10.3390/ijerph19052568

Catarino, L. M., Carvalho, H. M., & Gonçalves, C. E. (2017). Analysing tactical knowledge through team sport assessment procedure/TSAP: a case study in basketball. http://hdl.handle.net/10201/53150

Dimitric, G., Kontic, D., Versic, S., Scepanovic, T., & Zenic, N. (2022). Validity of the Swimming Capacities and Anthropometric Indices in Predicting the Long-Term Success of Male Water Polo Players: A Position-Specific Prospective Analysis over a Ten-Year Period. International journal of environmental research and public health, 19(8), 4463. https://doi.org/10.3390/ijerph19084463

García-Marín, P., & Argudo Iturriaga, F. M. (2017). Water polo: technical and tactical shot indicators between winners and losers according to the final score of the game. International Journal of Performance Analysis in Sport, 17(3), 334-349. https://doi.org/10.1080/24748668.2017.13

 DOI 10.26773/mjssm.230901

39258
Grehaigne, J. F., Godbout, P., & Bouthier, D. (1997). Performance assessment in team sports. Journal of teaching in Physical Education, 16(4), 500-516. https://doi.org/10.1123/jtpe.16.4.500
Light, R., & Georgakis, S. (2008). Invasion games in physical education: assessing knowledge-in-action in using the Team Sport Assessment Procedure. Authentic Assessment Practices for Student Learning.
Lupo, C., Tessitore, A., Cortis, C., Perroni, F., D'Artibale, E., & Capranica, L. (2007). Elite water polo: A technical and tactical analysis of the centre forward role. In Book of Abstracts 12th Annual Congress of the European College of Sport Science (pp. 468-468). Kallio J., Komi PV, Komulainen J., Avela J.-Department of Biology of Physical Activity and LIKES Reserach Center, University of Jyväskylä.
Lupo, C., Tessitore, A., Minganti, C., & Capranica, L. (2010). Notational analysis of elite and sub-elite water polo matches. The Journal of Strength & Conditioning Research, 24(1), 223-229. https://doi.org/10.1519/JSC.0b013e3181c27d36
Lupo, C., Tessitore, A., Minganti, C., King, B., Cortis, C., & Capranica, L. (2011). Notational analysis of American women's collegiate water polo matches. The Journal of Strength & Conditioning Research, 25(3), 753-757. https://doi.org/10.1519/JSC.0b013e3181cc245c
Lupo, C., Minganti, C., Cortis, C., Perroni, F., Capranica, L., & Tessitore, A. (2012a). Effects of competition level on the centre forward role of men's water polo. Journal of Sports Sciences, 30(9), 889-897. https://doi.org/10.1080/02640414.2012.679673
Lupo, C., Condello, G., & Tessitore, A. (2012b). Notational analysis of elite men's water polo related to specific margins of victory. Journal of sports science & medicine, 11(3), 516.
Lupo, C., Capranica, L., & Tessitore, A. (2014a). The validity of the session-RPE method for quantifying training load in water polo. International journal of sports physiology and performance, 9(4), 656-660. https://doi.org/10.1123/ijspp.2013-0297
Lupo, C., Condello, G., Capranica, L., & Tessitore, A. (2014b). Women's water polo World Championships: Technical and tactical aspects of winning and losing teams in close and unbalanced games. The Journal of Strength & Conditioning Research, 28(1), 210-222. https://doi.org/10.1519/JSC.0b013e3182955d90
McCormick, B. T., Hannon, J. C., Newton, M., Shultz, B., Miller, N., & Young, W. (2012). Comparison of physical activity in small-sided basketball games versus full-sided games. International Journal of Sports Science & Coaching, 7(4), 689-697. https://doi.org/10.1260/1747-9541.7.4.689
Nadeau, L., Richard, J. F., & Godbout, P. (2008). The validity and reliability of a performance assessment procedure in ice hockey. Physical Education and Sport Pedagogy, 13(1), 65-83. https://doi.org/10.1080/17408980701444718
Perazzetti, A., & Tessitore, A. (2021). USE OF TEAM SPORT ASSESSMENT PROCEDURE (TSAP) IN WATER POLO: ANALYSIS OF YOUTH INTERNATIONAL TEAMS. In Book of Proceedings (p. 32).
Perazzetti, A., Dopsaj, M., & Tessitore, A. (2022). ANALYSIS OF DIFFERENT SWIMMING ABILITIES IN YOUTH WATER POLO PLAYERS AND ITS COMPARISON IN TWO AGE CATEGORIES. In 15th Conference Of Baltic Society Of Sport Sciences (p. 72).
Platanou, T., & Varamenti, E. (2022). Impact of ball possession time and number of passes on the efficiency of scoring in men's water polo. Human Movement, 24 (2). https://doi.org/10.5114/hm.2023.114910
Richard, J.-F., Godbout, P. & Grèhaigne, J.-F. (2000) Students' Precision and Interobserver Reliability of Performance Assessment in Team Sports. Research Quarterly for Exercise and Sport, 71(1), 85-91. https://doi.org/10.1080/02701367.2000.10608885
Richard, J. F., & Griffin, L. L. (2002). Assessing game performance: an introduction to the team sport assesment procedure (TSAP). Physical & Health Education Journal, 68(1), 12.
Ruano, M. Á., Serna, A. D., Lupo, C., & Sampaio, J. E. (2016). Effects of game location, quality of opposition, and starting quarter score in the outcome of elite water polo quarters. The Journal of Strength & Conditioning Research, 30(4), 1014-1020. https://doi.org/10.1519/JSC.0b013e3182aa5f59
Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: appropriate use and interpretation. Anesthesia & analgesia, 126(5), 1763-1768. https://doi.org/10.1213/ANE.0000000000002864
Smith, H. K. (1998). Applied physiology of water polo. Sports medicine, 26(5), 317-334. https://doi.org/10.2165/00007256-199826050-00003

ORIGINAL SCIENTIFIC PAPER

Attainment of the Health Outcomes by Implementing Educational Videos During the Final Part of the Physical Education Lesson

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Abstract

This study investigated the impact of educational video content in the final part of the PE lesson on students' health literacy and their perceptions of the usefulness and satisfaction of PE lessons. The study included 160 students in grades 6 to 8 from an elementary school in Croatia, with an average age of 13.75 years, of which 93 (58%) were female. The experimental group (n=111) participated in the PE lessons with educational video content, while the control group (n=49) participated in the standard PE lesson. At the beginning and at the end of the research, both groups completed a theoretical written knowledge test on health literacy and a questionnaire to assess attitudes towards PE lessons. An ANCOVA was used to measure the impact of the experimental programme on post-intervention results while including initial results as a covariate. After the experiment, statistically significant differences were observed between the results of the experimental and control groups of students for Theoretical knowledge (9.90±0.29 vs. 8.33±0.43, $F(1,159) = 8.998$, $p = 0.003$) and Perception of the usefulness of PE lessons (2.93±0.06 vs 2.69±0.09, $F(1,163) = 4.434$, $p = 0.037$), while no statistically significant differences were observed for Satisfaction with PE lessons (2.95±0, 09 vs. 3.02±0.06, $p = 0.553$). The intervention positively affected students' knowledge and perception of PE lessons without impairing their satisfaction, indicating that integrating educational video content into PE lessons connecting physical activity and health literacy is viable.

Keywords: *health literacy, usefulness, satisfaction, attitude, elementary school*

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Introduction

Physical activity, like any physical movement produced by the skeletal muscles, which results in energy consumption above the level of consumption at rest, is a natural human need. It is necessary for preserving and improving health (Caspersen et al., 1985).

Guthold et al. (2020) reported that 81.0% of students aged 11-17 were not physically active, with 77.6% of male and 84.7% of female students falling into this category. To address this alarming trend, it is crucial to use Physical Education (PE) lessons in primary and secondary schools, which are mandatory components of the education system. PE classes can shape

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the outlook of children and adolescents towards physical activity and health due to their convenient availability as a mode of exercise. Therefore, PE lessons should be used to influence students positively, as they can reach all children (Lepir et al., 2020). Also, continuing physical activity beyond high school is important. Peralta et al. (2021) found positive correlation between physical activity and student well-being. This underscores the significance of maintaining an active lifestyle beyond high school and underscores the necessity for programs that address the issue of physical inactivity.

While the curricula of PE courses may vary across countries, the goals of PE are relatively uniform and are implemented in a similar manner in schools worldwide. A significant aspect of PE objectives is focused on educating children about healthy behaviors that can facilitate lifelong physical activity (Marttinen et al., 2018). Promoting responsible and protective behavior among children and adolescents can contribute to creating a safer and healthier community by ensuring their own safety and that of others (Curriculum for the cross-curricular topic of Health for primary and secondary schools in the Republic of Croatia, 2019).

The educational system in Croatia's primary and secondary schools is based on meeting the educational objectives outlined in the national curriculum for each subject. In addition to meeting the outcomes of the subject, all the teachers and professional associates also participate in the realization of educational expectations of cross-curricular topics. Cross-curricular topics are realised by connecting educational areas and teaching topics of all subjects. Of all defined cross-curricular topics, PE teachers plan to achieve the highest number of outcomes related to health literacy (Curriculum for the subject of physical and health education for elementary schools and high schools in the Republic of Croatia, 2019; Curriculum for the cross-curricular topic of Health for primary and secondary schools in the Republic of Croatia, 2019). The theme's emphasis is on a comprehensive approach to health as "physical, mental, and social well-being, not just the absence of disease" (WHO, 2006).

The development of health literacy means acquiring and developing positive thinking about health and a healthy lifestyle. To achieve the purpose of learning and teaching, it is important to convey knowledge to students in an understandable and interesting way. To achieve the desired health outcomes, it is important to incorporate theoretical knowledge about health literacy into PE lessons, as motor knowledge is mainly applied in this context (Curriculum for the subject of physical and health education for elementary and high schools in the Republic of Croatia, 2019; Curriculum for the cross-curricular topic of Health for primary and secondary schools in the Republic of Croatia, 2019).

PE lessons, like other subjects of the school curriculum, deal with learning and student development. However, physical education has the advantage of learning from physical experience. Hence, it is crucial to take note that students' beliefs and evaluations towards physical education are influenced by how they perceive their experiences (Silverman & Subramaniam, 1999). When the physical experience in class is evaluated in a positive way, students' attitudes reflect a greater willingness to repeat the experience. If these experiences are negative, it is likely that students will try to avoid these activities (Hopple & Graham, 1995). Altering one's attitude is not a simple task, although it can be achieved. Understanding how and to what extent attitudes can be changed enables teachers to influence the improvement of their students' attitudes, in this case on physical activity (Marttinen et al., 2018).

Sucuoglu and Atamturk (2020) explained in their empirical research that attitude theory explains attitudes through one-, two-, and multicomponent models. The first model deals only with emotions, the last multicomponent model deals with emotions, cognitive aspects, and behaviours, and the two-component model, which includes Student's Attitudes Toward Physical Education - SATPE, deals with emotions and cognitive aspects (Subramaniam & Silverman, 2000). The emotional component refers to satisfaction with lessons, and the second, cognitive component, to the perception of the usefulness of lessons (Subramaniam & Silverman, 2000).

Research indicates that most students have a favorable opinion about physical education classes (Silverman & Subramaniam, 1999; Subramaniam & Silverman, 2007; Papla et al., 2019; Phillips & Silverman, 2015), but the average attitude score declines with an increase in grade level (Subramaniam & Silverman, 2007; Philips & Silverman, 2015), particularly for girls (Mercier et al., 2017; Säfvenbom et al., 2014). Phillips and Silverman (2015) found that in the fourth and fifth grade, both male and female students had similar attitudes towards physical education, and research findings suggest that gender differences in attitudes start to emerge after the fifth grade. Their study also indicates that the teacher and curriculum can impact students' attitudes toward this subject. According to Shropshire et al. (1997), boys tend to display slightly higher levels of enthusiasm or interest in physical education. These findings are supported by the Carcamo-Oyarzun et al. (2022) review of previous research.

The use of video materials in classes has been shown to be effective (Podnar, Novak & Radman, 2018). Furthermore, video-based teaching has been found to engage students, leading to more favorable attitudes toward physical activity (Mok et al., 2020) and improved achievement of desired objectives (Mashari and S, 2021). While Kovac et al. (2021) highlighted teachers' lack of competence in utilizing technology for teaching, they also found that teachers felt confident in their understanding of the health aspects of physical activity. To address this, it is crucial to educate teachers on the significance of technology and its potential to enhance the health aspects of physical activity.

Therefore, the main objective of this study is to investigate the impact of integrating educational video content into the final part of Physical Education (PE) classes on achieving health outcomes, as well as improving the students' perception of the usefulness and satisfaction of the PE lessons. It is hypothesized that intervention will improve theoretical knowledge about health literacy and perception of the usefulness and students' satisfaction with PE lessons.

Methods

Participants

A total of 160 students in grades 6 to 8, with an average age of 13.75 years, and 93 of them (58%) were female, participated in the study. Students were selected from an elementary school in Croatia and divided into four experimental classes (n=111) and two control classes (n=49) through random selection. During the six-week study period, the experimental group watched 3-5 minute educational videos that connected physical exercise with health literacy in the final part of their PE lessons. On the contrary, the control group participated in regular PE classes that focused exclusively on physical activities. The study was approved by the Ethics Committee of the

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Faculty of Kinesiology of the University of Zagreb, Croatia. Each participant and their parents provided their informed written consent before participating.

Study protocol

Six classes were randomly assigned to either the control or experimental group, and in the initial lesson, all classes received instructions on the required procedures, with a reminder that data collection would be anonymous. At the beginning of the study, both groups completed a theoretical written knowledge test on health literacy and a questionnaire to evaluate their attitudes toward PE lessons. During six weeks, in the final part of the PE lesson, the experimental group watched and implemented educational video content related to the realization of the outcome of that day. The video showed the stretching exercises that the students performed and important information on health outcomes. This was accompanied by an audio description of the outcome with an explanation. A new video was shown in each class, with a total of six videos. The same six videos were repeated during the final three weeks of the study. Following each video, the experimental group answered a few questions related to the day's topic in a short theoretical test. After answering all the questions and submitting the completed form, the students were shown the correct answers with explanations. The control group continued with the usual PE lessons. After six weeks, both groups completed both questionnaires, i.e. the knowledge test and the attitude assessment questionnaire.

Instruments and Variables

To assess the achievement of health outcomes, a theoretical written knowledge test on health literacy was conducted. The test consisted of a total of 13 questions that the students solved using a Google form. There were two questions for each of the six topics that the students listened to and watched using video content, while for one topic there were a total of three questions. For each question, students were offered four possible answers, a, b, c, and d, and they could choose only one correct answer and get one point for it. This means that they could achieve a maximum of 13 points. To assess the perception of usefulness and satisfaction with PE lessons, the Croatian version of the attitude assessment questionnaire for PE lessons (Subramaniama & Silvermana 2000) was applied. The questionnaire was conducted using a Google form and comprised 20 questions, of which 10 pertained to perception of the usefulness of PE lessons and the other 10 were related to satisfaction with PE lessons. The students provided their responses to the questions using a Likert scale: 1 – completely disagree, 2 – partially disagree, 3 – neither agree nor disagree, 4 – partially agree, 5 – completely agree.

Statistical analyses

Data collected from the theoretical written knowledge test on health literacy were analyzed using descriptive statistics, and the results were presented visually and compared using the provided displays.

In addition, an analysis of covariance (ANCOVA) was conducted to assess the impact of the experimental program on the final measurements of students' perception of usefulness and satisfaction with PE lessons, with the initial measurements used as a covariate.

Results

The descriptive statistics for the results of the health literacy knowledge test, classified by the control and experimental groups, are presented in Table 1. The results of the written theory knowledge test taken by both groups at the initial and final measurements are presented in Figure 1.

Table 1. Descriptive Statistics of the Theoretical Written Test in Knowledge About Health Literacy

		Valid N	Mean	Min	Max	SD
Initial	E	115	6.92	1.00	11.00	2.06
	C	55	6.56	2.00	10.00	1.94
Final	E	111	9.90	1.00	13.00	3.15
	C	49	8.33	2.00	13.00	2.64

Note: E - experimental group, C - control group

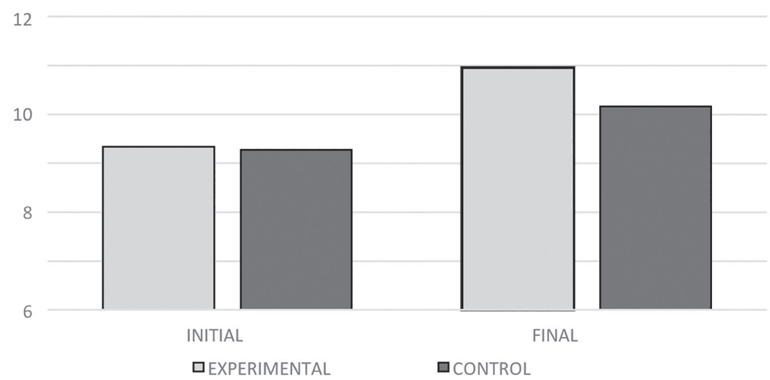

Figure 1. Results of the theoretical written test on knowledge about health literacy

In the initial measurement of the theoretical written knowledge test on health literacy, the experimental group comprised 115 students, while the control group comprised of 55 students. The difference in the average values of the correct answers between the two groups was minimal. The mean score for the experimental group was 6.92, with a standard deviation of ±2.06, while the control group had a slightly lower mean score of 6.56 ±1.94. The comparison of mean scores between the experimental and control groups at the initial measurement is presented in Figure 1.

The differences in the average values to the correct answers of the written final measurement in the theoretical knowledge test on health literacy of the control and experimental groups are not negligible in this case. In Figure 1, it can be seen that, in contrast to the results of the arithmetic means of the initial measurement, the value of the arithmetic mean of the experimental group differs significantly from the value of the arithmetic mean of the control group. The arithmetic mean of the correct answers of the control group is now 8.33±2.64, while it is slightly higher in the experimental group and amounts to 9.90±3.15.

A one-way ANCOVA was utilised to assess whether the experimental programme had an impact on post-intervention scores after controlling for pre-intervention scores.

The experimental group exhibited higher adjusted mean scores for theoretical knowledge (9.90 ± 0.29) compared to the control group (8.33 ± 0.43). Furthermore, when accounting for pre-intervention scores, a significant disparity in post-intervention scores was found for the Perception of Usefulness of PE Lessons, as indicated by an F-value of (1, 159) = 8.998 and a p-value of .003. Table 2 presents these findings.

The observed differences in the arithmetic means between the experimental and control groups suggest that the use of educational videos had a beneficial impact on the knowledge of students in the experimental group.

Table 2. Control and Experimental Adjusted Means and Variability for Post-Intervention Scores With Pre-Intervention Scores as a Covariate – Theoretical Knowledge

Component	Control (M±SE) n=96	Experimental (M±SE) n=186	F	p
Knowledge	8.33±0.43	9.90±0.29	8.998	.003

Note: M=Mean, SE=Standard Deviation

Tables 2 and 3 show the average results of the final measurement in the experimental and control groups. The result is shown as the arithmetic mean of all students with a possible standard deviation. In addition, the table lists the results of the statistical analysis F and p. The level of statistical significance is set at $p < 0.05$.

Students' Satisfaction with PE lessons adjusted post-intervention mean scores were similar for the control (2.95±0.09) and the experimental (3.02±0.06) group. Controlling for pre-intervention scores, the post-intervention scores for Satisfaction with PE classes did not show any statistically significant differences, as indicated by F (1, 163) = .353 and p = .553, according to Table 3.

Table 3. Control and Experimental Adjusted Means and Variability for Post-Intervention Scores With Pre-Intervention Scores as a Covariate – Satisfaction and Perception of Usefulness

Component	Control (M±SE) n=43	Experimental (M±SE) n=121	F	p
Satisfaction with PE lessons	2.95±0.09	3.02±0.06	.353	.553
Perception of PE usefulness	2.69±0.09	2.93±0.06	4.434	.037

Note: M=Mean, SE=Standard Error

Higher adjusted post-intervention mean scores were found for experimental (2.93±0.06) than for control (2.69±0.09) group for Perception of PE Usefulness. After controlling pre-intervention scores, there was a statistically significant difference in post-intervention scores for Perception of PE usefulness, F (1, 163) = 4.434, p = .037 (Table 3.)

By looking at the results of the experiment listed in Tables 2 and 3, it can be determined that the mentioned intervention had a positive effect on students' knowledge and their perception of usefulness of PE lessons, while their satisfaction with PE lessons was not impaired.

Discussion

The purpose of this research was to examine the impact of including educational content in the final phase of physical education (PE) classes, which integrates theoretical health knowledge with physical activity, on students in grades 6 to 8 attending an elementary school. The study aimed to measure the impact on the achievement of health outcomes, as well as on improving the perception of the usefulness and satisfaction of PE lessons. During the experiment, the experimental group watched 3-5 minute educational videos related to the day's learning objectives, while the control group attended conventional PE lessons with exercise content alone. At the beginning and end of the study, both groups completed a written test on health literacy and a questionnaire to evaluate their attitudes toward PE lessons. Additionally, after watching each video, the experimental group completed a brief theoretical knowledge test with questions regarding the day's topic.

In their review of the literature, Subramaniam and Silverman (2007) determined that students' attitudes can affect their learning. They also noted that a positive and supportive learning environment can enhance students' attitudes toward learning (Subramaniam & Silverman, 2007). After conducting a literature review, Silverman and Mercier (2015) concluded that several factors affect students' attitudes toward physical education, with the teacher and curriculum being the most prominent ones. Teacher interactions and decision-making in class can have a significant impact on students' attitudes towards PE lessons. Effective communication, respect for students, and promotion of knowledge are crucial for shaping positive attitudes. If students feel unsupported or incapable of succeeding in the classroom, they may view the teacher as unsupportive or unhelpful. In such cases, the teacher may not be seen as an ally by the students (Silverman & Mercier, 2015).

The results of the intervention indicate that by changing the way certain curriculum topics are presented, the

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students' attitudes toward PE have also positively changed. Phillips et al. (2020) went in the same direction in their research, in which they found that if the way the curriculum is implemented does not change, but the same contents are continuously implemented, students' attitudes will become increasingly negative. After six weeks of intervention, including interesting educational content related to health literacy, the students' perception of the usefulness of PE lessons improved.

According to Phillips et al. (2020), students may consider PE a less important or less useful subject if they do not learn anything in class. In their research, many students expressed dissatisfaction with the lack of learning in PE lessons, which may be the cause of more negative attitudes toward the subject. Subramaniam and Silverman (2002) showed that the students who had a more positive attitude towards PE were those who believed that they had learnt from the material and that they felt that the class was useful. The findings of this study confirm this relationship, as they reveal that the knowledge of the experimental group improved, which can relate to the increase in the perception of the usefulness of PE lessons.

The intervention implemented managed, as far as the perception of usefulness is concerned, to improve the students' attitudes towards PE lessons, but it did not affect the students' satisfaction with them. Previous studies have shown a positive correlation between students' positive attitudes towards PE lessons and their satisfaction with them. This suggests that higher levels of satisfaction with PE lessons could promote positive attitudes towards physical exercise and potentially motivate students to lead a more active lifestyle beyond school (Subramaniam & Silverman, 2007). The impact on students' attitudes toward physical activity through the PE curriculum is the first step in guiding students toward a healthy and active lifestyle, now and in the future.

There are several limitations to this study that must be considered. First, the sample size used was relatively small, which means that the results cannot be generalized to all students in the country. Additionally, the intervention period could have been longer, which may have produced more meaningful results. The study did not consider sociocultural factors, such as participation in sports activities during free time, which could have influenced knowledge about health literacy.

To address these limitations, future research should utilise more comprehensive measures to examine knowledge about health literacy, rather than relying solely on theoretical tests. Additionally, including a larger and more diverse sample size would allow for generalization of findings to a broader population. Furthermore, future research should consider sociocultural factors that can impact health literacy, and incorporate these factors into the study design.

Conclusion

The implemented intervention, which consisted of conducting 3-5-minute-long educational video content tried to improve students' knowledge about health literacy and improve their perception of usefulness and satisfaction with PE lessons.

According to the results, the intervention had a beneficial impact on the students' knowledge and their perception of the value of PE lessons. Additionally, the intervention did not diminish their satisfaction with the PE lessons. Therefore, these results suggest that the incorporation of educational videos that link exercise activities with theoretical knowledge of health literacy can be incorporated into daily PE lessons without any concerns about negatively affecting the students.

References

Carcamo-Oyarzun, J., Wydra, G., Hernandez-Mosqueira, C., Martinez-Salazar, C., & Souza de Carvalho, R. (2022). Attitudes towards physical education teachers from a cross-cultural perspective: German and Chilean students' viewpoints. *Cultura, Ciencia Y Deporte*, *17*(51). https://doi.org/10.12800/ccd.v17i51.1614

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public health reports (Washington, D.C.: 1974)*, *100*(2), 126–131.

Curriculum for the cross-curricular topic of Health for primary and secondary schools in the Republic of Croatia, 2019. Available at: https://mzo.gov.hr/istaknute-teme/odgoj-i- obrazovanje/nacionalni-kurikulum/medjupredmetne-teme/kurikulum-medjupredmetne- teme-zdravlje-za-osnovne-i-srednje-skole/3859

Curriculum for the subject of physical and health education for elementary schools and high schools in the Republic of Croatia, 2019. Available at: https://skolazazivot.hr/wp-content/uploads/2020/06/TZK_kurikulum.pdf

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *The Lancet. Child & adolescent health*, *4*(1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2

Hopple, C., & Graham, G. (1995). What Children Think, Feel, and Know about Physical Fitness Testing, *Journal of Teaching in Physical Education*, *14*(4), 408-417.

Kovac, K., Leskosek, B., Jurak, G., Marinsek, M., & Tul, M. (2021). Differences in Subject-Specific Competences between Slovenian and Italian Physical Education Teachers. *Montenegrin Journal of Sports Science and Medicine, 10*(2), 53-58. doi: 10.26773/mjssm.210908

Lepir, D., Pajkić, A., & Sekulić, Ž. (2020). Attitudes of primary school students toward physical education: Age and gender specifics. *Fizička kultura*, *74*(2), 152-161. http://dx.doi.org/10.5937/fizkul74-30164

Marttinen, R., Fredrick III, R. N., & Silverman, S. (2018). Changes in student attitude toward physical education across a unit of instruction. *Journal of Physical Education and Sport*, *18*(1), 62-70. http://dx.doi.org/10.7752/jpes.2018.01008

Mashari, M., & S, A. (2021, January 30). IMPROVING LEARNING OUTCOMES OF PHYSICAL EDUCATION USING MULTIMEDIA TECHNOLOGY IN 4.0 ERA. Acitya: *Journal of Teaching and Education, 3*(1), 27-33. https://doi.org/10.30650/ajte.v3i1.1409

Mercier, K., C. Donovan, A. Gibbone, and K. Rozga. 2017. "Three-year Study of Students' Attitudes Toward Physical Education: Grades 4–8." *Research Quarterly for Exercise and Sport 88* 3): 307-315. doi:10.1080/02701367.2017.1339862

Mok, M., M., C., Chin, M., Korcz, A., Popeska, B., Edginton, C.R., Uzunoz, F.,S., Podnar, H., Coetzee, D., Georgescu, L., Emeljanovas, A., Pasic, M., Balasekaran, G., Anderson, E. & Durstine, J.,L. (2020). Brain breaks® physical activity solutions in the classroom and on attitudes toward physical activity: A randomized controlled trial among primary students from eight countries. *International Journal of Environmental Research and Public Health, 17*(5), 1666. https://doi.org/10.3390/ijerph17051666

Papla, M., Wojdała, G., Rasek, J., Królikowska, P., Starzak, J., & Górna-Łukasik, K. (2019). Attitudes towards physical education lessons in students at different levels of education. *Journal of Education, Health and Sport, 9*(4), 301–316. Retrieved from https://apcz.umk.pl/JEHS/article/view/6809

Peralta, M., Santos, J., Bordado, J., Henriques-Neto, D., Martins, J., Cruz, P., Gouveia, E.R., & Marques, A. (2021). Participation in Physical Activity is Associated with Well-being in European University Students. *Montenegrin Journal of Sports Science and Medicine, 10*(2), 41-46. doi: 10.26773/mjssm.210906

Phillips, S. R., & Silverman, S. (2015). Upper elementary school student attitudes toward Physical Education. *Journal of Teaching in Physical Education, 34*(3), 461–473. http://dx.doi.org/10.1123/jtpe.2014-0022

Phillips, S., R., Marttinen, R., Mercier, K., & Gibbone, A. (2020). Middle school students' perceptions of physical education: A qualitative look. *Journal of Teaching in Physical Education*, *40*(1), 30-38.30-38. http://dx.doi.org/10.1123/jtpe.2019-0085

Podnar, H., Novak, D. & Radman, I. (2018). Effects of a 5-minute classroom-based physical activity on on-task behaviour and physical activity levels. Kinesiology, 50. (2.), 251-259. https://doi.org/10.26582/k.50.2.17

Säfvenbom, R., Haugen, T., & Bulie, M. (2014). Attitudes toward and motivation for PE. Who collects the benefits of the subject? *Physical education and sport pedagogy*, *20*(6), 629- 646. https://psycnet.apa.org/doi/10.1080/17408989.2014.892063

Shropshire, J., Carroll, B., Yim, S. (1997). Primary School Children's Attitudes to Physical Education: Gender Differences. *European Journal of Physical Education, 2(*1), 23–38. doi:10.1080/1740898970020103

Silverman, S. & Mercier, K. (2015). Teaching for physical literacy: Implications to instructional design and PETE. *Journal of Sport and Health Science, 4*(2), 150–155. doi:10.1016/j.jshs.2015.03.003

Silverman, S., & Subramaniam, P. R. (1999). Student attitude toward physical education and physical activity: A review of measurement issues and outcomes. *Journal of teaching in physical education*, *19*(1), 97-125. http://dx.doi.org/10.1123/jtpe.19.1.97

Subramaniam, P. R., & Silverman, S. (2000). Validation of scores from an instrument assessing student attitude toward physical education. *Measurement in physical education and exercise science*, *4*(1), 29-43. https://doi.org/10.1207/S15327841Mpee0401_4

Subramaniam, P. R., & Silverman, S. (2007). Middle school students' attitudes toward physical education. *Teaching and Teacher Education, 23*(5), 602–611. https://doi.org/10.1016/j.tate.2007.02.003

Sucuoglu, E., & Atamturk, H. (2020). Correlation relation between professional qualifications of physical education teachers and students' attitudes towards Physical Education classes. *Pedagogy of physical culture and sports*, *24*(1), 44-47. https://doi.org/10.15561/26649837.2020.0107

WHO (October 2006). *Constitution of the World Health Organization*. Available at: https://cdn.who.int/media/docs/default-source/documents/publications/basic-documents-constitution-of-who179f0d3d-a613-4760-8801-811dfce250af.pdf?sfvrsn=e8fb384f_1&download=true

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ORIGINAL SCIENTIFIC PAPER

The Effect of an Exercise Program on the Biomechanics of the Shoulder Girdle in Overhead Shooting in High-level Handball Players

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Abstract

Handball athletes are subjected to high loads, especially during the process of throwing or shooting overhead. These athletes often complain of pain and report unexplained loss of throwing velocity and throwing control. Shoulder dyskinesia and overuse syndrome have been identified as risk factors among elite handball athletes. Understanding the dynamics and kinematics of the throwing phase is vital for the exercise professional. This study evaluates the effect of an interventional exercise program on shoulder girdle biomechanics and overhead shooting. The sample consisted of 20 high level handball athletes from Greece. The athletes were divided into two groups: 10 in the study group, who were given the exercise program, and 10 in the control group, who only engaged in in-team handball training. Before and after the program, the following measurements were performed: a) angular measurements of abduction, adduction, flexion and extension of the shoulder; b) isokinetic evaluation of abduction flexion and adduction extension of the shoulder joint, at three angular velocities (60°/sec, 180°/sec and 300°/sec). Inferential statistics showed that there was a statistically significant difference in angular measurements with a reduction in range of motion for 10 of the study group. In the isokinetic assessment there was a statistically significant difference, in the 180°/sec velocities in flexion and extension, and in the deficit of flexion of both shoulders. In conclusion, the interventional exercise program had, to some extent, a beneficial effect on muscle strengthening of the shoulder girdle. The results of this study may suggest training guidelines, provide important information to exercise professionals, and provide feedback to handball athletes.

Keywords: *handball, goniometry, isokinetic dynamometry, shoulder girdle, biomechanics, scapular dyskinesia*

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Introduction

The majority of shoulder injuries in handball are caused by repetitive overhead activities leading to overuse injuries rather than a single traumatic mechanism (Landreau, Zumstein, Lubiatowski, &Laver, 2018). Werner and Plancher (1998) report that due to continuous throwing and repetitive wrist flexion and extension and radial and ulnar variations, overuse injuries occur in the upper extremities. The most common symptom in these injuries in athletes is chronic shoulder pain. These athletes, despite developing overuse injuries, continue to participate in the sport. Reckling et al. (2003), in a study of contact sports, observed that 53% of injuries occur during a game and are caused by an opponent, while only 3% are caused by a teammate. The shoulders (44.0%) and knee (26.7%) were the body areas most affected by overuse injuries (Giroto et al, 2017). It was also observed that in backcourt and extreme players, a high percentage of injuries were located in the upper extremities (shoulder or arm), with the majority of these athletes (89%), showing symptoms of overuse injuries in the shoulder (Seil, Rupp, Tempelhof, & Kohn, 1998).

When we raise our arm up to perform any activity, the scapula makes an upward rotational movement, accompanying and supporting the arm in its elevation. In order for this movement of the scapula to take place, several muscles are activated, such as the serratus anterior , upper, middle and lower trapezius (Kapandji, 2021). Many studies report that some of the muscles that move the scapula and stabilize the shoulder are not activated in the correct order (Mascarin, de Lira, Vancini, de CastroPochini, daSilva, & dos Santos Andrade, 2017; Kibler, Stone, Zacharias, Grantham&Sciascia, 2021; Henry, Spigelman, Sabin, &Sciascia2021). Altered patterns of muscle activity, reduced strength levels, and changes in the timing properties of the serratus anterior, upper, middle, and lower trapezius appear to create a problem in the region (Castelein, Cools, Parlevliet, &Cagnie, 2017). In its attempt to ensure normal function of the upper limb, the nervous system, over activates early, the upper trapezius combined with reduced strength of the serratus anterior, reduced activity and delayed activation of the middle and lower trapezius creating a muscular imbalance. When this coordinated movement occurs, certain muscles work harder, causing pain in the shoulder, scapula, and neck area (Ekstrom, Donatelli, &Soderberg, 2003). Inextricably linked to smooth shoulder function is the harmoniously regulated function of the scapula. Dyskinesia of the scapula is also associated with various pathologies of the shoulder, when there is a disturbance in some part of the above mechanism. Rapidly repeated, high mechanical loads of muscle activation are required, which the scapula is called upon to cope with. In the throwing phase, maximum flexion and abduction is ensured by a stabilized scapula (Smith, Dietrich, Kotajarvi, & Kaufman, 2006). This dynamic movement of the scapula, combined with the movement of the humerus, achieves precision movements and positions. The compression mechanism in the scapula cavity is maximized, reducing the internal impact created and thus minimizing stress on the whole joint. All of this miraculous mechanism is essential to the completion and success of the overhead throw (Sheean, Kibler, Conway, & Bradley, 2020). Although changes in scapular motion may be common in athletes throwing overhead, several reports have shown that recognizing and managing the changes can lead to improved recovery and performance outcomes (Tsuruike, Ellenbecker, & Lauffenburger, 2020; Andersson, Bahr, Clarsen, Myclebust 2017; Cools, Dewitte, Lanszweert, Notabaert, Roets, Soetens, Cagnie, Witvrouw 2007; Kibler, Stone, Zacharias, Grantham & Sciascia, 2021). Therefore, assessment and management starting at the scapula may produce improved outcomes related to shoulder pathology in overhead throwing athletes (Kibler, et.al. 2021). This led to the main objective of this study, which was to evaluate the effect of an exercise program designed to reduce the risk of shoulder injuries and problems in handball athletes.

Methods

Subjects

The study included female and male athletes who reported pain or dyskinesia of the shoulder blade. The study was conducted in adult athletes of the A1 handball league in Greece. Specifically, questionnaires were given to the men's teams PAOK, AESX Pylaia, PAS FOIVOS Sykes, GAS Kilkis, Phillipos Veria, AEROPOS Edessa, DRAMA 1986, ZAFEIRAKIS Naoussa. As well as the women's teams, PAOK, AEP Panorama, AESX Pylaia, VEROIA 2017, AO Prosotsani, OFN Ionia. Inclusion criteria: Athletes who had a history of shoulder or scapula pain in the past 6 months. Exclusion criteria: Athletes who had 1) a history of shoulder dislocation, fracture, or shoulder surgery in the past year, 2) intravascular injections in the shoulder in the past 3 months, 3) a history of neck or upper extremity injury in the past month, 4) cervical spine disease or a neurological disorder that may affect shoulder movement; 5) scoliosis or excessive kyphosis and 6) pain during the measurement procedure that may interfere with the measurement procedure.

Variables

Goniometry: the goniometry measurements taken were abduction, adduction in the standing position and extension, flexion of the scapula in the prone and supine positions. Measurements were made with a Myrin goniometer/clinometer (item no. 711432, Bålsta, Sweden). The purpose of the goniometry measurements was to record the range of motion of both shoulders.

Isokinetic dynamometry: the purpose of the isokinetic assessment was to measure the strength of the shoulder muscles during the concentric phase of muscle activation. Three angular velocities were selected: low (60°/s), intermediate (180°/s) and high (300°/s). Measurements were made using a HumacNorm 770 CSMi isokinetic dynamometer (Stoughton, MA, USA). flexion abduction/extension adduction or PNF D2 of the shoulder joint was performed for both shoulders. Differences in force level in n/m, deficit, between flexor and extensor muscles, and the flexor and extensor muscle ratio for both shoulders in were recorded and evaluated.

Procedure

During the preparation period of the teams, a questionnaire was administered to the teams of the first division of the A1 Men's and A1 Women's League. The purpose was to collect data for the selection of athletes who would meet the inclusion criteria for the study. A total of 198 male and female athletes responded to the questionnaire. A random selection of 20 individuals who met the inclusion criteria was then made. All of them showed evidence of scapular dyskinesia, they were divided into two groups of 10 subjects. In group A, the control group, each athlete followed the usual team training program. In group B, the study group, each athlete followed an inter-

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ventional training program (exercise program 3 times a week for 3 months) in addition to the usual team training program. The same measurements were made for all subjects. For the Goniometry measurements it was taken abduction, adduction in the standing position and extension, flexion of the scapula in the prone and supine positions. The purpose of the goniometry measurements was to record the range of motion of both shoulders. The purpose of the isokinetic assessment was to measure the strength of the shoulder muscles during the concentric phase of muscle activation. Differences in force level in n/m, deficit, between flexor and extensor muscles, and the flexor and extensor muscle ratio for both shoulders in %, expressed as Mean (M) and Standard Deviation (SD) were recorded and evaluated.

Intervention program of the study team

The investigation of the evaluation and impact of the program involved muscle activation of both shoulders. The study group had to perform the exercise program 3 times a week for 3 months. Each workout started with a range of motion warm-up followed by a strengthening workout. The exercises involving one arm were performed on the affected side only. If both shoulder blades were affected, then the entire exercise program was applied to both sides. Strengthening exercises focused on the general area of the scapula, specifically the transverse and lower trapezius and the anterior serratus, while stretching exercises focused on the upper trapezius, the pectoral muscles and the posterior glenohumeral joint capsule. The program included the following exercises:1) Cobra Stretch, with the palms next to the chest and the legs extended, lifting the torso with full extension at the elbows in forward flexion, and 2) Cross Body Stretch, cross extension with arm adduction in lateral flexion. Strengthening exercises: 3) Push-up plus external rotation, with shoulder abduction; 4) Supine punch, 5) Side Lying with Forward Flexion up to 135°, arm flexion ≥ 135° in lateral flexion, 6) Arm Extension in Prone Position, lateral forward flexion to 135°; 7) Prone horizontal abduction with external rotation. The exercise program was designed to improve muscle activation for muscular endurance and strength. In each exercise, each participant performed one training set using 50% resistance of perceived 1-RM. The strength training included 3 sets / 15 repetitions of each exercise. Figures 1- 7 shows the exercises included in the intervention program.

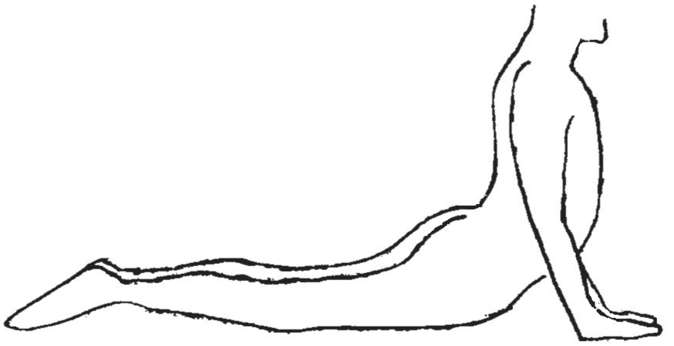

Figure 1. Cobra Stretch

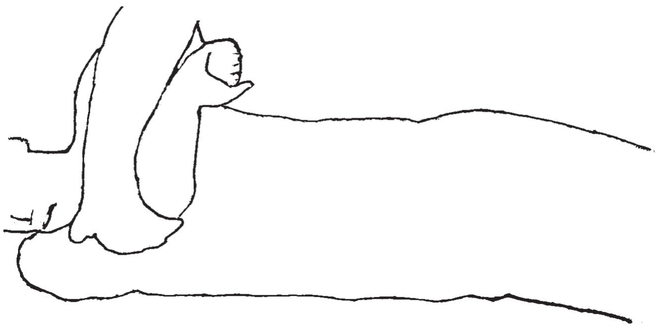

Figure 2. Cross Body Stretch

Figure 3. Push up Plus External Rotation

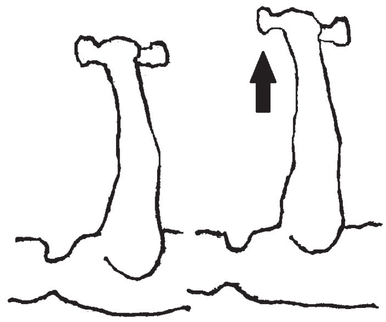

Figure 4. Supine Punch

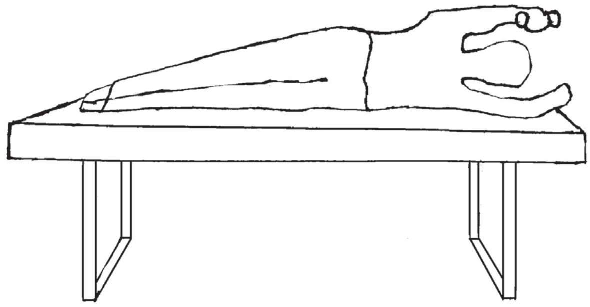

Figure 5. Side Lying with Forward Flexion up to 135°

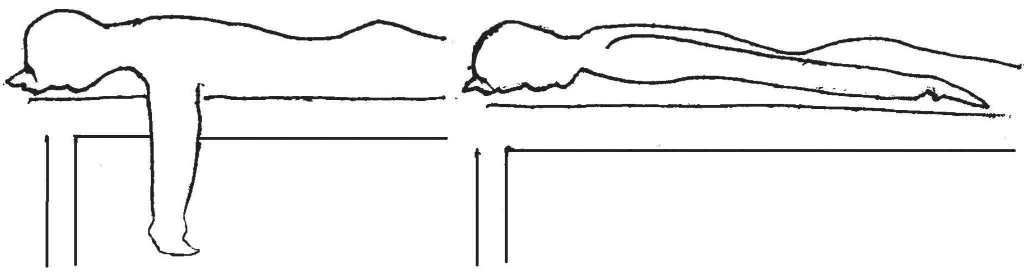

Figure 6. Arm Extension in Prone Position

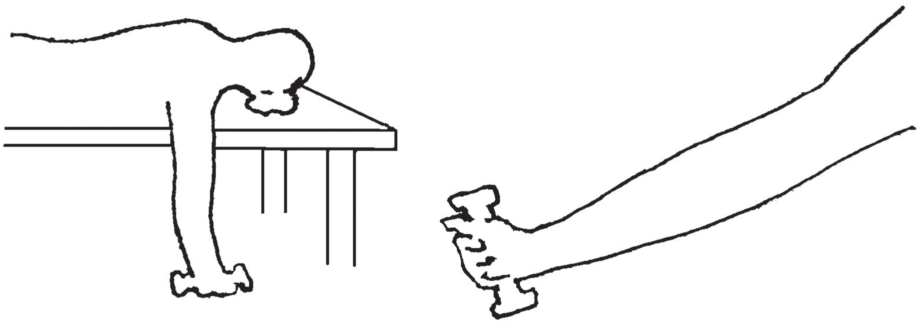

Figure 7. Prone horizontal abduction with external rotation

Statistical analysis

The results were analyzed both descriptively and inferentially. Descriptively, the mean (M) and standard deviation (SD) were used, as well as the frequency of values and their corresponding percentage. Inferentially, two way ANOVAs was used with repeated measures with group factors and measurement for main effects and with group factors and measurement for interaction. IBM SPSS 22.0 was used to statistically process the above and the significance level was set at 0.05.

This study was approved in advance by the Research Ethics Committee of the Department of Physical Education and Sports Science of Thessaloniki. Each participant voluntarily provided written informed consent prior to participation.

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Results

Shoulder goniometry

Table 1 shows the differences between the study group and the control group at the first and second goniometry, i.e. before and after the administration of the intervention program to the study group, expressed in sig and Partial Eta Square (PES). PES is a statistical indicator that shows the magnitude of the effect expressed by a value that shows sometimes small, sometimes medium and sometimes high. In this table we can see that in many cases we have a result that according to the value of PES, the load shows sometimes small, sometimes medium and sometimes high effect.

Isokinetic evaluation of the shoulders

Table 2 shows the results of the isokinetic assessment for the measurements taken before and after the intervention program was given to the study group expressed in sig and Partial Eta Square (PES). The same table presents the isokinetic assessment data in the study group and the control group. These were examined in terms of the deficit between flexor and extensor muscles, and the ratio between flexor and extensor muscles of both shoulders.

Table 1 First and second goniometry before and after the intervention programe (F-test - F, Partial Eta Square – PES) before intervention (1), and after intervention (2)

	Experimental Group	Control Group	Experimental Group	Control Group	Main effect			Interaction		
	1	1	2	2						
	Mean SD	Mean SD	Mean SD	Mean SD	F	p-value	PES	F	p-value	PES
Abduction right	135.5 ±14.17	125.5 ±12.69	134.8 ±17.08	138.8 ±13.76	2.238	0.152	0.111	2.796	0.112	0.134
Abduction left	135.2 ±12.68	122.8 ±13.14	132.2 ±17.81	138.5 ±15.28	1.903	0.185	0.960	4.018	0.096	0.182
Adduction right	23.30 ±7.76	24.7 ±7.07	23.20 ±7.24	22.10 ±5.70	0.817	0.378	0.043	0.700	0.414	0.037
Adduction left	22.07 ±7.15	21.8 ±6.32	17.00 ±4.52	16.9 ±4.12	16.026*	0.001	0.471	0.091	0.766	0.005
Extension right	32.4 ±13.86	31.5 ±8.22	30.1 ±11.66	41.1 ±13.91	1.972	0.177	0.099	5.239**	0.034	0.225*
Extension left	33.5 ±10.7	32.0 ±8.58	30.40 ±13.39	38.10 ±15.27	0.251	0.622	0.014	2.361	0.142	0.116
Flexion right	159.9 ±9.15	157.7 ±24.54	152.9 ±9.46	146.4 ±19.14	8.959*	0.008	0.332	0.495	0.491	0.027
Flexion left	156.2 ±18.93	163.7 ±18.47	145.7 ±19.62	151.10 ±12.83	14.105*	0.001	0.439	0.117	0.737	0.006

Note: Significance level *<0.01, **<0.05.

Table 2. Isokinetic assessment before and after the intervention program (F-test - F, Partial Eta Square – PES) before intervention (1), and after intervention (2)

	Experimental Group	Control Group	Experimental Group	Control Group	Main effect			Interaction		
	1	1	2	2						
	Mean SD	Mean SD	Mean SD	Mean SD	F	p-value	PES	F	p-value	PES
60°/sec right extension	63.20 ±17.59	62.10 ±20.28	67.20 ±23.74	64.20 ±11.19	0.756	0.396	0.040	0.073	0.790	0.004
60°/secleft extension	67.10 ±21.68	62.00 ±16.84	70.40 ±29.98	66.60 ±14.82	1.817	0.194	0.092	0.049	0.827	0.003
60°/sec Extensional deficit	8.9 ±4.68	15.3 ±15.24	9.50 ±5.02	5.90 ±4.98	2.715	0.117	0.131	3.506	0.077	0.163
60°/sec right flexion	90.50 ±37.28	84.40 ±29.91	87.20 ±33.56	91.50 ±27.50	0.157	0.697	0.009	1.176	0.292	0.061
60°/sec left flexion	84.60 ±37.85	76.50 ±16.95	87.50 ±35.00	83.30 ±22.05	1.955	0.179	0.098	0.316	0.581	0.017
60°/sec flexural deficit	11.50 ±6.54	21.20 ±20.19	7.20 ±5.00	13.10 ±7.46	2.163	0.159	0.107	.203	0.658	0.011
60°/sec Ratio right	140.5 ±24.63	133.6 ±22.57	128.6 ±18.90	140.6 ±23.67	0.191	0.667	0.011	2.849	0.109	0.137
60°/sec Ratio left	124.2 ±19.49	125.9 ±17.37	125.1 ±15.10	126.6 ±14.10	0.029	0.866	0.002	0.000	0.983	0.000
180°/sec right extension	45.40 ±21.30	50.50 ±12.10	55.20 ±20.12	54.70 ±10.90	11.213**	0.004	0.384	1.794	0.197	0.091
180°/sec left extension	51.00 ±19.84	53.60 ±12.43	57.30 ±25.71	56.70 ±11.64	4.998*	0.038	0.217	0.579	0.456	0.031

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Table 2. Isokinetic assessment before and after the intervention program (F-test - F, Partial Eta Square – PES) before intervention (1), and after intervention (2)

	Experimental Group	Control Group	Experimental Group	Control Group	Main effect			Interaction		
	1	1	2	2						
	Mean SD	Mean SD	Mean SD	Mean SD	F	p-value	PES	F	p-value	PES
180°/sec Extensional deficit	15.70 ±16.52	10.20 ±10.24	9.70 ±7.66	6.10 ±6.35	1.999	0.174	0.100	0.071	0.793	0.004
180°/sec right flexion	71.8 ±43.05	73.9 ±22.87	78.9 ±33.81	81.00 ±22.47	4.597*	0.046	0.203	0.000	1.00	0.00
180°/sec left flexion	73.20 ±35.95	70.30 ±15.87	80.00 ±30.95	71.40 ±19.43	1.326	0.265	0.069	0.690	0.417	0.037
180°/sec flexural deficit	24.80 ±20.76	25.20 ±17.33	11.20 ±5.14	12.8 ±8.42	7.718*	0.012	0.300	0.016	0.899	0.001
180°/sec Ratio right	146.4 ±37.11	133.1 ±53.40	140.5 ±27.11	150.5 ±30.41	0.330	0.573	0.018	1.356	0.259	0.070
180°/sec Ratio left	141.2 ±24.74	132.0 ±17.33	140.0 ±23.43	128.5 ±21.7	0.129	0.724	0.007	0.031	0.863	0.002
300°/sec right extension	46.5 ±19.93	40.5 ±15.87	41.20 ±17.91	40.9 ±8.34	0.324	0.576	0.018	0.439	0.516	0.024
300°/sec left extension	37.9 ±12.33	55.4 ±12.29	47.9 ±20.68	58.3 ±19.42	2.301	0.147	0.113	0.697	0.415	0.037
300°/sec Extensional deficit	27.20 ±18.91	22.30 ±27.13	17.5 ±8.70	26.5 ±20.47	0.258	0.618	0.014	1.648	0.215	0.084
300°/secright flexion	54.8 ±32.06	64.10 ±21.23	63.0 ±30.31	68.10 ±20.67	1.663	0.213	0.085	0.197	0.662	0.011
300°/secleft flexion	56.50 ±32.46	62.5 ±15.49	60.5 ±25.23	64.60 ±19.64	0.518	0.481	0.028	0.050	0.825	0.003
300°/sec flexural deficit	14.10 ±16.94	11.7 ±10.03	13.4 ±6.43	14.8 ±9.25	0.093	0.764	0.005	0.233	0.635	0.013
300°/sec Ratio right	125.7 ±75.82	163.5 ±46.51	154.3 ±33.63	157.4 ±68.08	0.410	0.530	0.022	0.974	0.337	0.051
300°/sec Ratio left	142.30 ±44.11	121.5 ±39.22	130.2 ±23.93	122.1 ±25.65	0.338	0.568	0.018	0.412	0.529	0.022

Note: Significance level *<0.01, **<0.05.

Discussion

Goniometry

The main findings of our study on goniometry are as follows. In the left adduction: Main effect with sig: 0.001.and PES: 0.471, with no present interaction. In the extension right: Lack of main effect, present interaction with sig: 0.034 and PES: 0.225. In flexion right: Main effect with sig: 0.008 and PES: 0.332, no interaction present. And in the left flexion: main effect with sig: 0.001 and PES: 0.439. The main findings at isokinetic dynamometry of our study are as follows. In the torque of 180°/s of extension right: Main effect with sig: 0.004 and PES: 0.384, no interaction present. On the torque of 180°/s of extension left: Main effect with sig: 0.038 and PES: 0.217, with no interaction present. On the torque of 180°/s of right flexion: Main effect with sig: 0.046 and PES: 0.203, with no present interaction. And on the 180°/s flexion deficit with sig: 0.012 and PES: 0.300, with no interaction present. More specifically at goniometry performed in this study, it is noted that in the measurement before the intervention program, statistically significant difference in both study and control groups was observed only in the left shoulder adduction test, with main effect shown. No interaction appeared to be present in this series. This appears to be in agreement with Dashottar et al. (2014), who made similar comparisons of angle measurements in the general population. There was a direct reduction in range of motion in all measurements except for adduction. In the present study, it appeared that there were better results on the first measurement than the second. In other words, there was a reduction in range of motion in both groups in the second measurement. Also, in the right extension with no main effect on any measurement, there was an interaction between the first and second measurement in the control group. From the results, it appeared that the control group had better adjustments in the second measurement. In flexion on both sides (left and right) had main effect with statistically significant difference in both groups (experimental and control). In right shoulder flexion, there was a main effect; this result is also strengthened by the strong load on the PES value. In left shoulder flexion, we also had a main effect and strong load on PES. It seems that from before both groups had better results compared to the second measurement, with no interaction. More specifically, there was a decrease in the range of motion of flexion of both shoulders in the initial measurement compared to the final measurement. In all other cases of the angle

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measurement, although in some there was strengthening and low, medium and high load was recorded in the PES value, no statistically significant difference was found. These results are in contrast to a study by Jurgel et al. (2005) conducted in patients with frozen shoulder. There it was shown that there were significant changes in shoulder range of motion after a 4-week rehabilitation program that improved range of motion in shoulder flexion, extension, abduction and adduction. However, these data should be interpreted with caution because it is difficult to compare the findings of this study with those of previous studies. This is due to differences in design, measurement methods and sample selection. The specific adaptations of our study are probably due to the fact that the intervention program given to the study group had only two stretching exercises, while it relied more on strengthening, which included five exercises. A second possible explanation is that the study group only applied the intervention program, possibly neglecting the range-of-motion exercises in the group training.

Isokinetic evaluation

Regarding the results of the isokinetic evaluation of the analysis of variance with Two Way ANOVAs with Repeated Measures, in the 180°/sec torque in extension on both sides (left and right), there was a main effect in the experimental group, having better results in the second measurement. This result is strengthened by the large load shown by the value of PES, revealing a large effect on both shoulders. However, there was no interaction reported at the series also.

In the present study it appeared that the experimental group had better results than the control group on the second measurement after the intervention program. Moreover, in the torque of 180°/sec in the right shoulder flexion there was a main effect in the experimental group, having better results in the second measurement. This result is strengthened by the large load shown by the value of PES, revealing a large effect. However, no interaction appeared to be present in this case either. In the 180°/sec deficit, there was also an effect in the experimental group, with the deficit decreasing more in the experimental group in the second measurement. This result is strengthened by the large load shown by the value of PES, revealing a large effect. However, there was no interaction appeared at this series, also. The better adaptation that the experimental group seemed to have to the above angular velocity suggests that the intervention program had, to some extent, a positive effect, increasing strength levels and reducing muscle deficits between the two shoulders. However, at the faster angular velocities, those of 300°/sec, no statistically significant difference in main effect was seen. The same seems to be the case in the interactions, where we also had no statistically significant difference. The only observation that could be mentioned is in the PES values, which at the 300°/sec speeds, had from low to moderate loading, revealing some kind of effect. In other words, we expected better adaptations at the faster angular velocities, i.e. those that more closely resemble the shoulder movement during the shoot. The most likely reason for this result is that, the smaller than expected adaptations were due to the small loading load demanded by the intervention program on the experimental group. In the literature, most studies report isometric measurements based on portable dynamometers and focus on internal and external rotation. The findings of the present study appear to be consistent with a previous, similar study by Cook et al. (1987), but that study involved baseball athletes. There it was reported that extensors produced greater movements than flexors at 180°/sec and 300°/sec. Although some useful conclusions can be drawn from the results of this study, the research was conducted with some limitations. More specifically, only handball players in the top leagues participated. Also, due to COVID-19, the study included mainly male and female athletes from Northern Greece and the study lasted more than one season.

Conclusions

Evaluating the sample of the present study, the intervention program was found to have a partially beneficial effect in some areas and to varying degrees. More specifically, in the goniometry of the experimental group we had a reduction in range of motion in both shoulder flexion, left shoulder adduction, and right shoulder extension. Therefore, the benefit of the intervention program on range of motion was not demonstrated. However, in isokinetic dynamometry we had positive adaptations in extension and flexion at some angular velocities. These are not the requested angular velocities, similar to shooting in handball, where most injuries occur. Perhaps in future similar studies, incorporate more stretching and more powerful strengthening exercises. Further analysis is needed to explore this issue with additional data, for example, a larger sample and research in wider geographical areas. In addition, the research should be conducted over a longer period of time with a greater number of functional exercises. Also, a specific outcome indicator should be defined for the whole process for the shoulders and the upper limbs in general, as is the case for the lower limbs, knee, and ankle. The observed adaptations of such interventional programs in handball athletes are useful and provide important information for the athletes (coaches, medical team, administrators), while providing feedback to the athletes.

References

Abassi (2019), Phases of throwing https://www.orthobullets.com/shoulder-and-elbow/3039/phases-of-throwing

Cook, E. E., Gray, V. L., Savinar-Nogue, E., & Medeiros, J. (1987). Shoulder antagonistic strength ratios: a comparison between college-level baseball pitchers and nonpitchers. *Journal of Orthopaedic& Sports Physical Therapy*, *8*(9), 451-461.

Dashottar, A., Costantini, O., &Borstad, J. (2014). A comparison of range of motion change across four posterior shoulder tightness measurements after external rotator fatigue. *International Journal of Sports Physical Therapy*, *9*(4), 498.

Giroto, N., Hespanhol Junior, L. C., Gomes, M. R. C., & Lopes, A. D. (2017). Incidence and risk factors of injuries in Brazilian elite handball players: a prospective cohort study. *Scandinavian Journal of Medicine &Science in Sports*, *27*(2), 195-202.

Ekstrom, R. A., Donatelli, R. A., & Soderberg, G. L. (2003). Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. *Journal of Orthopaedic& Sports Physical Therapy*, *33*(5), 247-258.

Jurgel, J., Rannama, L., Gapeyeva, H., Ereline, J., Kolts, I., &Paasuke, M. (2005). Shoulder function in patients with frozen shoulder before and after 4-week rehabilitation. *Medicina (Kaunas)*, *41*(1), 30-8.

Kapandji, I. A. (2001). *Λειτουργική Ανατομική των Αρθρώσεων,* *Τόμος Α: Άνω Άκρο.* ΕκδόσειςΠασχαλίδης, 396-112.

Landreau, P., Zumstein, M. A., Lubiatowski, P., & Laver, L. (2018). Shoulder injuries in handball. In *Handball Sports Medicine* (pp. 177-195). Springer, Berlin, Heidelberg.

Lauersen, J. B., Bertelsen, D. M., & Andersen, L. B. (2014). The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. *British Journal of Sports Medicine*, *48*(11), 871-877.

Lawrence, R. L., Braman, J. P., Staker, J. L., LaPrade, R. F., &Ludewig, P. M. (2014). Comparison of 3-dimensional shoulder complex kinematics in individuals with and without shoulder pain, part 2: glenohumeral joint. *Journal of Orthopaedic&Sports Physical Therapy*, *44*(9), 646-655.

Namdari, S., Yagnik, G., Ebaugh, D. D., Nagda, S., Ramsey, M. L., Williams Jr, G. R., & Mehta, S. (2012). Defining functional shoulder range of motion for activities of daily living. *Journal of Shoulder and Elbow Surgery*, *21*(9), 1177-1183.

Seil R, Rupp S, Tempelhof S, Kohn D. Sports injuries in team handball. A one-year prospective study of sixteen men's senior teams of a superior nonprofessional level. *Am J Sports Med*. 1998;26:681–7.

Sheean, A. J., Kibler, W. B., Conway, J., & Bradley, J. P. (2020). Posterior labral injury and glenohumeral instability in overhead athletes: Current concepts for diagnosis and management. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*, *28*(15), 628-637.

Smith, J., Dietrich, C. T., Kotajarvi, B. R., & Kaufman, K. R. (2006). The effect of scapular protraction on isometric shoulder rotation strength in normal subjects. *Journal of Shoulder and Elbow Surgery*, *15*(3), 339-343.

Werner, S. L., &Plancher, K. D. (1998). Biomechanics of wrist injuries in sports. *Clinics in Sports Medicine*, *17*(3), 407-420.

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ORIGINAL SCIENTIFIC PAPER

Well-being and Life Satisfaction of Strength Athletes During War: Role of Individual and Health-Related Determinants

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Abstract

The research aims to identify the determinants of well-being of youth strength athletes taking into account individual parameters (level of stress, anxiety, depression) and contextual parameters (change of place of residence, change of opportunity to train due to war), differences compared to an older age group. The online study was performed on elite strength athletes (N=172) in Ukraine during Russo-Ukrainian war. In addition to demographic characteristics, the survey included question to sports activity, issues related to hostilities, standardized questionnaires to measure life satisfaction (SWLS), perceived stress level (PSS-10), depression (PHQ-9), anxiety (GAD-7), physical, mental and social functioning (SF-36). Statistical analysis included descriptive statistics, correlation analysis to find association between variables, and building linear regression models. Samples of young and adult athletes that we analyzed did not differ in terms of life satisfaction. Among young athletes there were significantly fewer people with symptoms of stress (67%) and anxiety (25.53%). Three groups of factors that determine the life satisfaction of young Ukrainian athletes can be single out: individual (stress, depression), contextual (change of place of residence or training due to the war), and health-based (general perception of one's own health and pain sensations). The data highlight the critical importance of mental health monitoring for the overall well-being of athletes. The obtained results can be used to rapidly screen persons in the risk group during a war and further develop individual psychotherapeutic programs to overcome trauma and the consequences of war.

Keywords: *life satisfaction, mental health, health-related quality of life, youth, powerlifting*

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Introduction

Sports activity is a field of manifestation of human capabilities. It is characterized not only by the demonstration of muscle activity when performing physical exercises but also by mastering the high technique of their performance and often by the maximum and even marginal physical and mental stress (Campbell et al., 2018; Pope et al., 2018). This sets special requirements for the health of the athlete; in fact, health is an inte-

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gral aspect of the athlete's life and directly affects his/her welfare. In general, sports can both positively and negatively influence various aspects of well-being (Malm et al., 2019). Athletic trainings improve the work of the athlete's cardiovascular, respiratory and neuromuscular systems (Jones & Carter, 2000). An indispensable condition for sports activities is the enthusiasm of the athlete, a steady interest in one of athletic discipline. Athletic activities are accompanied by a sense of growth, development, and improvement (Eime et al., 2013). In fact, a person creates himself/herself: He/she is judged by his/her performance at competitions and activities in sports. As a result of sports activities, athletes develop a number of psychological skills that help maintain a high level of motivation, high level of self-esteem, and resistance to failures that undoubtedly have a positive effect not only on athletic activity but also on other aspects of their lives (Dohme et al., 2019). Sports is characterized by social importance: establishing friendly contact with foreign athletes, developing patriotic and international feelings, and forming special sports values (Bessa et al., 2019). Organized sporting events create an environment in which athletes communicate, develop relationships and cooperation, and form a sense of involvement.

The coronavirus pandemic has caused significant restrictions that have influenced the level of physical activity in the world. During the pandemic, there was a reduction in the number of training days and hours, which led to the deterioration of the overall activity and physical performance of athletes (Mehrsafar et al., 2021; Pillay et al., 2020). Among the negative results of isolation are the following conditions: depression, fear, confusion, and anxiety. In addition to difficulties in training, athletes were not able to participate in competition, faced financial difficulties and suffered from the loss of goals and satisfaction.

Recent studies have shown that athletes are not less prone to mental illness than the population as a whole (Rice et al., 2016). This problem is quite acute, particularly among young athletes. During youth and adolescence period many mental health problems, such as depression, anxiety, eating disorders, abuse of psychoactive substances and suicides, begin to appear or exacerbate. Some specific sports characteristics may contribute to behavioral problems with health, such as lack of time for training, training with a physical injury or a prolonged recovery after it, overtraining, preparation for the transition "to the next level", bullying, sleep deprivation, change in interests or giving up of sports that is especially critical when sports is a part of the athlete's personality and the social circle (Xanthopoulos et al., 2020).

In recent years, Ukrainian athletes have faced a number of growing external challenges. Thus, during the coronavirus epidemic in Ukraine, restrictions of varying degrees were introduced. During the coronavirus epidemic and the extended period of quarantine restrictions, the Russian-Ukrainian War began in the territory of Ukraine on 24 February 2022. Ukrainians have become direct witnesses to the destruction of civilian infrastructure and mass killings of civilians in occupied territories. Prime Minister noted at the government meeting on February 7, 2023, that since the beginning of large-scale Russian aggression in Ukraine, more than 200 Ukrainian athletes and coaches were killed, more than 120 sports facilities were destroyed by enemy rockets and artillery, more than 300 sports schools ceased to exist, and more than 150,000 athletes do not have conditions for training (Speech of the Prime Minister of Ukraine Denys Shmyhal at the Government meeting | Cabinet of Ministers of Ukraine, n.d.). Many Ukrainian athletes went to the ranks of the Armed Forces of Ukraine. All of these factors further exacerbate the existing difficulties of sports improvement.

Our research aimed to better understand the determinants of the well-being of strength athletes, considering parameters related to sports activity, individual parameters (level of stress, anxiety, depression), and context (change of residence, change of opportunity to train due to war, etc.). We analyzed life satisfaction as a cognitive part of well-being and the perception of well-being that is related to one's physical and mental capabilities. We take into account the importance of health for the athlete's well-being and focus attention on the physical and mental health that determine the athlete's ability to live a fulfilling life. We hypothesized that there would be a relationship between life satisfaction and the physical and mental components of well-being and assumed that the well-being of athletes of different ages and gender would differ. All these results are important from the point of view of practical application, as they allow us to outline the portrait of a athletes in war conditions and identify individuals who are at risk and, on the contrary, have a high level of resilience to adverse circumstances.

Materials and Methods

Procedure

The study was performed in Ukraine in 2022 (within a period from August 29 to September 18). On-line survey created with Google Forms and widespread among potential participants. The survey contained information about the purpose and objectives of the study, informed consent, sociodemographic questions, questions related to sports activity, issues related to hostilities, and standardized questionnaires concerning various aspects of well-being (stress level, depression, anxiety, satisfaction, physical health, level of physical, mental and social functioning).

The Bioethics Committee of Lviv State University of Physical Culture approved the study protocol (protocol number 11, 2022-12-09). The participants gave informed consent to participate in the study, and all measures were taken to ensure the anonymity of the participants.

Measurement

The assessment of the cognitive component of well-being was performed using the Satisfaction with Life Scale, which consists of five statements for evaluating the overall level of life satisfaction (Diener et al., 1985). The Ukrainian version of the questionnaire showed a high level of internal consistency in previous studies (Rogowska et al., 2021). The Cronbach's alpha for this set was 0.796.

Anxiety was evaluated by using the Generalized Anxiety Disorder (GAD-7) scale (Spitzer et al., 2006). The GAD-7 scale is intended for screening symptoms according to DSM-V criteria. A result above 10 points indicates anxiety disorder. The questionnaire has a sufficient level of internal consistency (Rogowska et al., 2020). For this set, the Cronbach's alpha was 0.914.

The Patient Health Questionnaire (PHQ-9) was used to evaluate the symptoms of depression (Kroenke et al., 2001). The questionnaire consists of nine statements that meet the DSM-IV diagnostic criteria. To diagnose the risk of major depressive disorders, a cutoff score of 10 or more is used. The questionnaire has a sufficient level of internal consistency (Rogowska et al., 2020), and the Cronbach's alpha for this sample was 0.817.

To estimate the level of stress, the Perceived Stress Scale (PSS-10) was used (Cohen et al., 1983). The questionnaire

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consists of 10 statements that allow us to analyze how often some or other stressful events occurred and to what degree the person considers his/her life unpredictable, unmanaged and overloaded over the last month. The questionnaire has a high level of international consistency (Ochnik et al., 2021). The Cronbach's alpha for this sample was 0.861.

Health-related quality of life was measured using the 36-Item Short Form Health Survey (SF-36) (Ware & Sherbourne, 1992). Questions are grouped into 8 scales: physical functioning (PF), physical role functioning (RF), bodily pain (BP), vitality (VT), social functioning (SF), mental health (MH), emotional role functioning (RE), and general health (GH). Additionally, all the scales can be grouped into two components – Physical Component Score (PCS) and Mental Component Score (MCS). A score below 50 points for these components indicates a worse quality of life compared with average indicators of the total population.

Data about age, gender, place of residence (rural area, urban area), marital status, changes in the place of residence through the war were collected. Highly qualified athletes were attributed to the winners of international competitions and/or Masters of Sports of Ukraine of the International Class (athletes can obtain this title only if they are participants of a national team at international competitions).

Participants

Sample N=172 people aged between 17 years and 79 years (M=27.8, SD=9.45) took part in the study. All participants were athletes in weightlifting or powerlifting of different levels. The overall set is dominated by persons who are engaged in powerlifting (79.1%), and participants represent all weight classes with a predominance of middle and heavy classes. The number of women in the total set amounted to 36.6%. The participants were divided into two groups with 25 years as cutoff criteria – young athletes (N=94, aged 21.3 years), and adult athletes (N=78, aged 35.7 years). With the exception of individual characteristics (age, relationship status, presence of children), the groups did not differ in socio-demographic data, as well as war-related variables. Detailed data on the sociodemographic characteristics of participants are provided in Table 1.

Table 1. Sociodemographic data and war-related variables

Variable	Youth (n=94)		Adults (n=78)		Total (n=172)		χ^2	p	φ
	N	%	N	%	N	%			
Gender							0.249	0.618	0.038
Men	58	33.7	51	29.7	109	63.4			
Women	36	20.9	27	15.7	63	36.6			
Relationship status							40.2	< .001	0.484
Single	80	46.5	30	17.4	110	64.0			
In a couple	14	8.1	48	27.9	62	36.0			
Children							66.3	< .001	0.621
Yes	2	1.2	45	26.2	47	27.3			
No	92	53.5	33	19.2	125	72.7			
Active hostilities in the area of residence							0.016	0.900	0.009
Yes	15	8.7	13	7.6	28	16.3			
No	79	45.9	65	37.8	144	83.7			
Change of place of residence and/or training due to hostilities							3.49	0.322	0.142
Yes	22	12.8	17	9.9	39	22.6			
No	72	41.9	61	35.4	133	77.3			
Qualification									
Highly qualified	64	37.2	65	37.8	129	75.0	5.29	0.021	0.173
Particularly high qualification	30	17.4	13	7.6	43	25.0			
Difficulties with training due to the war							2.38	0.123	0.118
Yes	72	41.9	67	39.0	139	80.8			
No	22	12.8	11	6.4	33	19.2			
Sport injuries							7.92	0.019	0.215
Yes	37	21.6	17	9.9	44	31.4			
No	57	33.1	61	35.5	118	68.6			

Statistical analysis

Analysis for continuous variables was conducted. The statistical analysis included descriptive statistics: mean (M), standard deviation (SD), and 95% confidence interval (CI) with lower limit (LL) and upper limit (UL). Data obtained on all scales were analyzed for normality. In the presence of a normal distribution, to analyze the differences between different continuous variables, Student's t test was used to compare independent samples, and Cohen's d as the effect size was also taken into account. We utilized the Pearson $\chi 2$ independence test for variables considered bicategorical variables, and the effect size was assessed using the phi (ϕ) value. Multiple linear regression was used to examine the relationship between well-being and predictors. All statistical analyses were conducted using JAMOVI software ver. 2.3.

Results

Pearson's χ2 test of independence was performed on youth and adult samples in terms of perceived stress, anxiety, and depression symptoms, life satisfaction, and physical and mental components of health-related quality of life. In the case of anxiety, depression, and life satisfaction, data were analyzed with cutoff criteria. The results are shown in Table 2. In the total sample, 73.3% of athletes had stress, 32.0% and 32.6% were at risk of anxiety and depression, respectively, and 54.7% and 77.9% had a low indicator of the physical or mental component of quality of life, respectively.

Table 2. Comparison of the youth sample with the adult sample in frequencies of life satisfaction, mental health variables, and health-related quality of life

Variable	Youth		Adults		Total		χ^2	p	φ
	N	%	N	%	N	%			
Life satisfaction							0.03	0.856	0.138
Low	35	37.2	28	35.9	63	36.6			
High	59	62.8	50	64.1	109	63.4			
Perceived stress							4.11	0.043	0.155
No symptoms	31	33.0	15	19.2	46	26.7			
Stress symptoms	63	67.0	63	80.8	126	73.3			
Anxiety							3.96	0.047	0.152
No symptoms	70	74.5	47	60.3	117	68.0			
Anxiety symptoms	24	25.5	31	39.7	55	32.0			
Depression							0.725	0.395	0.065
No symptoms	66	70.2	50	64.1	116	67.4			
Depression symptoms	28	29.8	28	35.9	56	32.6			
Physical component of life quality							2.17	0.141	0.112
Worse quality of life	23	24.5	12	15.4	35	20.3			
Better quality of life	71	75.5	66	84.6	137	79.7			
Mental component of life quality							5.29	0.021	0.175
Worse quality of life	67	71.3	67	85.9	134	77.9			
Better quality of life	27	28.7	11	14.1	38	22.1			

Young athletes did not differ from the set of adults in terms of life satisfaction, symptoms of depression and the physical component of health-related quality of life. Lower stress and no anxiety risk was found among young athletes, while high stress, higher level of anxiety was more often reported in the adult sample. Similarly, young athletes had higher scores of

Table 3. Comparison of life satisfaction, mental health, and health-related quality of life of women and men

Variable	Women		Men		p	Effect Size
	Mean	SD	Mean	SD		
Life satisfaction	21.56	6.26	23.05	5.35	0.100	0.262
Perceived stress	22.06	7.20	16.71	6.92	< 0.001	-0.763
Anxiety	9.83	5.47	5.89	4.60	< 0.001	-0.798
Depression	10.48	5.53	7.38	4.42	< 0.001	-0.639
Physical Component score	55.53	6.31	53.31	6.00	0.023	-0.364
PF	90.64	12.62	87.66	19.07	0.271	-0.175
RF	55.95	36.95	69.27	33.96	0.018	0.380
BP	69.81	23.34	75.65	22.20	0.105	0.258
GH	59.41	17.43	65.56	15.75	0.019	0.375
Mental component score	32.39	12.25	41.86	11.02	< 0.001	0.825
VT	43.25	17.25	55.23	16.95	< 0.001	0.702
SF	57.14	26.35	75.80	21.60	< 0.001	0.796
RE	39.15	43.40	58.72	40.04	0.003	0.474
MH	46.92	18.26	60.95	19.16	< 0.001	0.745

Note. PF: physical functioning; RF: physical role functioning; BP: bodily pain; GH: general health; VT: vitality; SF: social functioning; RE: emotional role functioning; MH: mental health

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mental component of life quality.

Women showed significantly higher scores than men in perceived stress (p<0.001, d=-0.763), anxiety (p<0.001, d=-0.798), and depression (p<0.001, d=-0.639) (Table 3). The male and female samples did not differ in terms of life satisfaction. Women had significantly lower parameters of physical role functioning (p=0.018, d=0.380), general health (p=0.019, d=0.375), vitality (p<0.001, d= 0.702), social functioning (p<0.001, d=0.795), and mental health (p<0.001, d=0.745).

Multiple linear regression was conducted to identify predictors of life satisfaction and physical and mental components of health-related quality of life for different age groups. The assumptions of regression were not acceptable, and the variance inflation factor for some predictors was higher than 4. Therefore, after additional analysis of the correlations between potential predictors and outcomes, some variables (for example, anxiety for adults) were excluded from the analysis. The assumption of regression for these modified cases was acceptable, including collinearity statistics (VIF<4), autocorrelation, no influential cases biasing the models of regression and multivariate normality. The results of the regression are shown in Table 4. Significant predictors of life satisfaction for youth athletes were gender, change of place of residence due to hostilities, stress, depression, bodily pain, and general health. The model can explain 54.4% of life satisfaction variance, R=0.738, R^2=0.54, F(14, 79)=6.74, p<0.001. Predictors of life satisfaction of adults were general health and emotional role functioning, and the model explained 26.1% of life satisfaction variance (R=0.614, R^2=0.26, F(12, 65)=6.74, p<0.001).

Table 4. Multiple linear regression for life satisfaction of athletes

Predictor	Youth				Adults			
	β	95% CI		p	β	95% CI		p
		LL	UL			LI	UI	
Gender	0.385	0.012	4.355	0.049	0.114	-0.338	0.567	0.616
Sport injuries	-0.302	-5.274	1.844	0.340	0.305	-1.507	2.116	0.738
Difficulties with training*	-0.098	-2.530	1.412	0.574	0.028	-0.426	0.483	0.901
Change of place of residence and/or training*	-0.547	-5.188	-1.030	0.004	-0.192	-0.657	0.273	0.413
Perceived stress	-0.289	-0.406	-0.026	0.027	0.045	-0.258	0.349	0.767
Anxiety	0.035	-0.292	0.368	0.820				
Depression	-0.269	-0.610	-0.007	0.045	-0.200	-0.477	0.077	0.154
PF	0.073	-0.044	0.098	0.456				
RF	0.138	0.0219	0.017	0.055				
BP	-0.257	-0.061	0.023	-0.015	-0.044	-0.275	0.186	0.702
GH	0.341	0.123	0.039	0.200	0.253	0.024	0.481	0.031
VT	0.016	0.005	0.034	0.073	0.096	-0.198	0.390	0.516
SF	-0.076	-0.017	0.027	0.036	0.104	-0.205	0.413	0.504
RE	-0.074	-0.010	0.017	0.023	0.269	0.007	0.531	0.044

Note. *due to hostilities; CI: confidence interval; LI: lower limit; UL: upper limit; PF: physical functioning; RF: physical role functioning; BP: bodily pain; GH: general health; VT: vitality; SF: social functioning; RE: emotional role functioning

Discussion

In sports psychology, scientists are increasingly seeking to operationalize and theoretically combine the spheres of well-being that characterize the experience of athletes (Dohme et al., 2019). In the case of athletes, various aspects of health are directly reflected in their well-being and are the cause of their poor well-being. According to our results, the majority of athletes had higher than average statistical parameters of the physical component of the quality of life related to health, which confirms high physical capabilities and the ability to cope with significant loads. It can be assumed that this tendency will persist as the athlete matures. However, in the case of the mental component, opposite conclusions can be obtained. Only 28.72% of participants have an index higher than the average for the population; among adult athletes, this parameter is two times lower. It should be emphasized that mental well-being aspects cannot be separated from physical health, as the symptoms of mental health and related systemic disorders increase the risk of physical trauma and delay recovery.

We did not find any difference between men and women in the case of life satisfaction. At the same time the difference in parameters related to health, in particular physical role functioning, general health, vitality, social functioning, and emotional role functioning was quite significant. For social functioning and physical role functioning difference was more than 13 points, which cannot be fully explained only by gender influences. Women were distinguished by particularly low parameters of physical role functioning, vitality, emotional role functioning, and mental health. The only indicator that was at a high level in both groups was physical functioning (above 85 points), while physical role functioning, which characterizes the relationship between the performance of daily tasks and the respondent's physical condition, was below the average level. In our study, most of the health indicators of female athletes were at a low level or close to this level, indicating low vitality, severe fatigue, a decrease in the number of social contacts due to an unsatisfactory physical and emotional state, the presence of negative emotions and poor physical well-being that limits work capacity and daily activity.

Our research revealed differences between individual parameters of well-being (stress, anxiety) of different generations of athletes, but we did not find a statistically significant difference between life satisfaction of adults and young athletes. Among young athletes, there were significantly fewer people with symptoms of stress (67%) and anxiety (25.53%). It can be argued that negative phenomena related to mental health that was observed to a greater extent have their own prerequisites and are obviously cumulative in nature. The sample of athletes analyzed by us was in the territory where there were active military operations or shelling and bombing. At the same time, the war began during the coronavirus epidemic, which had a negative impact on the physical and mental health of professional athletes (Jurecka et al., 2021). Among the effects that were most commonly observed were a decrease in physical activity, an increase in time spent in a sitting position, increased negative emotions (stress, fatigue, anger, tension and depression) and deterioration of sleep quality, in particular among persons who took care of children or older family members (Xu et al., 2023).

Another factor that can cause a decrease in well-being is lack of security and protection. However, in the case of athletes who have suffered from the war, development occurs in a dangerous and uncertain environment (Michelini, 2018; Newnham et al., 2018). One of the factors affecting the life satisfaction of young Ukrainian athletes is a change of residence. It can have different effects; many people demonstrate considerable ingenuity, competence and self-efficacy in the face of difficulties (Xu et al., 2023), using different available supports and opportunities. However, a large part of the population has problems with mental health that adversely influence their well-being and physical health (Kien et al., 2019; Kurapov et al., 2022; Mesa-Vieira et al., 2022). Indicators of mental health in persons who suffered from the war and refugees differ significantly (Kien et al., 2019). However, despite the variability of prevalence estimates, records indicate that there is an increased level of psychological disorders and maladaptation among people affected by the war.

Limitations and directions for future research

This is the first study that concerns the mental state and well-being of highly qualified athletes during the Russo-Ukrainian war and allows us to deepen the understanding of athletes' resilience in an adverse environment. We identified predictors of high levels of well-being in athletes taking into account not only individual and war-related indicators but also parameters related to health. At the same time, the limitations of this study are the involvement of only strength athletes, the use of a relatively small dataset, the non-consideration of the level of war-related trauma or previous history of mental illness, reliance on linear relationships between potential predictors, and the dependent variable. This requires expanding the research to athletes of other specializations and using modeling methods to more accurately analyze the interactions of potential predictors of athletes' well-being and life satisfaction.

Conclusions

Our data reveal low indicators of mental health and at the same time their importance in general well-being and the essential connection between parameters of physical functioning and mental state. According to the results of our research, we can single out three groups of factors that will determine the life satisfaction of young Ukrainian athletes – these are factors at the individual level (stress, depression) and contextual factors (change of place of residence or training due to the war). Health indicators can be combined into a separate group of factors (general perception of one's own health and pain sensations). The obtained results can be used to rapidly screen persons in the risk group during a war and further develop individual psychotherapeutic programs to overcome trauma and the consequences of war.

References

Bessa, C., Hastie, P., Araújo, R., & Mesquita, I. (2019). What do we Know About the Development of Personal and Social Skills within the Sport Education Model: a Systematic Review. *Journal of Sports Science & Medicine, 18*(4), 812.

Campbell, E., Irving, R., Bailey, J., Dilworth, L., Abel, W. (2018). Overview of Psychophysiological Stress and the Implications for Junior Athletes. *Am. J. Sport. Sci. Med, 6*(3), 72–78. https://doi.org/10.12691/ajssm-6-3-2.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *J Health Soc Behav, 24*(4), 385–396.

Diener, E., Emmons, R. A., Larsem, R. J., & Griffin, S. (1985). The Satisfaction with Life Scale. *Journal of Personality Assessment, 49*(1), 71–75. https://doi.org/10.1207/s15327752jpa4901_13

Dohme, L. C., Piggott, D., Backhouse, S., & Morgan, G. (2019). Psychological Skills and Characteristics Facilitative of Youth Athletes' Development: A Systematic Review. *The Sport Psychologist, 33*(4), 261–275. https://doi.org/10.1123/TSP.2018-0014

Eime, R. M., Young, J. A., Harvey, J. T., Charity, M. J., & Payne, W. R. (2013). A systematic review of the psychological and social benefits of participation in sport for children and adolescents: Informing development of a conceptual model of health through sport. *International Journal of Behavioral Nutrition and Physical Activity, 10*(1), 1–21. https://doi.org/10.1186/1479-5868-10-98/TABLES/2

Jones, A. M., & Carter, H. (2000). The effect of endurance training on parameters of aerobic fitness. *Sports Medicine, 29*(6), 373–386. https://doi.org/10.2165/00007256-200029060-00001/METRICS

Jurecka, A., Skucińska, P., & Gądek, A. (2021). Impact of the SARS-CoV-2 Coronavirus Pandemic on Physical Activity, Mental Health and Quality of Life in Professional Athletes—A Systematic Review. *International Journal of Environmental Research and Public Health, 18*(17), 9423. https://doi.org/10.3390/IJERPH18179423

Kien, C., Sommer, I., Faustmann, A., Gibson, L., Schneider, M., Krczal, E., Jank, R., Klerings, I., Szelag, M., Kerschner, B., Brattström, P., & Gartlehner, G. (2019). Prevalence of mental disorders in young refugees and asylum seekers in European Countries: a systematic review. *European Child and Adolescent Psychiatry, 28*(10), 1295–1310. https://doi.org/10.1007/S00787-018-1215-Z

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2001). The PHQ-9: Validity of a Brief Depression Severity Measure. *Journal of General Internal Medicine, 16*(9), 606. https://doi.org/10.1046/J.1525-1497.2001.016009606.X

Kurapov, A., Pavlenko, V., Drozdov, A., Bezliudna, V., Reznik, A., & Isralowitz, R. (2022). Toward an Understanding of the Russian-Ukrainian War Impact on University Students and Personnel. *Journal of Loss and Trauma*. https://doi.org/10.1080/15325024.2022.2084838

DOI 10.26773/mjssm.230904

Malm, C., Jakobsson, J., & Isaksson, A. (2019). Physical Activity and Sports—Real Health Benefits: A Review with Insight into the Public Health of Sweden. *Sports, 7*(5). https://doi.org/10.3390/SPORTS7050127

Mehrsafar, A. H., Moghadam Zadeh, A., Gazerani, P., Jaenes Sanchez, J. C., Nejat, M., Rajabian Tabesh, M., & Abolhasani, M. (2021). Mental Health Status, Life Satisfaction, and Mood State of Elite Athletes During the COVID-19 Pandemic: A Follow-Up Study in the Phases of Home Confinement, Reopening, and Semi-Lockdown Condition. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.630414

Mesa-Vieira, C., Haas, A. D., Buitrago-Garcia, D., Roa-Diaz, Z. M., Minder, B., Gamba, M., Salvador, D., Gomez, D., Lewis, M., Gonzalez-Jaramillo, W. C., Pahud de Mortanges, A., Buttia, C., Muka, T., Trujillo, N., & Franco, O. H. (2022). Mental health of migrants with pre-migration exposure to armed conflict: a systematic review and meta-analysis. *The Lancet Public Health, 7*(5), e469–e481. https://doi.org/10.1016/S2468-2667(22)00061-5

Michelini, E. (2018). War, migration, resettlement and sport socialization of young athletes: the case of Syrian elite water polo. European Journal for Sport and Society, 15(1), 5–21. https://doi.org/10.1080/16138171.2018.1440949

Newnham, E. A., Kashyap, S., Tearne, J., & Fazel, M. (2018). Child mental health in the context of war: An overview of risk factors and interventions for refugee and war-affected youth. *Mental Health of Refugee and Conflict-Affected Populations: Theory, Research and Clinical Practice*, 37–63. https://doi.org/10.1007/978-3-319-97046-2_3/COVER

Ochnik, D., Rogowska, A. M., Kuśnierz, C., Jakubiak, M., Schütz, A., Held, M. J., Arzenšek, A., Benatov, J., Berger, R., Korchagina, E. V., Pavlova, I., Blažková, I., Aslan, I., Çınar, O., & Cuero-Acosta, Y. A. (2021). Mental health prevalence and predictors among university students in nine countries during the COVID-19 pandemic: a cross-national study. *Scientific Reports, 11*(1), 1–13. https://doi.org/10.1038/s41598-021-97697-3

Pillay, L., Janse van Rensburg, D. C. C., Jansen van Rensburg, A., Ramagole, D. A., Holtzhausen, L., Dijkstra, H. P., & Cronje, T. (2020). Nowhere to hide: The significant impact of coronavirus disease 2019 (COVID-19) measures on elite and semi-elite South African athletes. *Journal of Science and Medicine in Sport, 23*(7), 670–679. https://doi.org/10.1016/J.JSAMS.2020.05.016

Pope, C. C., Penney, D., Smith, T. B. (2018). Reflective Practice International and Multidisciplinary Perspectives Overtraining and the Complexities of Coaches' Decision-Making: Managing Elite Athletes on the Training Cusp. *International and Multidisciplinary Perspectives, 19*(2), 145–166. https://doi.org/10.1080/14623943.2017.1361923

Rice, S. M., Purcell, R., De Silva, S., Mawren, D., Patrick, •, Mcgorry, D., & Parker, A. G. (2016). The Mental Health of Elite Athletes: A Narrative Systematic Review. *Orygen Youth Health Clinical Program, 46*, 1333–1353. https://doi.org/10.1007/s40279-016-0492-2

Rogowska, A. M., Ochnik, D., Kuśnierz, C., Jakubiak, M., Schütz, A., Held, M. J., Arzenšek, A., Benatov, J., Berger, R., Korchagina, E. V, Pavlova, I., Blažková, I., Konečná, Z., Aslan, I., Çınar, O., & Cuero-Acosta, Y. A. (2021). Satisfaction with life among university students from nine countries: Cross-national study during the first wave of COVID-19 pandemic. *BMC Public Health*. https://doi.org/10.1186/s12889-021-12288-1

Rogowska, A. M., Pavlova, I., Kuśnierz, C., Ochnik, D., Bodnar, I., & Petrytsa, P. (2020). Does physical activity matter for the mental health of university students during the COVID-19 pandemic? *Journal of Clinical Medicine, 9*(11), 1–19. https://doi.org/10.3390/jcm9113494

Speech of the Prime Minister of Ukraine Denys Shmyhal at the Government meeting Cabinet of Ministers of Ukraine. (n.d.). Retrieved August 6, 2023, from https://www.kmu.gov.ua/news/promova-premier-ministra-ukrainy-denysa-shmyhalia-na-zasidannia-uriadu

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A Brief Measure for Assessing Generalized Anxiety Disorder: The GAD-7. *Archives of Internal Medicine, 166*(10), 1092–1097. https://doi.org/10.1001/ARCHINTE.166.10.1092

Ware, J. E., & Sherbourne, C. D. (1992). The MOS 36-Item Short-Form Health Survey (SF-36) I. Conceptual Framework and Item Selection. *Med Care, 30*(6), 473-83

Xanthopoulos, M. S., Benton, T., Lewis, J., Case, J. A., & Master, C. L. (2020). Mental Health in the Young Athlete. *Current Psychiatry Reports, 22*(11), 1–15. https://doi.org/10.1007/S11920-020-01185-W/METRICS

Xu, W., Pavlova, I., Chen, X., Petrytsa, P., Graf-Vlachy, L., & Zhang, S. X. (2023). Mental health symptoms and coping strategies among Ukrainians during the Russia-Ukraine war in March 2022. International Journal of Social Psychiatry, 1–10. https://doi.org/10.1177/00207640221143919

ORIGINAL SCIENTIFIC PAPER

Bilateral Asymmetry and the Relationship Between Unilateral Isokinetic Strength and Balance Performance in Male Adolescent Football Players

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Abstract

Muscle strength and balance ability have been related to injury prevention and game actions performance in football. The aims of this study are twofold: (1) to examine bilateral asymmetries in isokinetic strength and balance assessments, and (2) to evaluate the relationship between muscle strength and balance measures. Eighty-eight male adolescent football players were assessed for body composition (InBody 770), isokinetic strength (Biodex System 4 Pro Dynamometer), and balance performance (Biodex Balance System). Paired samples t-tests were conducted to determine bilateral differences in strength and balance. Pearson correlations and multiple linear regression analyses evaluated the relationship between strength and balance. No significant bilateral strength differences were observed in knee flexors (KF) and knee extensors (KE) peak torque (PT) scores. No bilateral differences were found for balance measures, except in the lateromedial stability index, which was better while performing with the preferred leg ($p \leq 0.01$; $d = 0.29$). Significant correlations were found between KE PT and balance tasks ($p \leq 0.01$). KF and KE PT shared between 18 and 22% of the common variance in the overall stability index in the non-preferred and preferred leg, respectively. Monitoring strategies of bilateral asymmetries may be crucial to enhance performance in tasks underpinned by unilateral movements, such as changes of direction and sprints, and to identify players at risk of injury. Adopting these strategies during the early stages of football training might be crucial for players' long-term development.

Keywords: *soccer, peak torque, knee flexors, knee extensors, youth*

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Introduction

In football, players often perform jumping, sprinting, and rapid change of direction actions (Wisloff et al., 2004). Since these movements are associated with force-time characteristics (Suchomel et al., 2016; Wisloff et al., 2004), muscle strength is recognized as one critical physical attribute of football players. Greater muscle strength has been associated with enhanced sport-specific skills performance and decreased injury rates (Suchomel et al., 2016).

Meanwhile, lower-body strength assessments (i.e., squat or the half-squat) tend to be bilateral and fail to examine strength asymmetries in the lower limbs. The existence of bilateral strength differences between the preferred leg (PL) and the non-preferred leg (NPL) remains controversial, with acceptable deficits ranging between 10 and 15% (Teixeira et al., 2014). Pending the player's characteristics, the asymmetries between limbs can be functional at different magnitudes (Sannicandro et al., 2012). Previous research has reported that morphological adaptations between the kicking and support limbs of football players might occur in response to repetitious asymmetrical loading patterns resulting from their functional differences within the context of their sport (Hart et al., 2016). As an example, relationships between levels of training exposure and asymmetrical loading exposure (kicking limb vs support limb) were observed, with distinct morphological adaptation noted between limbs (Hart et al., 2016).

Although some literature suggests that significant imbalances can be associated with increased musculoskeletal injury occurrences (Croisier et al., 2008; Van Dyk et al., 2016), a recent systematic review reported that relationship as low to moderate, and there is inconsistency in the findings (Helme et al., 2021). Despite these inconsistencies, knowing the asymmetry level between limbs is helpful to address the detrimental effects of possible inter-limb asymmetry. A recent study described that inter-limb asymmetries seem to present a negative impact on tasks underpinned by unilateral movements, such as changes of direction and sprints (Fox et al., 2023). Therefore, monitoring strategies should be adopted to identify and address inter-limb asymmetries according to individual needs.

Frequently, muscle strength has been defined as the ability to produce a force on an external object or resistance (Suchomel et al., 2016). Thus, isokinetic strength assessments have become popular, safe, and reliable in the sports literature. Several investigations have examined bilateral strength imbalances through isokinetic strength tests in professional football (Croisier et al., 2008; Menzel et al., 2013; Van Dyk et al., 2016). Among 46 male professional footballers aged 24.8±3.2 years, the authors reported a mean of bilateral strength asymmetry of 9.14% at peak torque (PT) for concentric knee flexion (KF) while performing at 60º/s (Menzel et al., 2013). In the same testing conditions, another study showed a mean difference of 7% at KF and 6.5% at KE between the PL and the NPL in footballers aged 23.8±2.12 years (Teixeira et al., 2014). Although these strength asymmetries have been identified, the scores reported are within the respective average values. Besides strength comparison between limbs, research has also analyzed the hamstrings to quadriceps ratio (H:Q ratio) due to its relationship with injury. For isokinetic strength testing at 60º/s, lower values than 0.60 for the H:Q ratio has been associated with injuries, such as anterior cruciate ligament injuries and hamstring strains (Croisier et al., 2002). However, most data on lower-limb strength asymmetries are available at the professional football level, and a detailed analysis still lacks among youth.

Meantime, football players frequently perform actions using unilateral stances, such as kicking, passing, and dribbling, which demands balance control. Better balance ability, both in stable and dynamic conditions, was observed in elite players compared to their non-elite counterparts (França et al., 2022). Besides, a significant relationship between balance and injury prevention was previously found (Al Attar et al., 2022). In contrast, different reports have emerged concerning bilateral asymmetries in balance measures (Gkrilias et al., 2018; González-Fernández et al., 2022; McCurdy & Langford, 2006; Thorpe & Ebersole, 2008). While no differences were observed among healthy adults (McCurdy & Langford, 2006) and female collegiate football players (Thorpe & Ebersole, 2008), substantial bilateral asymmetries were found in youth footballers (Gkrilias et al., 2018; González-Fernández et al., 2022). Additionally, in youth football, inter-limb asymmetry in dynamic balance performance was reported (Gkrilias et al., 2018; González-Fernández et al., 2022), but no data concerning stability is available.

Of note, muscle strength levels may be beneficial to balance control (Booysen et al., 2015; Śliwowski et al., 2021).

The ability to generate eccentric strength and power presented moderate correlations with the Y-Balance scores on the NPL in male footballers (Booysen et al., 2015). Among volleyball players, both the KF and KE PT were significantly correlated with the overall stability index (OSI) in both legs' performance (Soylu et al., 2020). However, most of the previous research designed to examine the relationship between muscle strength and balance performance in sports has favored elite players or non-athlete populations, and importantly, detailed knowledge regarding youth is still lacking.

Therefore, the aims of this study are twofold: (1) to examine bilateral asymmetries according to the PL and NPL in strength and balance, and (2) to evaluate the relationship between strength and balance measures. First, it was hypothesized that superior levels of strength and balance would be observed in the performance of the PL, and secondly, it was expected a significant and positive relationship between strength and balance.

Methods

Study design

The study followed a descriptive cross-sectional design. The study protocol was approved by the Faculty of Human Kinetics Ethics Committee (CEIFMH N°34/2021) and followed the Declaration of Helsinki. All the assessments were conducted in a physical performance laboratory by trained staff from the research team. All participants were volunteers, and informed consent was obtained from their respective legal guardians.

The study was conducted during the sports season 2021/2022, after two months of training sessions. Each participant was assessed on two consecutive days, with a rest interval of at least 12h regarding the latest training session.

Participants

Eighty-eight male adolescent football players aged 15.9±1.6 years participated in this study. The optimal sample size calculation was performed using G*Power 3.1. A priori paired-sample t-test (two-tails) indicated a sample size of 54 participants to achieve 80% power to detect an interaction effect size of 0.5 at 0.05 level of significance. In the second anal-

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ysis, a priori Pearson product-moment correlation showed a total sample of 84 participants to achieve 80% power to detect an interaction effect size of 0.3 at 0.05 level of significance. Then, a priori multiple regression analysis indicated a sample size of 55 participants to achieve 80% power considering an effect size of 0.15 at 0.05 level of significance.

Twenty players had the left leg as the preferred limb. Limb preference was defined as the leg that is preferred when kicking a ball. Participants had at least three years of football training experience and competed at the regional level in Portugal. Training frequency was four times per week plus one match during the weekend.

Body composition

Body composition was evaluated during the early morning while participants were fasting. Stature was assessed to the nearest 0.01 cm using a stadiometer (SECA 213, Hamburg, Germany). A hand-to-foot bioelectrical impedance analysis (InBody 770, CA, USA) was used for measurement (McLester et al., 2020), with participants only wearing their underwear. Among the body composition variables, body mass, body fat percentage (BF%), total fat-free mass (FFM), and segmental FFM of the PL and the NPL were retained for analysis.

Isokinetic testing

Isokinetic measurements were performed on the hamstrings and quadriceps muscles using the Biodex System 4 Pro Dynamometer (Shirley, NY, USA) (Van Tittelboom et al., 2022). Before data collection, a 5-minute warm-up in a reclining bicycle (Technogym Xt Pro 600 Recline, Cesena, Italy) was performed. Then, participants were seated in the dynamometer following the manufacturer's guidelines. The lever arm of the dynamometer was aligned with the lateral epicondyle of the knee, while the trunk, the evaluated thigh, and the leg were stabilized with belts. The range of motion was defined as participants carrying the knee extension to its maximum range. Then, participants were asked to flex the kneed until 90º of flexion. As recommended, individual calibration for gravity correction was performed at 30º of knee flexion. During testing, participants were asked to keep their arms crossed with the hand on the opposite shoulder holding the belts, and verbal support was given throughout the tests. Three repetition trials were given before testing to ensure the correct execution. After, five repetitions of concentric contraction efforts of knee flexion and knee extension were performed at 60º/s, with a 60 s interval. This testing speed has been recommended to assess strength. For analysis, the peak torque (PT), the relative peak torque/body weight (PT/BW), and the conventional hamstring-to-quadriceps (H:Q) strength ratio for KF and KE in the PL and NPL were calculated. The H:Q conventional ratio was used since it was generally measured during concentric contraction (Aagaard et al., 1998) and was calculated by dividing the mean concentric KF PT by the mean KE concentric PT over the five repetitions. Finally, the limb symmetry index (LSI) was calculated using the equation (1):

Balance testing

Balance assessment was performed using the Biodex Balance System SD (Biodex, Shirley, NY, USA). For testing, participants were barefoot in an upright position, arms placed laterally to the body, and feet set shoulder-width apart. Before testing, the equipment was adjusted to the height of the participants. A single training session was allowed before data collection to ensure correct execution and minimize learning effects during the testing phase. The rest interval between testing conditions was set at 60 s. Bilateral comparison consisted of a protocol performed in a unilateral stance. Level 4 was the most stable, and level 1 was the most unstable. The testing scores reflect the level of deviation from the horizontal position. Therefore, lower scores indicate better balance performance (Yamada et al., 2012). For analysis, the Overall Stability Index (OSI), Anteroposterior Stability Index (APSI), and Lateromedial Stability Index (LMSI) were used.

Statistics

Descriptive statistics are presented as means ± standard deviation. All data were checked for normality using the Kolmogorov-Smirnov test. Paired samples t-tests were conducted to identify bilateral differences in isokinetic strength and balance assessments. Effect size (d) was interpreted using d-Cohen as follows (Cohen, 1988): $d < 0.2$ (small), $0.2 > d < 0.6$ (moderate), $0.6 > d < 1.2$ (large), and $d > 1.2$ (very large). The Pearson product-moment correlation was used to explore the relationships between isokinetic strength and balance tests according to each leg. Correlations values were interpreted according to their size (Cohen, 1988): $0.10 > r < 0.29$ (small), $0.30 > r < 0.49$ (medium), $0.50 > r < 1.0$ (large). Finally, multiple linear regression analyses were performed to determine the association between isokinetic strength and balance performance. To avoid heteroscedasticity, the dependent variable was transformed using the log. All analyses were performed using IBM SPSS Statistics software 28.0 (SPSS Inc., Chicago, IL, USA). The significance level was set at 0.05.

Results

Table 1 resumes descriptive statistics concerning age and body composition.

Table 1. Descriptive statistics for body composition of adolescent male football players (n = 88)

Variable	Mean (95% CI)	SD
CA (years)	15.9 (15.5 - 16.2)	1.6
Stature (cm)	172.3 (170.5 - 174.1)	8.3
Body mass (kg)	63.5 (61.5 - 65.5)	9.3
FFM (kg)	55.7 (54.0 - 57.5)	8.3
BF (%)	11.7 (10.6 – 12.9)	5.3

95% CI (95% confidence interval), SD (standard deviation), CA (chronological age), FFM (fat-free mass), BF (body fat)

Table 2 presents the descriptive statistics and bilateral comparison in strength and balance assessments. No significant differences between the PL and NPL were observed for KF PT/BW, KE PT/BW, and H:Q strength ratio in isokinetic strength parameters. LSI analysis showed a difference of 1.7% for KF PT and 1.2% for KE PT values when the PL was compared to the NPL.

Concerning body composition, FFM was significantly higher in the PL than in NPL (p≤0.01, trivial effect size). No overall differences were seen in balance performance, except in the LMSI testing, which was substantially better in the PL (p≤0.01, moderate effect size). Although the results are not statistically significant, better overall balance scores were achieved while performing with the PL compared to the NPL.

Table 2. Descriptive statistics and comparison of preferred and non-preferred leg performance in isokinetic dynamometer and unilateral balance assessment (n = 88)

Parameter	Preferred leg		Non-preferred leg		Paired comparisons			
	Mean (95% CI)	SD	Mean (95% CI)	SD	t	p	d	LSI (%)
Isokinetic strength								
KF PT (Nm)	90.0 (85.7 – 94.4)	20.7	88.5 (84.1 – 93.0)	21.2	1.184	0.24	0.07	98.3
KF PT/BW (Nm/kg)	1.36 (1.28 – 1.45)	0.38	1.35 (1.27 – 1.44)	0.37	0.499	0.62	0.03	
KE PT (Nm)	151.0 (141.7 – 160.3)	43.8	152.8 (144.2 – 161.3)	40.2	1.000	0.32	0.04	98.8
KF PT/BW (Nm/kg)	2.32 (2.15 – 2.49)	0.78	2.35 (2.18 – 2.52)	0.76	0.960	0.34	0.04	
H:Q strength ratio (%)	0.62 (0.59 – 0.65)	0.15	0.60 (0.57 – 0.63)	0.15	1.762	0.08	0.13	
Body composition								
FFM (kg)	8.93 (8.60 – 9.25)	1.46	8.86 (8.54 – 9.18)	1.43	4.947	≤ 0.01**	0.05	
Balance								
OSI (º)	2.14 (1.70 – 2.58)	2.06	2.37 (1.93 – 2.81)	2.07	1.775	0.08	0.11	
APSI (º)	1.64 (1.22 – 2.06)	1.97	1.73 (1.32 – 2.15)	1.95	0.739	0.46	0.05	
LMSI (º)	1.02 (0.85 – 1.20)	0.84	1.27 (1.08 – 1.46)	0.92	2.567	≤ 0.01**	0.29	

95% CI (95% confidence interval), SD (standard deviation), KF (knee flexors), KE (knee extensors), PT (peak torque), BW (bodyweight), H:Q (hamstrings/quadriceps), FFM (fat-free mass), OSI (overall stability index), APSI (anteroposterior stability index), LMSI (lateromedial stability index), LSI (limb symmetry index), ** p ≤ 0.01

Tables 3 and 4 show the significant correlation coefficients between isokinetic strength and balance parameters for the PL and NPL, respectively. Significant correlations were found between KF and KE PT/BW, both for the PL (r = 0.80, p≤0.01) and the NPL (r = 0.74, p≤0.01). The KE PT/BW presented strong and negative correlations with balance indicators both for the PL (p≤0.01) and the NPL (p≤0.01). In contrast, KF/PT only showed significant correlations with balance indicators in the PL analysis. Among balance parameters, the OSI correlated significantly and positively with the APSI and LMSI in both evaluations. Overall, the PL analysis observed the highest number of relationships between isokinetic strength and balance tasks.

Table 3. Correlation coefficients between isokinetic strength and balance in the preferred leg assessments

Parameter	1.	2.	3.	4.	5.
1. KF PT/BW	-	0.80**	-0.27*	-0.27*	-0.20
2. KE PT/BW		-	-0.48**	-0.44**	-0.40**
3. OSI			-	0.97**	0.63**
4. APSI				-	0.44**
5. LMSI					-

KF (knee flexion); KE (knee extension); PT/BW (Peak Torque/Bodyweight); OSI (overall stability index); APSI (anteroposterior stability index); LMSI (lateromedial stability index); * p ≤ 0.05; ** p ≤ 0.01

Table 4. Correlation coefficients between isokinetic strength and balance in the non-preferred leg assessments

Parameter	1.	2.	3.	4.	5.
1. KF PT/BW	-	0.74**	-0.16	-0.16	-0.11
2. KE PT/BW		-	-0.40**	-0.40**	-0.34**
3. OSI			-	0.97**	0.79**
4. APSI				-	0.63**
5. LMSI					-

KF (knee flexion); KE (knee extension); PT/BW (Peak Torque/Bodyweight); OSI (overall stability index); APSI (anteroposterior stability index); LMSI (lateromedial stability index); * p ≤ 0.05; ** p ≤ 0.01

Finally, the results of linear regression analyses with isokinetic strength (PT/BW) predicting balance performance are summarized in Figures 1 and 2. The model explained between 18 and 23% of the variance observed in the OSI performance for the NPL and PL, respectively. In both cases, KF PT/BW and KE PT/BW were significant predictors of the model. However, the strongest unique contribution for OSI scores was seen in KE PT/BW (PL: β = -0.712, p≤0.01, and NPL: β = -0.595, p≤0.01).

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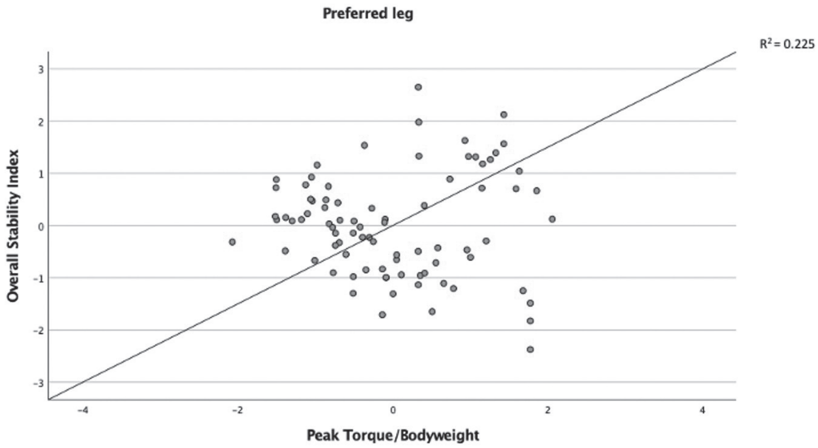

Figure 1. Multiple regression analyses with KF and KE PT/BW as predictors of the OSI scores in the preferred leg analysis.

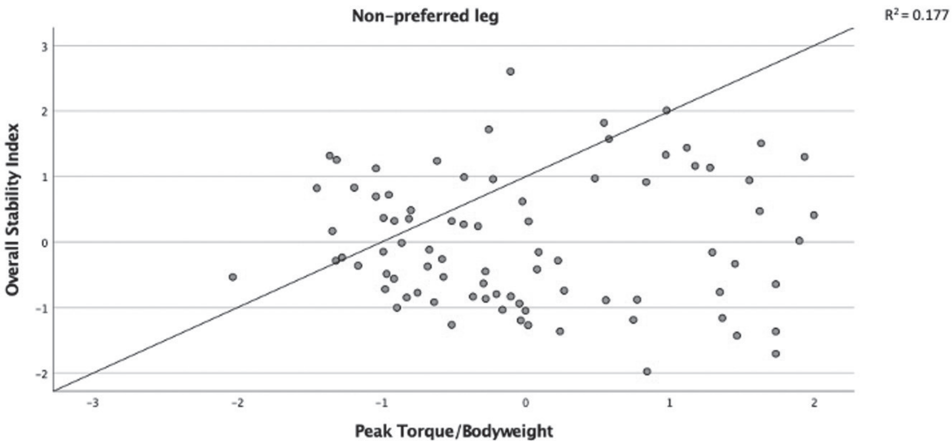

Figure 2. Multiple regression analyses with KF and KE PT/BW as predictors of the OSI scores in the non-preferred leg analysis.

Discussion

This study examined bilateral asymmetries according to the PL and NPL leg in muscle strength and balance tasks in youth football. Also, the relationship between strength and balance measures was assessed. First, it was hypothesized that superior levels of strength and balance parameters would be observed in the performance of the PL. However, no significant bilateral strength differences were observed in the isokinetic strength assessment or balance testing, except in the LMSI. Secondly, it was expected a substantial and positive relationship between strength and balance, which was underlined in the present study results. Overall, muscle strength was positively related to balance performance.

Bilateral asymmetry in youth football

Bilateral asymmetries have been observed in sports with predominant unilateral movements, such as football. Indeed, while playing, using the PL is often favored for football-specific skills performance (Zakas, 2006). In professional players, previous research reported a bilateral strength asymmetry ranging from 7% to 9% when muscle strength was assessed at an angular velocity of 60º/s (Croisier et al., 2003; Menzel et al., 2013). However, note that 10-15% bilateral strength differences have been suggested as relevant for injury occurrence (Croisier et al., 2003). In this study, significant statistical differences were seen in FFM between the PL and the NPL. However, LSI ranged between 98.3% and 98.8%, indicating the existence of small bilateral asymmetries. Previous research reported an average LSI of 103.8% among players between the U11 and U19 age categories when the jump performance was evaluated (Scinicarelli et al., 2022). Still, only one study examining bilateral asymmetry using isokinetic strength was found in youth football, with mean differences of nearly 8% being described at an angular velocity of 60º/s (Rutkowska-Kucharska, 2020). Indeed, performing an isokinetic strength assessment requires specialized measuring equipment that is not frequently available, particularly in youth samples.

Meanwhile, the H:Q strength ratio analysis did not show a significant muscle imbalance between KE and KF. The results indicate an acceptable H:Q score following the literature recommendations for the 60º/s testing speed (>0.60). In contrast, values below 0.60 indicate a substantial strength imbalance between the KE and KF, which could predispose the individual to a non-contact injury (Croisier et al., 2002). According to the literature, football training appears to increase the strength of the knee joint muscles. However, it seems that greater development of the quadriceps muscles is favored compared with the hamstrings muscles (Iga et al., 2009). Moreover, players with imbalances appeared five times more likely to sustain a hamstring strain (Croisier et al., 2003), underlining the importance of testing and monitoring muscle strength levels as a preventive measure.

Association between strength and balance

In this study, a significant correlation between muscle strength levels and balance performance was found. PT scores were significantly and negatively correlated to balance variables, indicating that a higher strength output contributes to a lower deviation from the horizontal position during balance tasks. This relationship is supported by the multiple regression analyses, which showed that PT values could explain between 18% and 22% of the variance observed in the OSI scores for the NPL and the PL, respectively. The results are in line with previous literature focused on the relationship between muscle strength and balance, although using different methods and protocols than the ones applied in this study. For example, among 26 football players aged 16.2±1.6 years, the values of maximal isometric strength were able to explain between 22% and 49% of the variance observed in the Y-balance performance (Chtara et al., 2018). In other studies, the KF PT was described as a significant predictor of the Star Excursion and Y-Balance Tests in athletes from several contexts (Ruiz-Pérez et al., 2019).

When analyzing the model, KF PT/BW and KE PT/BW were significant predictors of OSI in both legs' performance. However, the strongest unique contribution was made by KE PT/BW, emphasizing the role of quadriceps muscle strength in balance performance. Indeed, there is evidence in sports literature that the quadriceps muscle strength is the greater supporter of the knee joint during balance tasks (Śliwowski et al., 2021; Soylu et al., 2020). Reports in previous research described a strong correlation between KE strength and balance performance in male footballers (Śliwowski et al., 2021) and female volleyballers (Soylu et al., 2020), which is in line with the results of the present study.

Concerning balance, overall superior performance was observed with the PL compared to the NPL, although not significantly, except for the LMSI. Past research on this topic has reported controversial results. In football players, some authors reported no substantial asymmetry in balance performance between the lower limbs (Muehlbauer et al., 2019), while others said the opposite (Barone et al., 2011). However, note, that multiple factors could influence the postural balance differences between the lower limbs. Besides, the influence of leg dominance on unilateral balance should probably be context-dependent (Sannicandro et al., 2012).

Limitations and Strengths

This study presents some limitations, such as using cross-sectional data and the lack of assessment of participants' maturity status. Since strength gains are larger during and after the peak height velocity, the maturity status may play an important role in the present study results. Deploying a longitudinal analysis and controlling maturity status would be far more informative. However, few studies are available on isokinetic strength and balance assessment in such a representative sample of youth football players, which should be underlined. This study provides new insights into strength and balance performance in youth football and emphasizes the positive contribution of strength to balance performance. Finally, monitoring strategies of bilateral asymmetries may be crucial to enhance performance in tasks underpinned by unilateral movements, such as changes of direction and sprints, and to identify players at risk of injury. Adopting these strategies during the early stages of football training might be crucial for players' long-term development.

Conclusion

The results of the present study show no significant bilateral asymmetries in strength and balance performance among youth football players. However, a tendency for superior performance levels was seen for the PL. Moreover, strength (PT KE and PT KF) was able to explain between 18% and 22% of the variance observed in the OSI, which is believed to be the best indicator of the overall ability of the individual to balance the platform. Sports agents and coaches are advised to adopt monitoring strategies of strength and balance capabilities to detect inter-limb asymmetries that may compromise tasks supported by unilateral movements and/or enhance the risk of injury. These strategies might be decisive for youth players' long-term development. Future research should include a longitudinal assessment of strength and balance measures and control for the maturity status as a possible confounder of physical performance at this age gap.

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References

Aagaard, P., Simonsen, E. B., Magnusson, S. P., Larsson, B., & Dyhre-Poulsen, P. (1998). A new concept for isokinetic hamstring: quadriceps muscle strength ratio. *The American journal of sports medicine, 26*(2), 231-237.

Al Attar, W. S. A., Khaledi, E. H., Bakhsh, J. M., Faude, O., Ghulam, H., & Sanders, R. H. (2022). Injury prevention programs that include balance training exercises reduce ankle injury rates among soccer players: a systematic review. *Journal of physiotherapy*.

Barone, R., Macaluso, F., Traina, M., Leonardi, V., Farina, F., & Di Felice, V. (2011). Soccer players have a better standing balance in nondominant one-legged stance. *Open Access Journal of Sports Medicine, 2*, 1.

Booysen, M. J., Gradidge, P. J.-L., & Watson, E. (2015). The relationships of eccentric strength and power with dynamic balance in male footballers. *Journal of Sports Sciences, 33*(20), 2157-2165.

Chtara, M., Rouissi, M., Bragazzi, N. L., Owen, A. L., Haddad, M., & Chamari, K. (2018). Dynamic balance ability in young elite soccer players: implication of isometric strength. *J Sports Med Phys Fitness, 58*(4), 414-420.

Cohen, J. (1988). 1988: Statistical power analysis for the behavioural sciences. Hillsdale, NJ: Erlbaum.

Croisier, J.-L., Forthomme, B., Namurois, M.-H., Vanderthommen, M., & Crielaard, J.-M. (2002). Hamstring muscle strain recurrence and strength performance disorders. *The American journal of sports medicine, 30*(2), 199-203.

Croisier, J.-L., Ganteaume, S., Binet, J., Genty, M., & Ferret, J.-M. (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *The American journal of sports medicine, 36*(8), 1469-1475.

Croisier, J.-L., Réveillon, V., Ferret, J., Cotte, T., Genty, M., Popovic, N., Mohty, F., Faryniuk, J., Ganteaume, S., & Crielaard, J.-M. (2003). Isokinetic assessment of knee flexors and extensors in professional soccer players.

 DOI 10.26773/mjssm.230905

Isokinetics and Exercise Science, 11(1).
Fox, K. T., Pearson, L. T., & Hicks, K. M. (2023). The effect of lower inter-limb asymmetries on athletic performance: A systematic review and meta-analysis. *Plos One, 18*(6), e0286942.
França, C., Ihle, A., Marques, A., Sarmento, H., Martins, F., Henriques, R., & Gouveia, É. R. (2022). Physical Development Differences between Professional Soccer Players from Different Competitive Levels. *Applied Sciences, 12*(14), 7343.
Gkrilias, P., Zavvos, A., Fousekis, K., Billis, E., Matzaroglou, C., & Tsepis, E. (2018). Dynamic balance asymmetries in pre-season injury-prevention screening in healthy young soccer players using the Modified Star Excursion Balance Test—a pilot study. *Journal of physical therapy science, 30*(9), 1141-1144.
González-Fernández, F. T., Martínez-Aranda, L. M., Falces-Prieto, M., Nobari, H., & Clemente, F. M. (2022). Exploring the Y-Balance-Test scores and inter-limb asymmetry in soccer players: differences between competitive level and field positions. *BMC Sports Science, Medicine and Rehabilitation, 14*(1), 1-13.
Hart, N. H., Nimphius, S., Weber, J., Spiteri, T., Rantalainen, T., Dobbin, M., & Newton, R. (2016). Musculoskeletal asymmetry in football athletes: a product of limb function over time.
Helme, M., Tee, J., Emmonds, S., & Low, C. (2021). Does lower-limb asymmetry increase injury risk in sport? A systematic review. *Physical therapy in sport, 49*, 204-213.
Iga, J., George, K., Lees, A., & Reilly, T. (2009). Cross-sectional investigation of indices of isokinetic leg strength in youth soccer players and untrained individuals. *Scandinavian Journal of Medicine & Science in Sports, 19*(5), 714-719.
McCurdy, K., & Langford, G. (2006). The relationship between maximum unilateral squat strength and balance in young adult men and women. *Journal of sports science & medicine, 5*(2), 282.
McLester, C. N., Nickerson, B. S., Kliszczewicz, B. M., & McLester, J. R. (2020). Reliability and agreement of various InBody body composition analyzers as compared to dual-energy X-ray absorptiometry in healthy men and women. *Journal of Clinical Densitometry, 23*(3), 443-450.
Menzel, H.-J., Chagas, M. H., Szmuchrowski, L. A., Araujo, S. R., de Andrade, A. G., & de Jesus-Moraleida, F. R. (2013). Analysis of lower limb asymmetries by isokinetic and vertical jump tests in soccer players. *The Journal of Strength & Conditioning Research, 27*(5), 1370-1377.
Muehlbauer, T., Schwiertz, G., Brueckner, D., Kiss, R., & Panzer, S. (2019). Limb differences in unipedal balance performance in young male soccer players with different ages. *Sports, 7*(1), 20.
Ruiz-Pérez, I., Ayala, F., Puerta, J. M., Elvira, J. L., De Ste Croix, M., Hernández-Sánchez, S., & Vera-Garcia, F. J. (2019). A Bayesian Network approach to study the relationships between several neuromuscular performance measures and dynamic postural control in futsal players. *Plos One, 14*(7), e0220065.
Rutkowska-Kucharska, A. (2020). Asymmetry of lower limb strength and jumping ability of young soccer players. *Acta of bioengineering and biomechanics, 22*(1).
Sannicandro, I., Rosa, R., De Pascalis, S., & Piccinno, A. (2012). The determination of functional asymmetries in the lower limbs of young soccer players using the countermovement jump. The lower limbs asymmetry of young soccer players. *Science & Sports, 27*(6), 375-377.
Scinicarelli, G., Offerhaus, C., Feodoroff, B., Froboese, I., & Wilke, C. (2022). Functional performance and interlimb asymmetries of young football players during single-leg jump tests. *German Journal of Exercise and Sport Research, 52*(1), 76-86.
Śliwowski, R., Marynowicz, J., Jadczak, Ł., Grygorowicz, M., Kalinowski, P., & Paillard, T. (2021). The relationships between knee extensors/flexors strength and balance control in elite male soccer players. *Peerj, 9*, e12461.
Soylu, Ç., Altundağ, E., Akarçeşme, C., & Ün Yildirim, N. (2020). The relationship between isokinetic knee flexion and extension muscle strength, jump performance, dynamic balance and injury risk in female volleyball players. *Journal of Human Sport and Exercise 5*(13), 502-514. https://doi.org/10.14198/jhse.2020.153.03
Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The importance of muscular strength in athletic performance. *Sports Medicine, 46*(10), 1419-1449.
Teixeira, J., Carvalho, P., Moreira, C., & Santos, R. (2014). Isokinetic assessment of muscle imbalances and bilateral differences between knee extensores and flexores' strength in basketball, footbal, handball and volleyball athletes. *International Journal of Sports Science 4*(1), 1-6.
Thorpe, J. L., & Ebersole, K. T. (2008). Unilateral balance performance in female collegiate soccer athletes. *The Journal of Strength & Conditioning Research, 22*(5), 1429-1433.
Van Dyk, N., Bahr, R., Whiteley, R., Tol, J. L., Kumar, B. D., Hamilton, B., Farooq, A., & Witvrouw, E. (2016). Hamstring and quadriceps isokinetic strength deficits are weak risk factors for hamstring strain injuries: a 4-year cohort study. *The American journal of sports medicine, 44*(7), 1789-1795.
Van Tittelboom, V., Alemdaroglu-Gürbüz, I., Hanssen, B., Heyrman, L., Feys, H., Desloovere, K., Calders, P., & Van den Broeck, C. (2022). Reliability of isokinetic strength assessments of knee and hip using the Biodex System 4 dynamometer and associations with functional strength in healthy children. *Frontiers in Sports and Active Living, 4*, 817216.
Wisloff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004, Jun). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Br J Sports Med, 38*(3), 285-288. https://doi.org/10.1136/bjsm.2002.002071
Yamada, R. K. F., Arliani, G. G., Almeida, G. P. L., Venturine, A. M., Santos, C. V. d., Astur, D. C., & Cohen, M. (2012). The effects of one-half of a soccer match on the postural stability and functional capacity of the lower limbs in young soccer players. *Clinics, 67*(12), 1361-1364.
Zakas, A. (2006). Bilateral isokinetic peak torque of quadriceps and hamstring muscles in professional soccer players with dominance on one or both two sides. *Journal of Sports Medicine and Physical Fitness, 46*(1), 28.

ORIGINAL SCIENTIFIC PAPER

Evaluation of Different Equations for Resting Metabolic Rate Prediction in Female Combat Sports Athletes

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Abstract

Only a few studies have produced equations that can estimate resting metabolic rate (RMR) in female athletes, but the accuracy of these equations for combat athletes has not yet been tested. The aim of this study was to evaluate the 12 different equations which are commonly using to determine resting metabolite rate (RMR) in the literature. Twenty-three female combat sport athletes (24.23± 3.39 years; 166.8 ± 5.3 cm; 63.13±6.53 kg; 8.78±3.19 experience years.; 56.40±3.43 VO2 mL/kg/min) were participated this study in voluntarily basis. A cross-validation approach used to compare the accuracy of 12 commonly prediction equations with measured RMR by indirect calorimetry to determine RMR in female combat sports athletes. All the predictive equation was underestimated RMR when compared with the measured RMR ($p < 0.05$) and the smallest mean difference (92.46 ± 210.38 kcal·d^{-1}) was observed for Altman & Dittmer equation amongst the 12 predictive equations. The Altman & Dittmer equation was accurately predicted 16 out of 30 subjects' RMR value within the range ±10%. However, based on the Bland–Altman plots, the prediction equations were not accurately nor precisely predicted RMR in the current sample of female combat sport athletes. The results in the present study showed that the Altman & Dittmer equation is most suitable equation to predict RMR amongst 12 equations. Although the Altman & Dittmer equation was resulted with smallest mean difference, it seems that there is need to further research with longitudinal approach to understand the effects of training intensity and body mass changes on RMR in order to develop the formulas already exist used commonly.

Keywords: *energy expenditure, indirect calorimetry, prediction, martial arts*

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Introduction

Resting metabolic rate (RMR) measurement methods, which are used as a helpful tool in the treatment planning of metabolic diseases in clinical settings (Jeziorek et al., 2023; Thurairajasingam et al., 2022), are also widely used in sports to calculate energy expenditure and requirements for maintaining optimal performance and to prevent imbalances that may negatively affect weight control (MacKenzie-Shalders et

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al., 2020). RMR determination can be performed with indirect calorimetry, which provides non-invasive, valid, and reliable measurements by measuring the changes in the percentages of oxygen (O_2) and carbon dioxide (CO_2) in the airflow during respiration (Haugen, Chan, & Li, 2007). On the other hand, various predictive equations are commonly used to estimate RMR based on different factors, such as; Cunningham, De Lorenzo, Freire, Harris-Benedict, Mifflin, Nelson, Owen, Tinsley, Watson (for females), and Schofield equations. Unlike indirect calorimetry, these equations do not require expensive devices or experienced personnel (Fields et al., 2022). Compared with measurements made by indirect calorimetry, the predictive equations used can give overestimated or underestimated results than those obtained by indirect calorimetry (Fields et al., 2022; O'Neill et al., 2022). The results produced through equations with predicted values for energy expenditure can affect the aspects of individual factors such as sex, body composition, age (Müller et al., 2004), genetics (Bouchard et al., 1990; Nonsa-Ard et al., 2022), type of physical activity, and physical activity level (MacKenzie-Shalders et al., 2020).

It has been reported that recommended two equations named Benedict and Schofield by the past by World Health Organization (WHO), the equations overestimate and underestimate the energy expenditure in male and female Germans. In the study conducted with 2528 individuals aged between 5-91 years, significant deviations were observed in the results of individuals even with regular and underweight categories (Müller et al., 2004). In the study conducted by Jagim et al. (2018) with 50 National Collegiate Athletic Association (NCAA), athletes stated that the predictive equations yielded underestimated results compared to indirect calorimetry in determining RMR (Jagim et al., 2018). Additionally, in another study conducted with 187 National Collegiate Athletic Association (NCAA) athletes, when the RMR results obtained through indirect calorimetry and ten different equations were compared, it was emphasized that the results of the equations should be carefully considered and different equations should be preferred carefully according to sex, body type, and activity level (Fields et al., 2022). Although the athlete groups were similar in both studies, the recommended predictive equations are different according to obtained results.

Furthermore, it stated in a meta-analysis that different exercise types and intensities have different effects on RMR. Also, it has been observed that there are few studies in the literature on the equations used to determine RMR in female athletes (MacKenzie-Shalders et al., 2020). Therefore, it is understood that further research is needed on the predictive equation formulas used in determining RMR in terms of sex and sport-disciplines, especially in female athletes. This issue is significant for combat athletes and other sports in which athletes are categorized based on their body weight, and weight control needs to be monitored periodically. These sports require more precise equations to determine RMR with a reduced margin of error that is more closely aligned with indirect calorimetry results. Male and women's energy expenditure values could differ regarding their physiological specifications and training loads. The literature shows that most studies focused on male athletes or subjects while evaluating the existing equations (Balci et al., 2021; Joseph et al., 2017; Tortu et al., 2017). It is understood that, especially for female athletes, it is necessary to extend the data on which equations are more suitable for female athletes by testing these formulas. The present study aimed to evaluate most of the commonly used RMR prediction equations in a group of female combat sports athletes. In addition, the measurement of RMR with indirect calorimetry may need more cost and experienced staff to measure it. Therefore, the present study also aims to provide practitioners with the most accurate equation with the closest prediction compared to indirect calorimetry in female combat sports athletes.

Methods

Experimental Approach to the Problem

The current study compared the accuracy of 12 commonly used prediction equations with indirect calorimetry to calculate RMR in female combat sports athletes using a cross-validation approach. The study's participants were assessed daily to determine body composition and RMR. All tests were administered between 7:00 AM and 11:00 AM to avoid fasting differences and ensure participants were rested. Participants were warned not to exercise strenuously or consume alcoholic or caffeinated beverages for 24 hours before the measurements. RMR was calculated using 12 different predictive equations based on the subjects' physical characteristics and descriptive information.

Participants

Participants were female (24.23± 3,39 years; 166.8 ± 5.3 cm; 63.13±6.53 kg; 8.78±3.19 experience years.; 56,40±3,43 VO2 mL/kg/min) and included from different combat sports (Boxing, n = 10; Wrestling, n = 10; Karate, n = 3). Exclusion criteria were treatment or diagnosis of a cardiac, respiratory, circulatory, musculoskeletal, metabolic, immunological, autoimmune, psychological, hematological, neurological, or endocrine condition or disease. Participants were also excluded from the trial if their respiratory quotient (RQ) was less than 0.70 (Compher et al., 2006). This study was authorised by Trabzon University's Institutional Review Board, and all procedures followed the Helsinki Declaration. The benefits, dangers, and requirements of participating in the current study were explained to all athletes, and informed consent was acquired.

Resting Metabolic Rate and Body Composition

Indirect calorimetry was used since it is a reliable method for calculating an accurate RMR value. All athletes were measured for RMR using indirect calorimetry (Q-NRG®, Cosmed, Roma, Italy). Gas exchange simulations vs. mass spectrometry gas analysis and an ethanol burning test were used to confirm the accuracy and precision of the Q-NRG®'s gas analysis and RQ readings in-vitro. (Delsoglio et al., 2020; Oshima et al., 2019). Inspired and expired air samples are collected and analysed in an interior micromixing chamber utilising a chemical fuel cell O_2 sensor and a non-dispersive infrared adsorption digital CO_2 sensor. Every 30 seconds, the mean values of VO_2, VCO_2, RQ, and EE are presented. This was a non-exertional test in which participants remained supine on an examining table. A transparent, rigid plastic hood and a soft, clear plastic drape were put over the participant's neck, head, and shoulders to evaluate resting oxygen uptake and energy expenditure. Depending on measurement stability, the resting metabolic rate was measured for 20-30 minutes. The first ten minutes of the measurement were

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eliminated, and RMR was calculated as the first ten minutes multiplied by a CV of 5%. This method was adopted from earlier research (Graf et al., 2017) and it saved time when a consistent RMR measurement was detected early on, which could be useful in top sporting scenarios. This method is also the most practical, with a 10-minute test duration and a coefficient of variance of 10% over 5 minutes. (Graf et al., 2017). The subjects were supine and in a relaxed state. The temperature in the room was kept constant at 20-23° C, the lighting was muted, and all subjects took off their shoes. Following the RMR, all participants' height and weight were assessed with a SECA stadiometer. Hamburg, Germany (SECA).

Prediction equations

In this study, resting metabolic rate (RMR) values for each participant were estimated using 12 widely recognized prediction equations, including Harris and Benedict, Jagim, Watson, Mifflin-St.Jeor, De Lorenzo, WHO/FAO/UNU, Owen et al. (Athletes), Schofield, Liu, Altman & Dittmer, IMNA and Maffeis. These equations are summarized in Table 1.

Table 1. Resting metabolic rate predictive equations

Name	Equation
Harris and Benedict	RMR ($kcal{\cdot}d^{-1}$)= 655.1+9.56 x BM (kg) + 1.85 x H (cm)-4.66 x A (year)
Jagim	RMR (kcal.d-1)= 21.10 x (BM) + 288.6
Watson	RMR ($kcal{\cdot}d^{-1}$)=88.1 + 2.53x H (cm)18.42 x M (kg) + 19.46 x A (years)
Mifflin-St.Jeor	RMR ($kcal{\cdot}d^{-1}$)= 66.7+13.75 x BM (kg)+5 x H (cm) - 4.92 x A-161
De Lorenzo	RMR ($kcal{\cdot}d^{-1}$) = 2857 + 9 x BM (kg) + 11.7 x H (cm)
WHO/FAO/UNU	RMR ($kcal{\cdot}d^{-1}$)= 13.3 x BM (kg)+334 x H (m)+35
Owen et al. (Athletes)	RMR ($kcal{\cdot}d^{-1}$)= 50.4 + (21 × BM)
Schofield	RMR ($kcal{\cdot}d^{-1}$)[8.361 ×BM] + [4.654 × H (cm)] + 200.0
Liu	(13.88 x BM(kg) + (4.16 x H (cm) - (3.43 x A (years) - 112.4
Altman & Dittmer	RMR ($kcal{\cdot}d^{-1}$)=[(0.788 ×BM) + 24.11] × 24
IMNA	RMR ($kcal{\cdot}d^{-1}$)=189 - [17.6 × A] + [625 × (H(cm)/100)] + [7.9 ×BM]
Maffeis	RMR ($kcal{\cdot}d^{-1}$)={1552 + [35.8 ×BM] + [15.6 × H(cm)] -[36.3 × A]}/4.18

RMR, resting metabolic rate in kcal/day. BM, body mass (kilograms). H, height A, age (all equations [except the WHO/FAO/UNU equation, which uses height in meters] use height in centimeters).

Statistical Analyses

The paired sample t-test was used to evaluate the result obtained by each prediction equation to the measured indirect calorimetry values. The individual level's accuracy was determined by calculating the percentage of projected values that were within 10% of the measured values. For multiple paired t-test comparisons, the Bonferroni correction was applied. To analyse and compare the accuracy and precision of the prediction equations with indirect calorimetry, Bland-Altman graphs were constructed. The significance level's Alpha value was set at 0.05. The Statistical Package for the Social Sciences (SPSS, Version 21.0; SPSS, Inc., Chicago, IL) was used to analyse the data, and GraphPad Prism Version 8.0 (GraphPad Software, San Diego, CA) was used to generate the figures.

Results

The mean differences in measured vs. predicted RMR in female athletes are summarised in Table 2. All of the prediction algorithms produced statistically different results than the measured RMR value. RMR was severely underestimated by all prediction equations, with the Altman & Dittmer equation

Table 2. A comparison of measured and predicted RMR values (paired t-tests).

RMR Method	RMR ($kcal{\cdot}d^{-1}$) (mean ± SD)	Mean of Differences ($kcal{\cdot}d^{-1}$) (mean ± SD)	95% Confidence Interval	Effect Size (d)	p
Indirect calorimetry	1812.033±266.6				
Harris and Benedict	1463.08±75.9	348.96±224.1	265 to 433	1.78	0.00
Jagim	1620.71±137.8	191.32±207.7	114 to 269	0.9	0.00
Watson	1446.79±114.5	365.24±279.8	261 to 470	1.78	0.00
Mifflin-St.Jeor	1387.73±93.7	424.30±219.0	343 to 506	2.13	0.00
DeLorenzo	1625.32±104.7	186.71±226.0	102 to 271	0.92	0.00
WHO/FAO/UNU	1421.10±96.3	390.91±218.3	309 to 472	1.96	0.00
Owenetal.(Athletes)	1376.20±137.2	435.83±207.8	358 to 513	2.06	0.00
Schofield	1422.11±96.8	389.92±217.9	309 to 471	1.95	0.00
Liu	1371.63±107.3	440.40±212.5	361 to 520	2.17	0.00
Altman&Dittmer	1719.58±123.5	92.46±210.38	14 to 171	0.44	0.02
IMNA	1336.56±128.7	475.49±224.7	392 to 559	2.27	0.00
Maffeis	1338.17±88.1	473.86±222.6	391 to 557	2.39	0.00

having the smallest mean difference (92 kcals).

The Altman & Dittmer equation performed best, predicting 16 out of 30 subjects' RMR accurately within ±10%. The Harris and Benedict, Jagim, Watson, Mifflin-St.Jeor, De Lorenzo, WHO/FAO/UNU, Owen et al. (Athletes), Schofield, Liu, Altman & Dittmer, IMNA, Maffeis, equations predicted, respectively, 5, 9, 5, 3, 13, 5, 3, 3, 3, 16, 2 and 2 participant' RMR accurately (Table 3).

Table 3. Percentage of combat female athletes whose RMR was accurate, overpredicted, or underpredicted as per predictive equation*

Equation	Accurate	Overpredicted	Underpredicted
Harris and Benedict	16.67	6.67	76.67
Jagim	30.00	6.67	63.33
Watson	16.67	3.33	80.00
Mifflin-St.Jeor	10.00	0.00	90.00
De Lorenzo	43.33	6.67	50.00
WHO/FAO/UNU	16.67	0.00	83.33
Owen et al. (Athletes)	10.00	0.00	90.00
Schofield	10.00	3.33	86.67
Liu	10.00	0.00	90.00
Altman & Dittmer	53.33	13.33	33.33
IMNA	6.67	0.00	93.33
Maffeis	6.67	0.00	93.33

*For each equation, data are expressed as percent of the total sample. Each row sums to 100%. Accurately predicted resting metabolic rate falls within ±10% of the value obtained from measured RMR. Overpredicted resting metabolic rate is ≥10% of the value obtained from measured RMR. Underpredicted resting metabolic rate is ≤ -10% of the value obtained from measured RMR

In female athletes, all prediction equations demonstrated a heteroscedastic distribution when compared to observed RMR using indirect calorimetry. The prediction equations did not accurately or precisely estimate resting metabolic rate in the current sample of female athletes based on the Bland-Altman plots. Figure 1 depicts the findings of the Bland-Altman study.

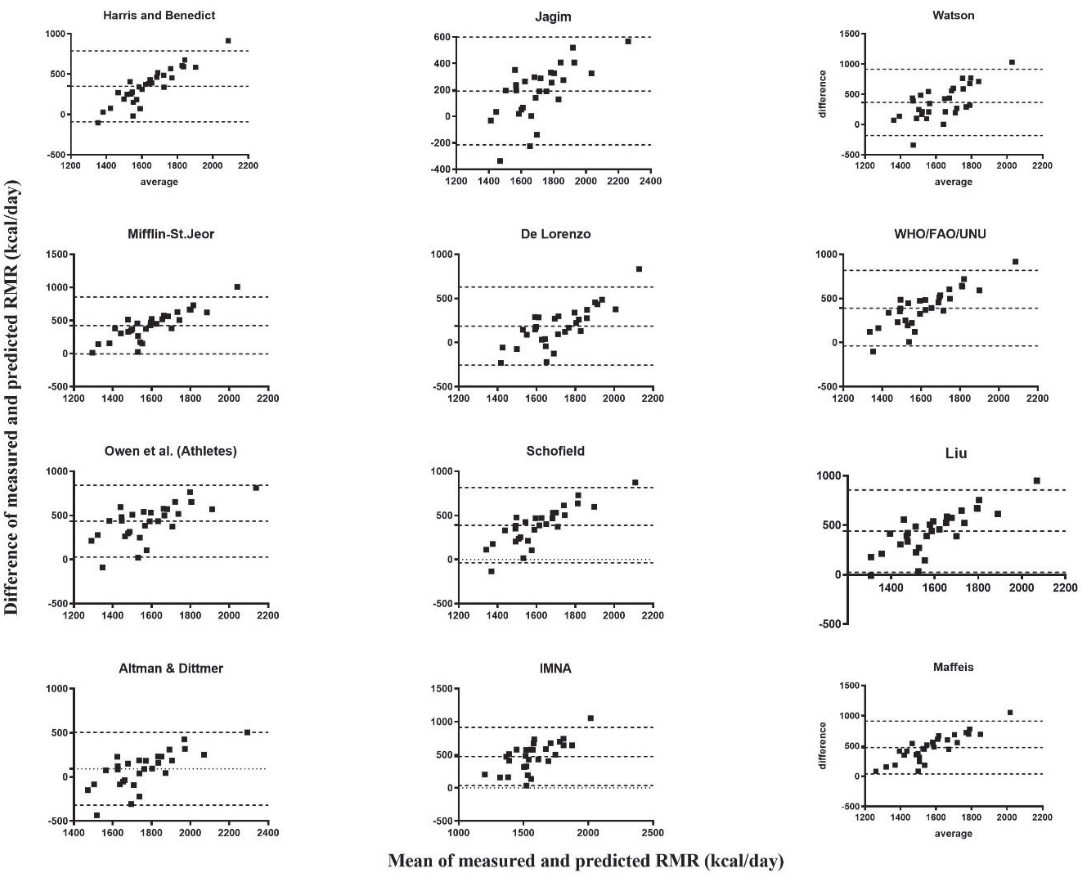

Figure 1.

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Discussion

The current study assessed the accuracy of various commonly used RMR prediction equations among female combat sports athletes. This study presents statistics on the accuracy of RMR prediction equations in female combat sports athletes for the first time. According to the current study, all prediction models greatly underestimated RMR, with the Altman & Dittmer equation having a minor mean discrepancy (92 kcals). However, the mean difference remained considerable, implying that the equation did not reliably predict observed RMR. Differences in anthropometric characteristics between athlete groups, as well as variables used in prediction equations, may explain the variation in accuracy. Our findings show that the accuracy of projected values varies depending on the equation utilized, emphasizing the significance for practitioners to consider numerous criteria when deciding the best equation to apply in a specific athlete group.

Previous studies found that most prediction algorithms underestimate RMR in female athletes (Cunningham, 1980; De Lorenzo et al., 1999). In this investigation, all of the prediction equations drastically underestimated RMR when compared to indirect calorimetry RMR observations. This indicates that the predicted RMR values and their accuracy level may differ based on RMR prediction models used in which population. De Oliveira et al. (de Oliveira et al., 2011), for example, discovered that the World Health Organisation (FAO/WHO/UNU) and Harris-Benedict equations predicted the best RMR (2180 kcals) in overweight and obese people (Harris & Benedict, 1918; Livesey, 1987). The current study's findings show that most of the RMR prediction models employed underestimated RMR values in female athletes. As a result, it is critical to recognize that the equations may underestimate the actual RMR. All equations should be handled cautiously when recommending athletes based on their energy needs. Other studies in the literature have revealed results consistent with the current study about the inaccuracy of RMR prediction equations in athletic populations, particularly in endurance-trained athletes (De Lorenzo et al., 1999; ten Haaf & Weijs, 2014; Thompson & Manore, 1996).

In a study of 51 well-trained male athletes from diverse sports, De Lorenzo et al. (De Lorenzo et al., 1999) discovered that the Harris-Bennett-Mifflin equation overestimated RMR. Similarly, Thompson and Manore (Thompson & Manore, 1996) discovered that among male and female endurance athletes, all mean projected RMR values were lower than measured RMR. Several factors may contribute to RMR underestimation, although the explanation is unknown. Individuals with high levels of physical activity or training status have greater RMR values than individuals with low levels of physical activity or sedentary individuals, which may depend on sport-specific activities. The athletes' current training status, in particular, could impact the measured RMR values (Bullough et al., 1995; Speakman & Selman, 2003; Speakman & Westerterp, 2010). RMR is also affected by the current state of energy balance, according to Bullough et al.(Bullough et al., 1995). The scientists discovered that a high degree of recent exercise activity and a sufficient caloric intake was linked to higher rates of RMR. Recent physical activity status may even influence acute RMR values up to 72-96 hours postexercise (Bullough et al., 1995; Herring et al., 1992; Speakman & Selman, 2003), which may explain the reason for the underestimation or overestimation of any of the specific RMR prediction equations and emphasizes the need for more sport-specific RMR prediction equations to reflect daily metabolic activity fluctuations accurately.

Watson (Watson et al., 2019) and Jagim (Jagim et al., 2019) verified equations in large samples of collegiate athletes from a number of sports (including track and field, swimming, soccer, tennis, softball, volleyball, and field hockey) and gave useful information on validated equations for usage in these groups. On the other hand, female combat athletes were not tested in the scope of the two studies described. As a result, the findings of this study may be valuable in providing information about the most widely utilized equations, particularly in terms of female combat sports athletes.

According to the ACSM's most recent policy statement on nutrition and athletic performance (Thomas, Erdman, & Burke, 2016) appropriate energy intake for athletes is a cornerstone. The Harris-Benedict equation was recommended to predict RMR in the athletic population. However, the advice presented is generalized for the entire athletic population, with no specialized instructions for any specific demographic regarding sport-specific requirements. Specific suggestions are required because each sport discipline has varied needs due to physiological characteristics, weight control, and energy metabolism (Joseph et al., 2017). In this study, the Harris-Benedict equation accurately predicted RMR values within the range ±10% for 5 out of 30 subjects. However, the detected mean difference for energy demand was underestimated as 348,96 kcals.

Devrim-Lanpir et al. (Devrim-Lanpir et al., 2019) found that the Mifflin-St. Jeor equation for women predicts a value close to observed RMR within acceptable limits in ultra-endurance athletes with improved accuracy. In agreement with Jagim et al., the Harris-Benedict equation did not reliably predict values near measured RMR in female ultra-endurance athletes (mean difference 554.86 kcals) (Jagim et al., 2018). In the present study, both the Harris-Benedict and Mifflin-St. Jeor equations (mean differences respectively; 348,96, 424,30 kcals) did not accurately predict the RMR values. Harris-Benedict and Mifflin-St. Jeor accurately predicted the RMR values in only 10.0-16,67% and underestimated in 76,67-90 % of the athletes in this study.

One of the few RMR prediction equations built utilising data from a group of athletes is the De Lorenzo equation (De Lorenzo et al., 1999). It is based on 51 male athletes averaging at least 3 hours of exercise daily. In line with the current study's findings, BM was identified as a significant predictor factor for RMR prediction equations. De Lorenzo et al. (De Lorenzo et al., 1999) also found that BM was a stronger predictor of RMR than FFM in male athletes. Fields et al. (Fields et al., 2022) found that for female athletes, the De Lorenzo and Watson equations yielded the lowest mean difference values of 171 and 211 kcals, respectively, accounting for 54% and 39% of the variance in observed RMR.

Furthermore, no significant mean differences were found for any equation. The De Lorenzo equation revealed the highest consistency with observed RMR values in the female sample, consistent with previous research in athletic groups (Frings-Meuthen et al., 2021; ten Haaf & Weijs, 2014). This equation was proposed as the best successful prediction equation in a sample with heterogeneous body features (Freire et al., 2022). In the current study, the De Lorenzo equation prediction produced the most negligible mean difference (186,71) when compared to the Altman and Dittmer equation (Altman & Dittmer, 1968). De Lorenzo equation accurately predicted the RMR values within the range ±10% for 13 out of 30 subjects.

Balci et al., found no difference in observed and projected RMR using the Mifflin and Owen equations in Turkish Olympic-level female athletes for both equations that gave large root-mean-squared error values in the current investigation (Balci et al., 2021). It is also likely that minor variations in RMR may occur in female athletes throughout the menstrual cycle due to oscillations in ovarian hormone levels, which could affect the accuracy of selected RMR prediction equations (Benton, Hutchins, & Dawes, 2020). As a result, future research should look into how the menstrual cycle affects RMR and total daily energy expenditure in female athletes.

Female participants in the current study had a mean RMR of 1812,033 kcal.d-1, which is higher than earlier studies that indicated a mean RMR range of 1,500-1,594 kcal.d-1 in female athletes (Fields et al., 2022; ten Haaf & Weijs, 2014; Tinsley, Graybeal, & Moore, 2019). Because particular equations may not be applicable across varied populations, more sport-specific or body-type RMR estimates are required. Developed a somatotype-specific equation, it could not be used in the current study due to a lack of skinfold data (Freire et al., 2022). As a result, their equation's agreeability level may be studied and compared with the measured RMR using indirect calorimetry in the population of female athletes in future investigations.

Furthermore, there may have been evolutions in body stature and composition in sports during the last 20-30 years, resulting in results acquired in the scope of the studies conducted over the two decades having wide range variances in terms of longitudinal viewpoint (Norton & Olds, 2001). When examining the accuracy of various RMR prediction equations, particularly those established +20 years ago from smaller or larger athletes with lower or higher RMR levels relative to certain periods representing differing demands for any activity, this may be a complicating variable. When the Bland-Altman plots were examined, it was obvious that most of the predictive equations were more accurate at lower recorded RMR values. Because of the heteroscedasticity demonstrated by the Bland-Altman plots, it is obvious that prediction equations are less likely to accurately estimate RMR for athletes with higher RMR values, as would be the case for athletes with greater body mass. According to the findings of this study, all RMR prediction algorithms produced underestimated RMR levels in female combat athletes.

RMR prediction equations should be used with caution when recommending to athletes regarding actual energy requirements for maintaining energy balance due to their underestimation characteristics. The most suitable equation should be preferred depending on the equation developed for which sport and sex [5]. Furthermore, future research should focus on athletes' training plans or existing training practices. RMR can be increased for several days following some forms of activity, particularly if there is a high degree of exercise-induced muscle damage (Hudson et al., 2019). Underestimation of RMR may result in inappropriate nutrition plans for athletes, which may be problematic and result in insufficient fueling, affecting sports performance and resulting in poorer health outcomes, as well as increasing the risk of low energy availability [43, 44], fat-free mass loss, and injuries (Mountjoy et al., 2018). On the other hand, overestimation of energy requirements might result in weight gain, which can impair performance or periodization for weight control in female combat athletes (Thomas, Erdman, & Burke, 2016). When indirect calorimetry cannot quantify RMR, an accurate RMR estimation equation becomes a critical tool for practitioners and combat athletes.

Conclusion

The results in the present study indicate that the Altman & Dittmer equation is the more suitable equation to predict RMR among 12 equations. If direct access to metabolic equipment is unavailable, Altman & Dittmer prediction equations can be used to estimate RMR for combat athletes. Although the Altman & Dittmer equation resulted in the slightest mean difference, there is a need for further research with a longitudinal approach to understand the effects of training intensity and body mass changes on RMR to develop the formulas already exist used commonly. However, to minimize the mean difference between the predictive equation calculations and indirect calorimetry results and determine the most appropriate equation for combat sports athletes, it is understood that classifications are needed to be based on weight categories to establish homogenized groups. Future studies may consider classifying participants based on their weight category and re-evaluating the accuracy of the equations in a more narrow context regarding participants' demographic factors.

References

Altman, P., & Dittmer, D. (1968). Energy metabolism at various weights. *Metabolism*, 343-345.

Balci, A., Badem, E. A., Yılmaz, A. E., Devrim-Lanpir, A., Akınoğlu, B., Kocahan, T., Hasanoğlu, A., Hill, L., Rosemann, T., & Knechtle, B. (2021). Current predictive resting metabolic rate equations are not sufficient to determine proper resting energy expenditure in Olympic Young Adult National Team Athletes. *Frontiers in Physiology*, *12*, 625370. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7890252/pdf/fphys-12-625370.pdf

Benton, M. J., Hutchins, A. M., & Dawes, J. J. (2020). Effect of menstrual cycle on resting metabolism: A systematic review and meta-analysis. PloS one, 15(7), e0236025. https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0236025&type=printable

Bouchard, C., Tremblay, A., Després, J.-P., Nadeau, A., Lupien, P. J., Thériault, G., Dussault, J., Moorjani, S., Pinault, S., & Fournier, G. (1990). The response to long-term overfeeding in identical twins. *New England Journal of Medicine*, *322*(21), 1477-1482.

Bullough, R. C., Gillette, C. A., Harris, M. A., & Melby, C. L. (1995). Interaction of acute changes in exercise energy expenditure and energy intake on resting metabolic rate. *The American journal of clinical nutrition*, *61*(3), 473-481.

Compher, C., Frankenfield, D., Keim, N., Roth-Yousey, L., & Group, E. A. W. (2006). Best practice methods to apply to measurement of resting metabolic rate in adults: a systematic review. *Journal of the American Dietetic Association*, *106*(6), 881-903.

Cunningham, J. J. (1980). A reanalysis of the factors influencing basal metabolic rate in normal adults. *The American journal of clinical nutrition*, *33*(11), 2372-2374.

 DOI 10.26773/mjssm.230906

De Lorenzo, A., Bertini, I., Candeloro, N., & Piccinelli, R. (1999). A new predictive equation to calculate resting metabolic rate in athletes. *Journal of sports medicine and physical fitness*, *39*(3), 213.

de Oliveira, E. P., Orsatti, F. L., Teixeira, O., Maestá, N., & Burini, R. C. (2011). Comparison of predictive equations for resting energy expenditure in overweight and obese adults. *Journal of obesity*, *2011*.

Delsoglio, M., Dupertuis, Y. M., Oshima, T., van der Plas, M., & Pichard, C. (2020). Evaluation of the accuracy and precision of a new generation indirect calorimeter in canopy dilution mode. *Clinical nutrition*, *39*(6), 1927-1934.

Devrim-Lanpir, A., Kocahan, T., Deliceoðlu, G., Tortu, E., & Bilgic, P. (2019). Is there any predictive equation to determine resting metabolic rate in ultra-endurance athletes? *Prog. Nutr*, *21*, 25-33.

Fields, J. B., Magee, M. K., Jones, M. T., Askow, A. T., Camic, C. L., Luedke, J., & Jagim, A. R. (2022). The accuracy of ten common resting metabolic rate prediction equations in men and women collegiate athletes. *European journal of sport science*, 1-10.

Freire, R., Pereira, G., Alcantara, J. M., Santos, R., Hausen, M., & Itaborahy, A. (2022). New Predictive Resting Metabolic Rate Equations for High-Level Athletes: A Cross-validation Study. *Medicine and science in sports and exercise*.

Frings-Meuthen, P., Henkel, S., Boschmann, M., Chilibeck, P. D., Alvero Cruz, J. R., Hoffmann, F., Möstl, S., Mittag, U., Mulder, E., & Rittweger, N. (2021). Resting energy expenditure of master athletes: accuracy of predictive equations and primary determinants. *Frontiers in Physiology*, *12*, 641455.

Graf, S., Pichard, C., Genton, L., Oshima, T., & Heidegger, C. P. (2017). Energy expenditure in mechanically ventilated patients: the weight of body weight! *Clinical nutrition*, *36*(1), 224-228.

Harris, J. A., & Benedict, F. G. (1918). A biometric study of human basal metabolism. *Proceedings of the National Academy of Sciences*, *4*(12), 370-373.

Haugen, H. A., Chan, L. N., & Li, F. (2007). Indirect calorimetry: a practical guide for clinicians. *Nutrition in Clinical Practice*, *22*(4), 377-388.

Herring, J., Mole, P., Meredith, C., & Stern, J. (1992). Effect of suspending exercise training on resting metabolic rate in women. *Medicine and science in sports and exercise*, *24*(1), 59-65.

Hudson, J. F., Cole, M., Morton, J. P., Stewart, C. E., & Close, G. L. (2019). Daily changes of resting metabolic rate in elite rugby union players. *Medicine & science in sports & exercise*, *52*(3), 637-644.

Jagim, A. R., Camic, C. L., Askow, A., Luedke, J., Erickson, J., Kerksick, C. M., Jones, M. T., & Oliver, J. M. (2019). Sex differences in resting metabolic rate among athletes. *The Journal of Strength & Conditioning Research*, *33*(11), 3008-3014.

Jagim, A. R., Camic, C. L., Kisiolek, J., Luedke, J., Erickson, J., Jones, M. T., & Oliver, J. M. (2018). Accuracy of resting metabolic rate prediction equations in athletes. *The Journal of Strength & Conditioning Research*, *32*(7), 1875-1881.

Jeziorek, M., Szuba, A., Kujawa, K., & Regulska-Ilow, B. (2023). Comparison of actual and predicted resting metabolic rate in women with lipedema. *Lymphatic Research and Biology*.

Joseph, M., Gupta, R. D., Prema, L., Inbakumari, M., & Thomas, N. (2017). Are predictive equations for estimating resting energy expenditure accurate in Asian Indian male weightlifters? *Indian Journal of Endocrinology and Metabolism*, *21*(4), 515.

Livesey, G. (1987). Energy and protein requirements the 1985 report of the 1981 Joint FAO/WHO/UNU Expert Consultation. *Nutrition Bulletin*, *12*(3), 138-149.

MacKenzie-Shalders, K., Kelly, J. T., So, D., Coffey, V. G., & Byrne, N. M. (2020). The effect of exercise interventions on resting metabolic rate: A systematic review and meta-analysis. *Journal of sports sciences*, *38*(14), 1635-1649.

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Ackerman, K. E., Blauwet, C., Constantini, N., Lebrun, C., Lundy, B., Melin, A., & Meyer, N. (2018). International Olympic Committee (IOC) consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *International journal of sport nutrition and exercise metabolism*, *28*(4), 316-331.

Müller, M. J., Bosy-Westphal, A., Klaus, S., Kreymann, G., Lührmann, P. M., Neuhäuser-Berthold, M., Noack, R., Pirke, K. M., Platte, P., & Selberg, O. (2004). World Health Organization equations have shortcomings for predicting resting energy expenditure in persons from a modern, affluent population: generation of a new reference standard from a retrospective analysis of a German database of resting energy expenditure. *The American journal of clinical nutrition*, *80*(5), 1379-1390.

Nonsa-Ard, R., Aneknan, P., Tong-Un, T., Honsawek, S., Leelayuwat, C., & Leelayuwat, N. (2022). Telomere Length Is Correlated with Resting Metabolic Rate and Aerobic Capacity in Women: A Cross-Sectional Study. *International Journal of Molecular Sciences*, *23*(21), 13336.

Norton, K., & Olds, T. (2001). Morphological evolution of athletes over the 20th century: causes and consequences. *Sports medicine*, *31*, 763-783.

O'Neill, J. E. R. G., Walsh, C. S., McNulty, S. J., Gantly, H. C., Corish, M. E., Crognale, D., & Horner, K. (2022). Resting metabolic rate in female rugby players: differences in measured versus predicted values. *Journal of strength and conditioning research*, *36*(3), 845-850.

Oshima, T., Dupertuis, Y. M., Delsoglio, M., Graf, S., Heidegger, C.-P., & Pichard, C. (2019). In vitro validation of indirect calorimetry device developed for the ICALIC project against mass spectrometry. *Clinical nutrition ESPEN*, *32*, 50-55.

Speakman, J. R., & Selman, C. (2003). Physical activity and resting metabolic rate. *Proceedings of the Nutrition Society*, *62*(3), 621-634.

Speakman, J. R., & Westerterp, K. R. (2010). Associations between energy demands, physical activity, and body composition in adult humans between 18 and 96 y of age. *The American journal of clinical nutrition*, *92*(4), 826-834.

ten Haaf, T., & Weijs, P. J. (2014). Resting energy expenditure prediction in recreational athletes of 18–35 years: confirmation of Cunningham equation and an improved weight-based alternative. *PloS one*, *9*(10), e108460.

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: nutrition and athletic performance. *Journal of the Academy of Nutrition and Dietetics*, *116*(3), 501-528.

Thompson, J., & Manore, M. M. (1996). Predicted and measured resting metabolic rate of male and female endurance athletes. *Journal of the American Dietetic Association*, *96*(1), 30-34.

Thurairajasingam, N., Palaniapan, T. P., Bhojaraja, V. S., Matpady, P., Naik, V. R., & Shetty, J. K. (2022). The Influence of Resting Metabolic Rate in Type 2 Diabetes Mellitus: A Systematic Review. *International Medical Journal*, *29*(4), 228-232.

Tinsley, G. M., Graybeal, A. J., & Moore, M. L. (2019). Resting metabolic rate in muscular physique athletes: validity of existing methods and development of new prediction equations. *Applied Physiology, Nutrition, and Metabolism*, *44*(4), 397-406.

Tortu, E., Deliceoğlu, G., Kocahan, T., & Hasanoğlu, A. (2017). İndirekt Kalorimetre İle Ölçülen Dinlenik Metabolik Hız Değerlerinin Bazı Kestirim Formülleri İle Karşılaştırılması. *Spor Bilimleri Dergisi*, *28*(2), 103-114.

Watson, A. D., Zabriskie, H. A., Witherbee, K. E., Sulavik, A., Gieske, B. T., & Kerksick, C. M. (2019). Determining a resting metabolic rate prediction equation for collegiate female athletes. *The Journal of Strength & Conditioning Research*, *33*(9), 2426-2432.

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A COMPREHENSIVE REVIEW PAPER

Optimizing Athletic Performance and Post-Exercise Recovery: The Significance of Carbohydrates and Nutrition

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Abstract

Aim: This research examines the role of nutrition, particularly carbohydrate consumption, in optimizing athletic performance and post-exercise recovery. Method: A systematic review of relevant literature was conducted, encompassing various study types such as meta-analyses, systematic reviews, case reports, editorials, original research articles, and abstracts. Databases including PubMed/Medline, Web of Science, Taylor & Francis, and Google Scholar were comprehensively searched. The review adhered to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, utilizing a narrative synthesis approach due to the heterogeneity of collected data. Results: Carbohydrates emerged as a vital energy source for athletic performance. Adequate carbohydrate intake, appropriate timing, and nutrient composition were found to be critical for maintaining muscle glycogen levels during intense physical activity. Sports nutrition practices, such as high-carbohydrate diets and carbohydrate intake during exercise, have implications for athletes' immune system status. Low glycemic-index carbohydrates exhibited benefits in endurance sports by promoting fat oxidation and reducing glucose oxidation. Gender-specific dietary guidelines were recommended to address substrate utilization differences during exercise. Conclusion: Nutrition, particularly carbohydrate consumption, significantly influences athletic performance and post-exercise recovery. The study underscores the importance of individualized nutrition plans, considering nutrient timing and composition, to optimize performance and overall well-being. Further research is needed to address limitations and establish conclusive evidence on the relationship between carbohydrate intake, recovery, and athletic performance. Overall, the research provides valuable insights for athletes, coaches, and practitioners aiming to enhance performance through effective nutritional strategies.

Keywords: *Carbohydrates, Nutrition, Athletic Performance, Post-Exercise Recovery, Glycogen Storage, Sports Nutrition*

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ROLE OF CARBOHYDRATES AND NUTRITION IN ATHLETIC PERFORMANCE
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Introduction

Nutrition has long been recognized as a critical factor in athletics, contributing to both health and athletic performance (Gleeson, 2016). Since ancient times, the importance of nutrition in enhancing athletes' well-being and optimizing their physical capabilities has been acknowledged. However, athletes differ in their understanding, attitudes, and practices when it comes to nutrition. To address this, collaboration between sports dietitians, nutritionists, athletes, their families, coaches, and support staff is crucial (Kalman & Campbell, 2004). By working together, they can develop and implement personalized strategies that are realistic and effective, leading to positive and long-term performance outcomes.

The significance of carbohydrates as a fuel source during muscle contraction was first discovered over a century ago by Chauveau and Kaufmann (Ivy, J. L. 1999). They observed an increase in glucose absorption as a horse began chewing its meal, highlighting the connection between glucose availability and physical performance. Subsequent research in the early twentieth century further supported this link. Krogh, A., and Lindhard, J. (1920) found that individuals on a high-fat diet experienced fatigue and difficulties in performing a standard cycling protocol, which improved after three days on a high-carbohydrate diet. Similarly, Christensen et. al., 2002 observed that hypoglycemia during exercise could be alleviated by carbohydrate supplementation during recovery, restoring blood glucose levels and enabling extended activity. These findings aligned with the work of Levine et al. (1924), who observed hypoglycemia and associated symptoms of exhaustion in runners during a race.

Carbohydrates are known to be a primary energy source in sports, particularly in endurance activities. However, there is limited research on the effects of carbohydrates during practice sessions (Gomes & Aoki, 2010). Glycogen storage, regulated by insulin and the availability of glucose substrate, suggests that carbohydrates with a moderate to high glycemic index (GI) would enhance post-exercise recovery. Studies have supported this notion, showing that glucose and sucrose lead to faster rates of muscle glycogen regeneration compared to low-GI sugars like fructose (Blom et al., 1987). However, early studies categorizing carbohydrates as "simple" or "complex" resulted in conflicting results due to the inability to achieve consistent differences in glycemic index (Costillet et al., 1981; Roberts et al., 1988).

The quantity of carbohydrates consumed also affects blood sugar levels, and the concept of glycemic load (GL) considers both the quality and quantity of carbohydrates ingested (Beavers & Leutholtz, 2008). Ingesting carbohydrates during exercise, especially in combination with electrolytes, has been associated with improved performance, likely due to the availability of glucose as a substrate for central and peripheral processes. In hot conditions, fatigue during variable-speed running is primarily attributed to hyperthermia rather than muscle glycogen availability. Additionally, consuming carbohydrates shortly after exercise and competition aids in replenishing liver and muscle glycogen stores (Williams & Rollo, 2015).

Over the past five decades, the landscape of sports nutrition has undergone remarkable advancements, transitioning from glycogen loading techniques to the endorsement of scientifically proven ergogenic aids. (Kalman & Campbell, 2004) Amid these strides, certain conventional practices like incorporating high-carbohydrate diets and administering carbohydrates during exercise exert notable effects on athletes' immune system functions. Upholding a resilient immune system necessitates athletes to adopt a meticulously balanced diet that caters to their requirements for lipids, carbohydrates, proteins, and micronutrients (Gleeson, 2016).

The nutritional needs of athletes are intricately linked to the nature of their activity, the timing of exercise, and even the changing seasons. Although specific micronutrient mandates for sporting pursuits remain undefined, individuals grappling with deficiencies or injuries might find value in supplementation. Moreover, those who opt to exclude specific food groups, as seen among vegetarians, could necessitate supplementary nutrients to avert potential shortfalls (Bytomski, 2018).

In the current research landscape, there is a need to explore the lack of understanding regarding the crucial role of carbohydrate consumption in aiding recovery after intense exercise sessions.

Methods

A. Inclusion Criteria:

The study included various types of literature, such as meta-analyses, systematic reviews, case reports, editorials and letters, review reports, original research articles, previous experiments, and abstracts.

B. Search Strategy and Study Selection:

In this study, a thorough systematic review was carried out, involving a comprehensive search of prominent databases such as PubMed/Medline, Web of Science, Taylor & Francis, and Google Scholar. The review strictly adhered to the guidelines set by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to ensure a rigorous and standardized approach (see Figure 1). Notably, the review was not pre-registered, and the search terms used encompassed a range of relevant keywords. These keywords included "carbohydrates," "CHO-recovery," "nutrition," "nutrients," "athletic nutrition," "nutrition and rehabilitation," "nutrition and recovery," "carbs," "macronutrients," "glycogen," and "glycemic index." The purpose of utilizing such a diverse set of keywords was to ensure the inclusion of a wide range of studies and literature pertinent to the research topic.

C. Exclusion Criteria:

Studies were not included if they did not satisfy the subsequent conditions:

- Lack of pertinence to the research subject concerning carbohydrate intake and its influence on athletic performance and recovery after physical activity.
- Not authored in the English language.
- Absence of peer-reviewed validation.
- Employment of non-human models that lacked a distinct relevance to human participants.
- Inadequate presentation of details regarding carbohydrate consumption, duration of recovery, or outcomes related to performance.
- Repetitive publications or superfluous data.

D. Categorization of Studies for Synthesis:

The chosen studies were categorized into specific groups based on their specific focus and applicability to the objectives of the research. These groupings encompassed, but were not confined to, the subsequent domains:

- Relationship Between Carbohydrate Consumption and

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the Preservation of Muscle Glycogen

- Optimization of Nutrient Timing for Recovery Enhancement
- Role of Carbohydrates in Influencing Immune Function
- Disparities in Nutrient Usage Based on Gender
- Effects of Low Glycemic-Index Carbohydrates on Enhancing Fat Oxidation
- Contributions of Supplements and Micronutrients to the Recovery Process

E. Assessment of Bias Risk:

The current text lacks an evaluation of bias risk within the included studies. This omission is crucial as it pertains to gauging the methodological soundness of the research and comprehending potential limitations in study designs, execution, and reporting. Thoroughly assessing bias risk is instrumental in upholding the validity and dependability of the conclusions drawn from the examined studies.

F. Quality Evaluation Scores:

The text does not make any reference to the allocation of methodological quality scores to the studies that were included. The assignment of quality scores or a meticulous assessment of the methodological rigor in each study is indispensable for assessing the collective robustness of evidence and the extent to which the studies' findings can be deemed trustworthy. This systematic process assists in differentiating well-structured studies from those that might be susceptible to biases or constraints. Within a systematic review, presenting a transparent and explicit appraisal of bias risk alongside methodological quality scores serves to elevate the credibility and dependability of the outcomes. It allows readers to grasp the strengths and limitations inherent in individual studies, thereby contributing to a more knowledgeable interpretation of the cumulative evidence.

There was no specific restriction placed on the time period of the studies considered, allowing for a comprehensive analysis of both historical and contemporary research in the field. Given the varying nature of the collected data, the review opted for a narrative synthesis approach rather than conducting a quantitative meta-analysis. This decision was made to effectively accommodate the heterogeneous findings and nuances presented by the different studies.

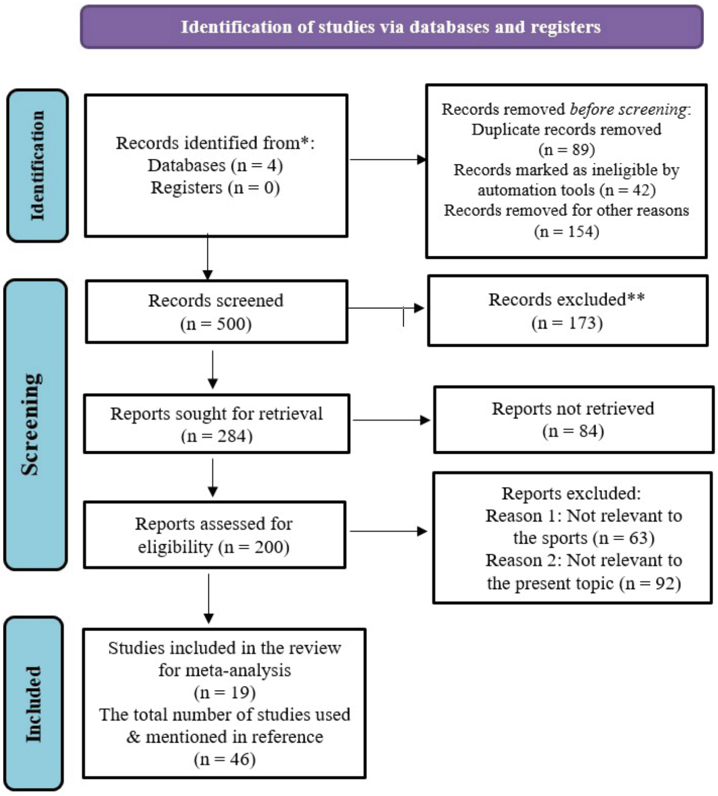

Figure 1. PRISMA flowchart of the included studies

Result

Evidence-Based Guidelines for Carbohydrate Consumption and Recovery:

This section delves into an extensive exploration of evidence-based recommendations related to carbohydrate intake in the context of short-term recovery following prolonged exercise. The investigative approach involved a thorough analysis of literature sources, drawing from reputable databases including PubMed, Web of Science, Taylor and Francis, and Google Scholar. The primary objective was to identify studies that investigated the recovery of physical performance among human participants who exclusively consumed carbohydrates during recovery periods extending from 2 to 6 hours (refer to Table I). Rigorous selection criteria dictated the inclusion of complete publications exclusively from peer-reviewed scientific journals. In instances where human data was unavailable, data from non-human models were only employed to support certain mechanistic concepts. Beyond the presentation of findings, this study undertakes an examination of the relative significance of diverse dietary and exercise parameters, and their intricate interplay, within the broader framework of carbohydrate consumption and post-exercise recovery. Subsequently, the focus shifts towards investigating studies that explore the potential for enhanced benefits through carbohydrate ingestion during the recovery phase (Betts, J. A., & Williams, C., 2010).

Exploring the Impact of Carbohydrate Combinations on Recovery and Physical Performance:

Parallel to its primary focus, this study embarks on an additional pursuit - delving into the direct effects of various carbohydrate combinations on recovery and physical performance. This exploration extends beyond their direct influence on muscle glycogen resynthesis. It also encompasses pertinent aspects such as metabolic responses, specifically glucose and insulin dynamics during both the recovery period and subsequent exercise.

Nutritional Considerations for Enhanced Athletic Performance and Recovery:

The central role of addressing nutritional facets becomes evident, as imbalances in nutrition can substantially affect athletes' performance. This underscores the need for a thorough assess-

Table 1. Overview of research assessing muscle glycogen resynthesize during short-term (i.e., 2–6 hours) recovery from exercise at various rates of carbohydrate consumption alone

Study (year)	Mode of exercise prior to recovery	Post-exercise muscle glycogen concentration (mmol glucosyl units/kg dm/h)[1]	Duration of Recovery (hours)	Rate of carbohydrate ingestion during recovery (g/kg/h)[2]	Type of carbohydrate ingested during recovery	Rate of muscle glycogen resynthesize during recovery (mmol glucosyl units/kg dm/h)
Battram et al. (2004)[9]	Free style Swimming	51	6	0.99	Glucose polymer	49
Berardi et al. (2006)[10]	20 km cycling	55	6	0.81	Glucose polymer/ meal	22
Betts et al. (2008) [11]	Non-exhaustive running	200	4	0.78	Sucrose	12
Blom et al. (1987) [12]	Exhaustive cycling	35 65 97 96 135	5	0.36 0.36 0.36 0.71 0.16	Sucrose Glucose Fructose Glucose Glucose	27 25 14 24 9
Blom (1989)[13]	Butterfly Swimming	95	3	0.95	Glucose	40
Carrithers et al. (2000)[14]	Marathon	107	4	1.00	Glucose	31
Casey et al. (2000) [15]	Marathon	56 64	4	0.27 0.27	Sucrose Glucose	24 32
Casey et al. (1995) [16]	40 km Cycling	26	3	1.05	Glucose	40
De Bock et al. (2005)[17]	Cycling	112 191	4	1.53	Glucose polymer	33 11
Doyle et al. (1993) [18]	Marathon	143 146	4	1.61	Glucose polymer	43 39
Howarth et al. (2009)[19]	Cycling	100 100	4	1.20 1.60	Glucose polymer	23 25
Ivy et al. (1988)[20]	Swimming	136 156	4	1.20	Glucose polymer	14 17
Ivy et al. (1988)[21]	Triathlon	136 152 155	4	1.52 0.76 0.00	Glucose polymer	22 19 2
Jentjens et al. (2001)[22]	Intense Cycling	105	3	1.22	Glucose polymer	40
Pedersen et al. (2008)[23]	Intense Cycling	75	4	1.00	Glucose	38
Slivka et al. (2008) [26]	Intense Cycling	194	4	0.95	Glucose polymer	34
Tsintzas et al. (2003)[27]	Marathon	254 260	4	0.16 0.55	Glucose polymer	8 19
Ruby et al. (2005) [24]	Continuous Swimming	57	4	0.90	Glucose	28
Shearer et al. (2005)[25]	Intense Cycling	59	5	1.03	Glucose polymer	48

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ment of athletes' nutritional needs (Mujica and Burke, 2010). The customization of hydration and carbohydrate intake strategies, tailored to the patterns of physical activity and rest intervals, emerges as a critical approach to optimize recovery, refueling, repair, and regulatory mechanisms (Mujica and Burke, 2010). The crucial impact of adequate carbohydrate intake on sustaining optimal muscle glycogen levels during intense physical exertion is well-documented. This emphasizes not only the timing but also the composition of carbohydrate consumption (Maughan, 2002).

Influence of Carbohydrate and Protein Intake on Muscle Damage and Immune Function:

However, the impact of carbohydrate and protein intake on exercise-induced minor muscle damage and subsequent function appears limited (Roberts et al., 2011). Nevertheless, a range of common sports nutrition practices can influence athletes' immune systems. These practices include high-carbohydrate diets, carbohydrate intake during exercise, training under conditions of low glycogen stores, intentional weight loss diets, high-dose antioxidant supplementation, and protein intake post-workout (Gleeson, 2016). The necessity for a balanced diet to support robust immune function in athletes is thereby underscored (Gleeson, 2016).

Optimal Strategies for Muscle Glycogen Preservation and Personalized Nutritional Approaches:

Strategies aimed at preserving muscle glycogen between intense sessions or competitive events necessitate a precise alignment of fuel supply with the demands of exercise. Noteworthy is the potential of co-ingesting carbohydrates and protein to enhance glycogen preservation, particularly in situations characterized by limited carbohydrate or energy availability (Burke et al., 2017). Athletes' macronutrient requirements fluctuate based on factors such as activity type, training duration, and seasonal variations. While specific micronutrient needs are not exclusively determined by sports, individuals with dietary restrictions, such as vegetarians, may need dietary supplementation to prevent nutrient deficiencies (Bytomski, 2018).

Micronutrients, Supplements, and Gender-Specific Variances:

The recovery process for athletes encompasses fundamental elements including protein, carbohydrates, and hydration. Furthermore, specific micronutrients and supplements like vitamin D, omega-3 polyunsaturated fatty acids, creatine, collagen, vitamin C, and antioxidants contribute to facilitating the recovery journey (Heaton et al., 2017). It is imperative to tailor and fine-tune nutritional intake and hydration status to align with the distinct characteristics of each competition (Martinez-Sanz et al., 2020).

Significance of Low Glycemic-Index Carbohydrates and Gender-Specific Strategies:

The utility of low glycemic-index carbohydrates shines in endurance sports, offering benefits such as heightened fat oxidation and reduced glucose oxidation due to decreased insulin secretion (Caviani et al., 2019). Moreover, pre-exercise consumption of low glycemic-index carbohydrates is proposed to confer advantages over their high glycemic-index counterparts, favoring fat oxidation while curtailing carbohydrate oxidation (Caviani et al., 2020). Gender differences in substrate utilization during endurance exercise warrant recommendations for gender-specific dietary guidelines, particularly for active individuals and specific cardiac patients (Lamont, 2005). A notable observation surfaces: male athletes may exhibit greater susceptibility to shifts in macronutrient utilization, favoring fat utilization during submaximal exercise on a ketogenic diet (Durkalec-Michalski et al., 2019).

Study's Strengths and Limitations:

The study's strengths are rooted in its adherence to PRISMA guidelines during the systematic review examining the impact of carbohydrates on post-exercise recovery. However, the diversity within the range of included publications precluded a formal meta-analysis (Barghouthy and Somani, 2021). Limitations are acknowledged, encompassing potential biases in sampling and withdrawal in epidemiological studies, lack of control groups in prospective clinical trials, and constrained sample sizes in studies focused on stone development. Inconsistent findings across various prospective and cohort studies are attributed to the diversity of dietary patterns. The study underscores the need for future research to employ well-defined methodologies, robust controls, precise carbohydrate intake protocols, and extended follow-up durations (Barghouthy and Somani, 2021).

Role of Carbohydrates, Performance, and Tailored Nutritional Approaches:

The central role of carbohydrates in optimizing athletic performance becomes apparent, particularly when they are thoughtfully integrated within a training context. However, the study underscores the importance of prudent nutritional decisions, considering their potential impact on exercise performance. Consequently, athletes are advised to calibrate their fluid and carbohydrate consumption in harmony with their activity patterns and rest intervals. The inclusion of high-carbohydrate foods, carbohydrate intake during exercise, low-glycemic index carbohydrate sources, and targeted dietary strategies to optimize glycogen storage are underscored. Meticulous attention to the temporal and compositional aspects of nutrient intake can expedite the recovery process. Athletes are cautioned against practices like weight loss strategies, excessive antioxidant supplementation, and immediate post-workout protein consumption due to their potential influence on the immune system. The study emphasizes the necessity of tailoring and adjusting nutrient intake and hydration status to align with the unique characteristics of each activity (Martinez-Sanz et al., 2020).

Concluding Remarks:

The research underscores the pivotal role of nutrition in elevating athletic performance and facilitating post-exercise recovery. The significance of adequate carbohydrate intake, in conjunction with precise timing and nutrient composition, for maintaining optimal muscle glycogen levels during intense physical exertion is unequivocal. While recovery involves intricate interactions among protein, carbohydrates, and hydration, the study accentuates the importance of micronutrients and supplements in bolstering the recovery trajectory.

The study's insight is that common sports nutrition practices can impact glycogen storage, yet the extent of carbohydrate and protein intake's impact on minor muscle damage and immune function remains confined. The need for a balanced diet to support a robust immune function among athletes is reemphasized. Strategies aimed at optimizing muscle glycogen preservation necessitate meticulous alignment of fuel supply and exercise demands, possibly through co-ingestion of carbohydrates and protein. Athletes' macronutrient requirements are subject to variability, and dietary supplementation is advocated for those with dietary constraints.

The recovery process benefits from the inclusion of crucial elements, supplements, and micronutrients, all contributing to the path of recuperation. Gender-specific considerations and the utility of low glycemic-index carbohydrates further underscore the significance of nuanced nutritional strategies. While the study aligns with PRISMA guidelines and conducts a comprehensive systematic review, the absence of a formal meta-analysis due to diverse publications is acknowledged (Barghouthy and Somani, 2021). The study's limitations stem from biases and constraints across various study designs, serving as a catalyst for future research featuring enhanced methodologies and well-defined protocols. In conclusion, the study underscores the importance of carbohydrates, mindful nutritional choices, and tailored strategies in augmenting athletic performance and facilitating post-exercise recovery.

Discussion

The discussion section of the research paper underscores the importance of nutrition, with a specific focus on carbohydrate consumption, in the context of enhancing athletic performance and facilitating post-exercise recovery. The study's primary outcomes, supported by a meticulous analysis of diverse literature sources, illuminate the indispensable role that carbohydrates play as a fundamental energy source during physical exertion. The research underscores the critical significance of maintaining appropriate levels of carbohydrate intake, alongside careful consideration of timing and nutrient composition, to ensure the preservation of optimal muscle glycogen levels amid demanding exercise regimens.

The study is in harmony with historical insights that have long emphasized the pivotal connection between nutrition and athletic endeavors. Pioneering observations such as the correlation between glucose availability and physical prowess have laid the groundwork for comprehending the essential contribution of carbohydrates in powering muscular contractions. The research further advances the knowledge gained from prior investigations that delved into the ramifications of carbohydrate consumption on aspects encompassing exercise performance, recovery kinetics, and immune system function.

A central theme that emerges is the imperative of customizing nutrition strategies for athletes. The discussion sheds light on the multifaceted and intertwined nature of athletes' nutritional requisites, which encompass variables such as the nature of physical activity, duration of training, and even seasonal fluctuations. The study emphasizes targeted dietary approaches, including integrating high-carbohydrate foods and strategically incorporating carbohydrate intake during exercise, as strategies to bolster recovery mechanisms and amplify performance outcomes. Moreover, the research underscores the advantages associated with low glycemic-index carbohydrates in endurance-based sports, while also highlighting the potential divergence in nutrient utilization patterns based on gender.

While the study furnishes a comprehensive exploration and novel insights, it remains attuned to certain limitations inherent in its methodology. These limitations encompass potential biases stemming from the sampling process, the absence of control groups in select studies, and the divergence in study designs across the reviewed literature. Acknowledgment is also extended to the fact that the diverse array of publications precluded a formal meta-analysis, which constitutes a genuine limitation.

The study's strengths reside in its meticulous adherence to the PRISMA guidelines, and its substantive contribution to our comprehension of the pivotal role carbohydrates play in the trajectory of post-exercise recovery. The research serves as a poignant reminder of the criticality of maintaining a holistic nutritional approach that encompasses not just macronutrients like carbohydrates and proteins, but also micronutrients and supplementary elements. The discussion further underscores the ongoing necessity for sustained research endeavors aimed at addressing inherent limitations and substantiating conclusive evidence concerning the intricate interplay between carbohydrate consumption, recovery kinetics, and the broader panorama of athletic performance.

Conclusion

In conclusion, this research underscores the essential role of nutrition, particularly carbohydrate consumption, in optimizing athletic performance and accelerating post-exercise recovery. In practical terms, athletes, coaches, and practitioners can glean valuable insights from this study to enhance performance through effective nutritional strategies. The findings emphasize the value of integrating high-carbohydrate foods, strategically timing carbohydrate intake during exercise, and incorporating low glycemic-index carbohydrates in endurance sports. By aligning nutrition with the unique requirements of athletes, recovery can be enhanced, leading to improved overall performance. Nevertheless, it's crucial to acknowledge the study's limitations, including potential sampling biases and the diversity of study designs. To advance our understanding, future research should focus on addressing these limitations and establishing a comprehensive framework that delves into the intricate relationship between carbohydrate intake, recovery kinetics, and athletic achievement.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Ivy, J. L. (1999). Role of carbohydrate in physical activity. Clinics in sports medicine, 18(3), 469-484.

Krogh, A., & Lindhard, J. (1920). The relative value of fat and carbohydrate as sources of muscular energy: with appendices on the correlation between standard metabolism and the respiratory quotient during rest and work. Biochemical Journal, 14(3-4), 290.

Chattopadhyay, A., Majumder, P., & Mondal, T. Chapter-1 Effects of Various Types of Carbohydrate Supplements in

DOI 10.26773/mjssm.230907

Endurance Performance.
Levine, S. A., Gordon, B., & Derick, C. L. (1924). Some changes in the chemical constituents of the blood following a marathon race: with special reference to the development of hypoglycemia. Journal of the American Medical Association, 82(22), 1778-1779.
Blom, P. C., Høstmark, A. T., Vaage, O., Kardel, K. R., & MæHLUM, S. V. E. R. R. E. (1987). Effect of different post-exercise sugar diets on the rate of muscle glycogen synthesis. Medicine and Science in Sports and Exercise, 19(5), 491-496.
Costill, D. L., Sherman, W. M., Fink, W. J., Maresh, C., Witten, M., & Miller, J. M. (1981). The role of dietary carbohydrates in muscle glycogen resynthesis after strenuous running. The American journal of clinical nutrition, 34(9), 1831-1836.
Roberts, K.M., Noble, E.G., Hayden, D.B. and Taylor,A.W. (1988). Simple and complex carbohydrate-rich dietsand muscle glycogen content of marathon runners.European Journal of Applied Physiology,57, 70–74.
Battram, D. S., Shearer, J., Robinson, D., & Graham, T. E. (2004). Caffeine ingestion does not impede the resynthesis of proglycogen and macroglycogen after prolonged exercise and carbohydrate supplementation in humans. Journal of Applied Physiology, 96(3), 943-950.
Berardi, J. M., Price, T. B., Noreen, E. E., & Lemon, P. W. (2006). Postexercise muscle glycogen recovery enhanced with a carbohydrate-protein supplement. Medicine & Science in Sports & Exercise, 38(6), 1106-1113.
Betts JA, Williams C, Boobis L, et al. Increased carbohydrate oxidation after ingesting carbohydrate with added protein. Med Sci Sports Exerc 2008; 40 (5): 903-12
Blom CS, Hostmark AT, Vaage O, et al. Effect of different post-exercise sugar diets on the rate of muscle glycogen synthesis. Med Sci Sports Exerc 1987; 19 (5): 491-6
Blom CS. Post-exercise glucose uptake and glycogen synthesis in human muscle during oral or i.v. glucose in take. Eur J Appl Physiol 1989; 59 (5): 327-33
Carrithers JA, Williamson DL, Gallagher PM, et al. Effects of postexercise carbohydrate-protein feedings on muscle glycogen restoration. J Appl Physiol 2000; 88 (6): 1976-82
Casey A, Mann R, Banister K, et al. Effect of carbohydrate ingestion on glycogen resynthesis in human liver and skeletal muscle, measured by 13C MRS. Am J Physiol
2000; 278: E65-75
Casey A, Short AH, Hultman E, et al. Glycogen resynthesis in human muscle fibre types following exercise-induced glycogen depletion. J Physiol (Lond) 1995; 483 (1): 265-71
De Bock K, Richter EA, Russell AP, et al. Exercise in the fasted state facilitates fibre type-specific intramyocellular lipid breakdown and stimulates glycogen resynthesis in humans. J Physiol (Lond) 2005; 564 (2): 649-60
Doyle JA, Sherman WM, Strauss RL. Effects of eccentric and concentric exercise on muscle glycogen replenishment. J Appl Physiol 1993; 74 (4): 1848-55
Howarth KR, Moreau NA, Phillips SM, et al. Coingestion of protein with carbohydrate during recovery from endurance exercise stimulates skeletal muscle protein synthesis in humans. J Appl Physiol 2009; 106 (4): 1394-402
Ivy JL, Katz AL, Cutler CL, et al. Muscle glycogen synthesis after exercise: effect of time of carbohydrate ingestion. J Appl Physiol 1988; 64 (4): 1480-5
Ivy JL, Lee MC, Brozinick Jr JT, et al. Muscle glycogen storage after different amounts of carbohydrate ingestion. J Appl Physiol 1988; 65 (5): 2018-23
Jentjens RLPG, van Loon LJC, Mann CH, et al. Addition of protein and amino acids to carbohydrates does not enhance postexercise muscle glycogen synthesis. J Appl Physiol 2001; 91 (2): 839-46
Pedersen, D. J., Lessard, S. J., Coffey, V. G., Churchley, E. G., Wootton, A. M., Watt, M. J., & Hawley, J. A. (2008). High rates of muscle glycogen resynthesis after exhaustive exercise when carbohydrate is coingested with caffeine. Journal of Applied Physiology.
Ruby, B. C., Gaskill, S. E., Slivka, D., & Harger, S. G. (2005). The addition of fenugreek extract (Trigonella foenum-graecum) to glucose feeding increases muscle glycogen resynthesis after exercise. Amino acids, 28(1), 71.
Shearer, J., Wilson, R. J., Battram, D. S., Richter, E. A., Robinson, D. L., Bakovic, M., & Graham, T. E. (2005). Increases in glycogenin and glycogenin mRNA accompany glycogen resynthesis in human skeletal muscle. American Journal of Physiology-Endocrinology and Metabolism, 289(3), E508-E514.
Slivka, D., Cuddy, J., Hailes, W., Harger, S., & Ruby, B. (2008). Glycogen resynthesis and exercise performance with the addition of fenugreek extract (4-hydroxyisoleucine) to post-exercise carbohydrate feeding. Amino Acids, 35, 439-444.
Tsintzas, K., Williams, C., Boobis, L., Symington, S., Moorehouse, J., Garcia-Roves, P., & Nicholas, C. (2003). Effect of carbohydrate feeding during recovery from prolonged running on muscle glycogen metabolism during subsequent exercise. International journal of sports medicine, 24(06), 452-458.
Betts, J. A., & Williams, C. (2010). Short-term recovery from prolonged exercise: exploring the potential for protein ingestion to accentuate the benefits of carbohydrate supplements. Sports medicine, 40, 941-959.
Beavers, K., & Leutholtz, B. (2008). Glycemic Load Food Guide Pyramid for Athletic Performance. *STRENGTH AND CONDITIONING JOURNAL*, *30*(3), 10–14. https://doi.org/10.1519/SSC.0b013e3181770a59
Burke, L., van Loon, L., & Hawley, J. (2017). Postexercise muscle glycogen resynthesis in humans. *JOURNAL OF APPLIED PHYSIOLOGY*, *122*(5), 1055–1067. https://doi.org/10.1152/japplphysiol.00860.2016
Bytomski, J. (2018). Fueling for Performance. *SPORTS HEALTH-A MULTIDISCIPLINARY APPROACH*, *10*(1), 47–53. https://doi.org/10.1177/1941738117743913
Durkalec-Michalski, K., Nowaczyk, P., & Siedzik, K. (2019). Effect of a four-week ketogenic diet on exercise metabolism in CrossFit-trained athletes. *JOURNAL OF THE INTERNATIONAL SOCIETY OF SPORTS NUTRITION*, *16*. https://doi.org/10.1186/s12970-019-0284-9
Gilbert, N. (2009). Symposium on "Performance, exercise and health" Practical aspects of nutrition in performance. *PROCEEDINGS OF THE NUTRITION SOCIETY*, *68*(1), 23–28. https://doi.org/10.1017/S0029665108008793
Gleeson, M. (2016). Immunological aspects of sport nutrition. *IMMUNOLOGY AND CELL BIOLOGY*, *94*(2), 117–123. https://doi.org/10.1038/icb.2015.109
Gomes, R., & Aoki, M. (2010). Does Carbohydrate Supplementation Maximize Performance of Tennis Players? *REVISTA*

BRASILEIRA DE MEDICINA DO ESPORTE, *16*(1), 67–70. https://doi.org/10.1590/S1517-86922010000100013

Heaton, L., Davis, J., Rawson, E., Nuccio, R., Witard, O., Stein, K., Baar, K., Carter, J., & Baker, L. (2017). Selected In-Season Nutritional Strategies to Enhance Recovery for Team Sport Athletes: A Practical Overview. *SPORTS MEDICINE*, *47*(11), 2201–2218. https://doi.org/10.1007/s40279-017-0759-2

Kalman, D., & Campbell, B. (2004). SPORTS NUTRITION: WHAT THE FUTURE MAY BRING. *JOURNAL OF THE INTERNATIONAL SOCIETY OF SPORTS NUTRITION*, *1*, 61–66. https://doi.org/10.1186/1550-2783-1-1-61

Kaviani, M., Chilibeck, P., Gall, S., Jochim, J., & Zello, G. (2020). The Effects of Low- and High-Glycemic Index Sport Nutrition Bars on Metabolism and Performance in Recreational Soccer Players. *NUTRIENTS*, *12*(4). https://doi.org/10.3390/nu12040982

Kaviani, M., Chilibeck, P., Jochimi, J., Gordon, J., & Zello, G. (2019). The Glycemic Index of Sport Nutrition Bars Affects Performance and Metabolism During Cycling and Next-Day Recovery. *JOURNAL OF HUMAN KINETICS*, *66*(1), 69–79. https://doi.org/10.2478/hukin-2018-0050

Lamont, L. (2005). Gender differences in amino acid use during endurance exercise. *NUTRITION REVIEWS*, *63*(12), 419–422. https://doi.org/10.1301/nr.2005.dec.419-422

Martinez-Sanz, J., Nunez, A., Sospedra, I., Martinez-Rodriguez, A., Dominguez, R., Gonzalez-Jurado, J., & Sanchez-Oliver, A. (2020). Nutrition-Related Adverse Outcomes in Endurance Sports Competitions: A Review of Incidence and Practical Recommendations. *INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH*, *17*(11). https://doi.org/10.3390/ijerph17114082

Maughan, R. (2002). The athlete's diet: Nutritional goals and dietary strategies. *PROCEEDINGS OF THE NUTRITION SOCIETY*, *61*(1), 87–96. https://doi.org/10.1079/PNS2001132

Mujika, I., & Burke, L. (2010). Nutrition in Team Sports. *ANNALS OF NUTRITION AND METABOLISM*, *57*, 26–35. https://doi.org/10.1159/000322700

Roberts, S., Stokes, K., Trewartha, G., Hogben, P., Doyle, J., & Thompson, D. (2011). Effect of combined carbohydrate-protein ingestion on markers of recovery after simulated rugby union match-play. *JOURNAL OF SPORTS SCIENCES*, *29*(12), 1253–1262. https://doi.org/10.1080/02640414.2011.587194

Williams, C., & Rollo, I. (2015). Carbohydrate Nutrition and Team Sport Performance. *SPORTS MEDICINE*, *45*, S13–S22. https://doi.org/10.1007/s40279-015-0399-3

Barghouthy, Y., & Somani, B. K. (2021). Role of citrus fruit juices in prevention of kidney stone disease (KSD): a narrative review. Nutrients, 13(11), 4117.

Boskov Hansen, H., Andreasen, M., Nielsen, M., Larsen, L., Knudsen, B. K., Meyer, A., ... & Hansen, Å. (2002). Changes in dietary fibre, phenolic acids and activity of endogenous enzymes during rye bread-making. European Food Research and Technology, 214, 33-42.

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ORIGINAL SCIENTIFIC PAPER

Differences between barefoot and shod performance in selected fitness tests in adolescents

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Abstract

Physical fitness is an important health indicator and component of physical literacy. Therefore, monitoring youth fitness performance is crucial for identifying potential health risks and tracking physical literacy development. Over the years, many fitness test batteries have been developed while different protocols for footwear have been used in fitness testing. The comparison of fitness results performed in different footwear could therefore be questioned. Thus, the purpose of this study was to examine the differences between barefoot and shod performance of selected motor tests in adolescents. Eighty-six adolescents aged between 14 and 16 years performed standing long jump, 20-m shuttle run, and polygon backwards in both footwear conditions. A strong correlation (r=0.83-0.95) was noted between both performances. No significant differences between barefoot and shod performance in the standing long jump and the backward obstacle course test were found, while significant differences were noted in the 20-m shuttle run. In this test, both, boys and girls performed better in shod conditions. Interestingly, there were no significant differences in performance of all tests among those who are habitually barefoot and others. From practical perspective, this study demonstrated that researchers could compare scores of samples in barefoot and shod performance of standing long jump and backward obstacle course tests. However, when physical teachers compare individual scores over the years, this should be made under the same footwear conditions, as differences in test conditions can provide a distorted picture of motor development.

Keywords: *physical fitness, motor test, coordination, shuttle run, standing long jump, athletic footwear, kinematics, running*

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Introduction

Physical fitness is a good indicator of health status among youth (Ortega et al., 2008). Higher fitness levels suggest better health outcomes in children and adolescents (Ortega et al., 2008) while physically less fit individuals tend to be at higher risk for developing chronic diseases (Högström et al., 2015; Hurtig-Wennlöf et al., 2007; Lätt et al., 2016), mental health disorders (Ortega et al., 2008) and are at higher risk for all-cause mortality (Ortega et al., 2012; Sato et al., 2009). Monitoring physical fitness is especially important at a young age considering that physically fit children and adolescents are more likely to become physically fit and active

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adults (Malina, n.d.). Since positive effects of physical activity on health can be seen in adulthood Ortega and colleagues (2008) recommend physical fitness testing and health monitoring already in childhood and adolescence.

Many test batteries have been developed for physical fitness testing of youth and adults over the years (Council of Europe, 1993; Jurak et al., 2019; Kolimechkov, 2017; Mood et al., 2007; Ruiz et al., 2011; Shingo & Takeo, 2002; Vanhees et al., 2005). Although test batteries are standardized, there are many modifications of specific tests that appear in the literature. Moreover, when performing motor tasks, including running and jumping, footwear can differ between subjects, which can alter motor performance. These different conditions are constraints that could promote or interfere with the results of fitness tests. Robinson and colleagues (2011) highlight the importance of footwear when testing motor skill performance in young children and teaching them locomotor skills.

Several studies evaluated biomechanical differences in locomotion of children and adolescents between shod and barefoot conditions and concluded that there are kinematic and kinetic differences when comparing running and walking, yet no changes were observed in jumping tasks (Khajooei et al., 2020; Wegener et al., 2011). Much less is known about the effect of two conditions on motor performance.

Harry and colleagues (2015) examined the effects of footwear on jumping tasks in adults and found that jump performance was perceived equal between shod and barefoot condition in both standing long jump and vertical jump. On the contrary, La Porta and colleagues (2013) showed better vertical jump performance when adults were barefoot (LaPorta et al., 2013). Researchers assume this might be due to the cushion of the shod condition where applied forces dissipate instead of transition into the ground during the propulsion phase. Another study on 810 children and adolescents in age range 6-18 years included two groups of participants that were either habitually shod or habitually barefoot (Zech et al., 2018). When standing long jump performance was compared between groups, habitually barefoot participants jumped further in standing long jump with the largest difference among participants being observed in adolescents. When comparison was done within groups, habitually barefoot participants continuously performed better without shoes, however no differences were found between barefoot and shod condition in habitually shod participants. On the contrary, researchers in a smaller study showed that children jumped further with shoes (Wegener et al., 2012) .

When comparing running barefoot and shod most studies focus on the biomechanical aspect and much less is known about its effect on motor performance. One study in adults showed that running with shoes presents a significantly higher oxygen cost than running barefoot and the authors concluded that barefoot running is more economical than running shod (Hanson et al., 2011). On the contrary, when shorter running distances were used, habitually shod children and adolescents performed better. Surprisingly, when the same participants were compared in both condition no difference was observed in the 20-meter sprint test (Zech et al., 2018).

Physical fitness testing for children and adolescents usually happens during physical education classes where children are shod or barefoot. There is a concern that the assessment of adolescents' motor performance could be compromised by footwear conditions. Moreover, modifications of some fitness tests exist, and their use worldwide is not standardized. Thus, comparison of results for similar motor tasks in different conditions is difficult among studies. It seems that, there are no clear effects of shod or barefoot conditions on motor performance in children and adolescents. The purpose of the study was to examine differences in adolescents' motor performance in different footwear conditions. Based on the current evidence it was hypothesised that no difference will be observed between the barefoot and shod condition in selected motor tasks that are used in fitness testing: standing long jump (explosive strength), 20-m shuttle run (cardiovascular endurance), and polygon backwards (coordination of whole-body movement).

Methods

Study sample and design

Data were collected within the ACDSi study, approved by the Slovenian National Medical Ethics Committee (ID 52/03/14), following the Declaration of Helsinki. The ACDSi is a cross-sectional decennial study that includes 16 upper secondary schools and investigates adolescents' biological, psychological and social development, described in detail elsewhere (Starc et al., 2015). A national, representative sample was selected for the ACDSi 2014 study using a multi-stage, stratified design. Written, informed consent was obtained from parents or legal guardians of all adolescents before voluntary participation; adolescents could withdraw from the study, in whole or in part, anytime they wished. For the purpose of the present study 86 adolescents (28 male) aged between 14 and 16 years (14.8 ± 0.6) from the initial sample were included in the analysis. All participants in this subsample were first year students at upper secondary schools and completed all fitness tests in barefoot and shod condition. To examine potential bias, we compared results of used motor tests between age-matched participants in sample and subsample and found that there were no statistically significant differences among them.

Data collection was performed by a team of researchers well-familiarised with all test protocols. Fitness testing took place indoors (room temperature ranged between 20-24°C), between 8:00‑14:00 lasting two or three days for each school involved. All data collection took place in the academic fall term, September-October 2014. Each adolescent was present for measurements on two days. Participants completed 20-m shuttle run test on one day and remaining fitness tests on other day. During the first measurement period all participants performed motor tests in barefoot condition. After two weeks the same participants completed same motor tests in shod condition with athletic footwear.

Fitness tests

Physical fitness tests were performed and scored using SLOfit (Strel et al., 1997) and EUROFIT (CDDS, 1983) protocols.

Standing long jump

Explosive power was assessed by standing long jump test. Participants stood behind a labelled take-off line and were instructed to jump as far as possible. A two-foot take-off and landing was used, with swinging of the arms and bending

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of the knees to provide forward drive. The jump distance was measured manually from the take-off line to the nearest point of contact on the landing, usually back of the hell. The best of three attempts was recorded, and the result was given in centimetres.

Backwards obstacle course

Backwards obstacle course was used to assess coordination of whole-body movement. Participants had to manoeuvre over a set polygon by moving backwards supported by their hands and feet on the ground as fast as possible. Participants began the test behind the starting line with feet behind the line (backwards on all fours). After three meters participants had to climb over the upper part of Swedish chest (a total height = 50 cm). After additional 3 meters (6 meters from starting line) a frame of Swedish chest was placed perpendicular to the corridor and participants had to crawl through it. Participants had to cross the finish line on their feet and hands on the ground, which was placed 10 meters from the starting line. The time stopped when participants crossed the finish line with their hands. The best of two attempts was recorded and the result was rounded up to the nearest tenth of a second.

20-m shuttle run

Léger's original 20-m shuttle run protocol (Léger et al., 1988) was conducted indoors to determine cardiovascular endurance and it involved continuously running between two lines 20 meters apart in time to audio signals. It consisted of multiple stages which lasted approximately one minute, starting at a speed of 8.5 km/h and increases by 0.5 km/h every minute thereafter. With stage progression the required running speed increased until volitional fatigue or when participant was no longer able to complete the distance of 20 meters in-line with the audio signal. Participants stood behind the first line, facing second line, and began running when instructed by the audio signal. If participants reached the line before the signal, they had to wait for the signal to continue running. Participants had to keep running and complete as many stages as possible in time to reach the lines before the audio signal. The test ended when participants were not able to reach the line on two consecutive audio signals. The result was the last level in which participants successfully reached the lines. These results can further be used to calculate maximal aerobic power of the participants (Léger et al., 1988).

Habit to be barefoot

In addition, we asked subjects during second fitness testing if they are used to walk and run barefoot. Dichotomous variable was constructed from their replies.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 27 (IBM Corporation, Chicago, IL, USA). Descriptive statistics were calculated for age, gender and all motor tasks and presented as means, standard deviations, medians, and interquartile ranges where appropriate. Paired sample t-test and Wilcoxon signed-rank test were used to assess differences among conditions. Cohen's d was calculated as effect size measure for statistically significant results. Bland–Altman plots were used to present systematic and random (individual) differences between performance in both conditions. To determine relationship between barefoot and shod performance, Pearson correlation coefficients were calculated. Levene's test and ANOVA was used to compare how habitually barefoot condition affects the results when participants perform fitness tests barefoot and shod. An a priori Alpha of 0.05 was used to determine significance.

Results

Descriptive data of motor performance for both test conditions are shown in Table 1. There were no statistically significant differences among barefoot and shod conditions in standing long jump distance ($p=0.063$), although on average boys performed slightly better in barefoot condition. Likewise, performance in backwards obstacle course did not differ between both conditions in boys or girls, although boys had slightly better (shorter) times for shod condition and the opposite was true for girls. Shuttle run performance was significantly better (more stages run) in shod condition for both, boys and girls ($p<0.001$, ES=0.71 for boys, $p<0.001$, ES=0.47 for girls, respectively).

Table 1. Descriptive data of standing long jump, backwards obstacle course and 20-m shuttle run performance divided by gender and both test conditions (barefoot vs. shod testing).

Fitness test		Male (N = 28)	Female (N = 58)
Standing long jump (cm)	Barefoot	208±24.2	170.5±16.7
	Shod	204.7±24.8	170.3±17.1
Backwards obstacle course (s)	Barefoot	11.1±3.4	12.6±2.4
	Shod	10.7±2.3	12.9±2.6
20-m shuttle run (stages)	Barefoot	8±4*	5±6*
	Shod	9±3*	6±3

Notes: Values for the standing long jump and backwards obstacle course tests are presented as mean±SD; values for the 20-m shuttle run test are presented as median±IQR; * significant differences between barefoot and shod conditions ($p<0.05$).

There were significant and strong correlations between barefoot and shod performance for all fitness tests. The strongest correlation was noticed in standing long jump ($r=0.95$, $p<0.001$), followed by backwards obstacle course ($r=0.84$, $p<0.001$), and 20-m shuttle run test ($r=0.83$, $p<0.001$).

Figure 1 shows relationship between results in shod and barefoot condition for all tests.

No significant differences in the results in those who are habitually barefoot and those who are habitually shod were noted in standing long jump distance ($p=0.098$), backwards obstacle course ($p=0.563$), and 20-m shuttle run test ($p=0.704$).

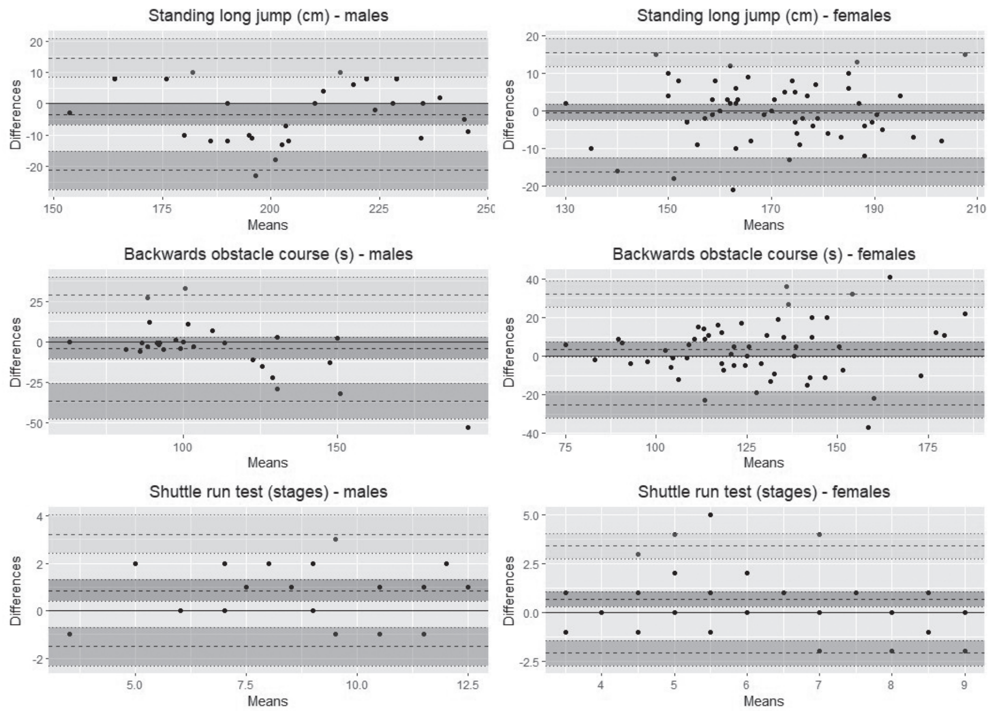

Figure 1. Bland–Altman plots of the relationship between results in shod and barefoot condition for all tests (difference = shod minus barefoot performance).

Discussion

The purpose of this study was to determine whether there is a difference when adolescents perform fitness tests barefoot or wearing athletic footwear. First important finding is that there is a strong correlation (r=0.83-0.95) between barefoot and shod performance of selected fitness tests. Second, there were no significant differences in results of the standing long jump and the backward obstacle course performed barefoot or shod. Third, significant differences performing 20-m shuttle run in barefoot or shod conditions were found, whereby both, boys and girls performed better in shod running. Interestingly, there were no significant differences in test results in those who are habitually barefoot and those who are habitually shod.

Many studies have examined the biomechanical differences in locomotion of children and adolescents between shod and barefoot conditions (Khajooei et al., 2020; Wegener et al., 2011), however, much less is known about whether performing tests shod or barefoot affects motor performance. In this study, three fitness tests were used to investigate these differences.

A strong correlation and no significant differences between performing standing long jump barefoot and shod were found in our study. This is consistent with previous findings on children aged 4 to 7 years (Khajooei et al., 2020), children aged 8 to 12 years (Wegener et al., 2013), and adults (Harry et al., 2015). Namely, standing long jump is a fundamental movement pattern and it has been shown that jump performance depends on a variety of factors such as level of upper and lower body coordination (Wu et al., 2003), application of proper jumping technique, body power, countermovement and take off angle (Zhou et al., 2020). According to the literature, the longest jump is achieved when using arm motion with feet in a straddle position (Mackala et al., 2013), and when take-off angle is less than 45 degrees. All these biomechanical variables improve take-off velocity of centre of mass and increase the power in the lower extremities which affects long jump performance (Zhou et al., 2020). Moreover, one kinematic study (Fernandez-Santos et al., 2018) in children showed that 51 % of jump distance variance is accounted by sex, age and body mass index and that among kinematic variables take-off distance and take-off speed were most important. To the best of our knowledge, no studies have compared biomechanical aspects between barefoot and shod condition in children and adolescents, however, motor performance studies show that there are no differences between conditions (Zech et al., 2018). Thus, we can assume that shod conditions represent such small variance of performance in standing long jump that this does not affect scores when we observe this on group level. However, we should be more careful on individual level. Although there were no statistical differences among footwear conditions performing this test, boys scored on average 3.3 cm better when they were barefoot, whereas almost no differences were found in girls. This could be an important difference when evaluating individual results, especially in fitness monitoring, when results of certain individual are compared within some period.

Next, a strong correlation and no significant difference were also found between performing backward obstacle course barefoot and shod. This fitness test indicates on the coordination of whole-body movement. It is performed at the same time on all four limbs; therefore, importance of footwear should be logically lower, however all movement is performed backwards which represents somehow specific placement of foot which could influence speed of foot movement. By our best knowledge, no similar study was done in the past. Therefore, we cannot compare our results with previous findings. However, from perspective of physical education practice such results were expected, since teachers do not notice specific problems of students when performing such kind of movements barefoot.

Opposite to other two fitness tests, significant differences

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between shod and barefoot performance were noted in 20-m shuttle run, although correlation between performance in both conditions was strong. Better scores were achieved in shod condition in boys and girls. Based on previous findings we explain such differences with better body mass handling when performing test shod in our subjects. Namely, 20-m shuttle run test consists of accelerated running at the beginning, then steady running, stopping, and changing direction, which is similar to agility tests, especially at high velocity. At such movements athletic footwear can play a role as it was shown in some studies. Wegener et al. (2015) reported that gait velocity increased during walking and running with shoes in children aged 8 to 10 years. Lythgo et al. (2009) also reported that gait speed and step length increased when wearing shoes. However, Wegener et al. (2012) found no differences between barefoot running and running with shoes in an agility test in nineteen children aged 10 years. The same was reported by Khajooei et al. (2020), who studied fourteen children aged 4 to 7 years and found that the children's gait velocity remained unchanged when they walked barefoot or with shoes. However, participants in our study were much heavier (at least 20 kg) and they run faster (on average with final speed 11 – 12.5 km/h) than participants in mentioned studies, including turning at each side of the line. Thus, they had to tackle greater forces on their feet. This was also noticed in the barefoot test performing where some participants got blisters during changing the running direction.

Interestingly, there were no significant differences in all three test results in those who are habitually barefoot and those who are habitually shod. In 20-m shuttle run, most participants who are habitually barefoot run better when barefoot, while those who are habitually shod had similar results when running shod or barefoot. This is somehow opposite to findings of Zech et al. (2018) who found that habitually shod children aged 11-14 years had significantly faster 20-m sprint time compared with habitually shod children, whereas no differences were found between groups in the standing long jump and balance test.

Based on our knowledge, this is the first study to examine how footwear affects adolescent motor performance, including whole-body movement coordination, explosive power, and cardiovascular endurance. However, the results of this study should be considered with following limitations: a) reliability of selected fitness tests and possible interpersonal differences in both conditions performance could blur real correlations between barefoot and shod performance; b) small sample of adolescents who are habitually barefoot can affect the results of analysis difference between habitually barefoot and shod adolescents' test scores.

Conclusions

Findings of this study have practical implications for researchers on physical fitness and physical education teachers who are monitoring fitness of their students. Researchers use different protocols in fitness testing associated with footwear, therefore comparing fitness results between studies could be questioned. This study demonstrated that researchers could compare samples' scores in barefoot and shod performance of fitness tests similar like standing long jump and backward obstacle course. However, some caution compering running tests with changing direction (e.g., shuttle run or the agility tests) should be applied. However, when it comes to comparison of individual results, like it is in annual fitness monitoring in schools, it is important for physical education teacher to consider that students perform tests in same footwear conditions as before, since differences can provide distorted picture about their motor development.

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Conflict of interest

There is no conflict of interest.

References

CDDS. (1983). *Testing Physical Fitness: EUROFIT. Experimental Battery - Provisional Handbook*. Council of Europe.

Council of Europe. (1993). *EUROFIT: Handbook for the EUROFIT tests of physical fitness*. Strasbourg : Sports Division Strasbourg, Council of Europe Publishing and Documentation Service.

Fernandez-Santos, J. R., Gonzalez-Montesinos, J. L., Ruiz, J. R., Jiménez-Pavón, D., & Castro-Piñero, J. (2018). Kinematic analysis of the standing long jump in children 6-to 12-years-old. *Measurement in Physical Education and Exercise Science*, *22*(1), 70–78.

Hanson, N. J., Berg, K., Deka, P., Meendering, J. R., & Ryan, C. (2011). Oxygen cost of running barefoot vs. running shod. *International Journal of Sports Medicine*, *32*(6), 401–406. https://doi.org/10.1055/s-0030-1265203

Harry, J., Paquette, M., Caia, J., Townsend, R., Weiss, L., & Schilling, B. (2015). Effects of Footwear Condition on Maximal Jumping Performance. *Journal of Strength and Conditioning Research*, *29*(6).

Högström, G., Nordström, A., Eriksson, M., & Nordström, P. (2015). Risk factors assessed in adolescence and the later risk of stroke in men: a 33-year follow-up study. *Cerebrovascular Diseases*, *39*(1), 63–71.

Hurtig-Wennlöf, A., Ruiz, J. R., Harro, M., & Sjöström, M. (2007). Cardiorespiratory fitness relates more strongly than physical activity to cardiovascular disease risk factors in healthy children and adolescents: the European Youth Heart Study. *European Journal of Preventive Cardiology*, *14*(4), 575–581.

Jurak, G., Kovac, M., Sember, V., & Starc, G. (2019). 30 Years of SLOfit: Its Legacy and Perspective. *Turkish Journal of Sports Medicine*, *54*(Supp1), 23–27. https://doi.org/10.5152/TJSM.2019.148

Khajooei, M., Wochatz, M., Baritello, O., & Mayer, F. (2020). Effects of shoes on children's fundamental motor skills performance. *Footwear Science*, *12*(1), 55–62. https://doi.org/10.1080/19424280.2019.1696895

Kolimechkov, S. (2017). European Journal of Physical Education and Sport Science Physical fitness assessment in children and adolescents: A systematic review. *European Journal of Physical Education and Sport Science*, *3*, 66. https://doi.org/10.5281/zenodo.495725

LaPorta, J. W., Brown, L. E., Coburn, J. W., Galpin, A. J., Tufano, J. J., Cazas, V. L., & Tan, J. G. (2013). Effects of different footwear on vertical jump and landing parameters. *Journal of Strength and Conditioning Research*, *27*(3), 733–737. https://doi.org/10.1519/JSC.0b013e318280c9ce

Lätt, E., Mäestu, J., Rääsk, T., Jürimäe, T., & Jürimäe, J. (2016). Cardiovascular fitness, physical activity, and metabolic syndrome risk factors among adolescent estonian boys: A longitudinal study. *American Journal of Human Biology*, *28*(6), 782–788. https://doi.org/10.1002/AJHB.22866

Léger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences*, *6*(2), 93–101. https://doi.org/10.1080/02640418808729800

Lythgo, N., Wilson, C., & Galea, M. (2009). Basic gait and symmetry measures for primary school-aged children and young adults whilst walking barefoot and with shoes. *Gait & Posture*, *30*(4), 502–506. https://doi.org/https://doi.org/10.1016/j.gaitpost.2009.07.119

Mackala, K., Stodólka, J., Siemienski, A., & Coh, M. (2013). Biomechanical analysis of standing long jump from varying starting positions. *The Journal of Strength & Conditioning Research*, *27*(10), 2674–2684.

Malina, R. M. (n.d.). *Physical activity and fitness: Pathways from childhood to adulthood*.

Mood, D. P., Jackson, A. W., & Morrow Jr, J. R. (2007). Measurement of physical fitness and physical activity: Fifty years of change. *Measurement in Physical Education and Exercise Science*, *11*(4), 217–227. https://doi.org/https://doi.org/10.1080/10913670701585502

Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjöström, M. (2008). Physical fitness in childhood and adolescence: A powerful marker of health. *International Journal of Obesity*, *32*(1), 1–11. https://doi.org/10.1038/sj.ijo.0803774

Ortega, F. B., Silventoinen, K., Tynelius, P., & Rasmussen, F. (2012). Muscular strength in male adolescents and premature death: cohort study of one million participants. *Bmj*, *345*, e7279.

Robinson, L. E., Rudisill, M. E., Weimar, W. H., Shroyer, J. F., Breslin, C. M., & Morera, M. (2011). Footwear and locomotor skill performance in preschoolers. *Perceptual and Motor Skills*, *113*(2), 534–538.

Ruiz, J. R., Castro-Piñero, J., España-Romero, V., Artero, E. G., Ortega, F. B., Cuenca, M. M., Jimenez-Pavón, D., Chillón, P., Girela-Rejón, M. J., & Mora, J. (2011). Field-based fitness assessment in young people: the ALPHA health-related fitness test battery for children and adolescents. *British Journal of Sports Medicine*, *45*(6), 518–524.

Sato, M., Kodama, S., Sugawara, A., Saito, K., & Sone, H. (2009). *Physical Fitness During Adolescence and Adult Mortality*. *20*(3), 462–470.

Shingo, N., & Takeo, M. (2002). The educational experiments of school health promotion for the youth in Japan: analysis of the 'sport test' over the past 34 years. *Health Promotion International*, *17*(2), 147–160. https://doi.org/10.1093/HEAPRO/17.2.147

Starc, G., Kovač, M., Strel, J., Pajek, M. B., Golja, P., Robič, T., Kotnik, K. Z., Grum, D. K., Filipčič, T., Sorí, M., Durakoví, M. M., Šajber, D., Leskošek, B., Ulaga, M., Pinter, S., Hadžić, V., Zaletel, P., Zaletel-Kragelj, L., Djomba, J. K., … Jurak, G. (2015). The ACDSi 2014 - a decennial study on adolescents' somatic, motor, psychosocial development and healthy lifestyle: Study protocol. *Anthropological Notebooks*, *21*(3), 107–123.

Strel, J., Ambrožič, F., Kovač, M., Leskošek, B., Štihec, J., & Šturm, J. (1997). *Sports Educational Chart*. Ministry of Education and Sport.

Vanhees, L., Lefevre, J., Philippaerts, R., Martens, M., Huygens, W., Troosters, T., & Beunen, G. (2005). How to assess physical activity? How to assess physical fitness? *European Journal of Preventive Cardiology*, *12*(2), 102–114. https://doi.org/10.1097/01.hjr.0000161551.73095.9c

Wegener, C., Greene, A., Burns, J., Hunt, A. E., Vanwanseele, B., & Smith, R. M. (2015). In-shoe multi-segment foot kinematics of children during the propulsive phase of walking and running. *Human Movement Science*, *39*, 200–211. https://doi.org/https://doi.org/10.1016/j.humov.2014.11.002

Wegener, C., Greene, A., Burns, J., Vanwanseele, B., Hunt, A. E., & Smith, R. (2013). Effect of sports shoes on children's vertical jump performance and midfoot and ankle kinetics. *Footwear Science*, *5*(sup1), S58–S59. https://doi.org/10.1080/19424280.2013.799555

Wegener, C., Greene, A., Millar, R., Burns, J., Hunt, A. E., Vanwanseele, B., & Smith, R. M. (2012). Children's functional performance barefoot and in sports shoes. *Journal of Foot and Ankle Research*, *5*(S1), 2012. https://doi.org/10.1186/1757-1146-5-s1-p31

Wegener, C., Hunt, A. E., Vanwanseele, B., Burns, J., & Smith, R. M. (2011). Effect of children's shoes on gait: A systematic review and meta-analysis. *Journal of Foot and Ankle Research*, *4*(1), 3. https://doi.org/10.1186/1757-1146-4-3

Wu, W.-L., Wu, J.-H., Lin, H.-T., & Wang, G.-J. (2003). Biomechanical analysis of the standing long jump. *Biomedical Engineering: Applications, Basis and Communications*, *15*(05), 186–192.

Zech, A., Venter, R., De Villiers, J. E., Sehner, S., Wegscheider, K., & Hollander, K. (2018). Motor skills of children and adolescents are influenced by growing up barefoot or shod. *Frontiers in Pediatrics*, *6*, 115.

Zhou, H., Yu, P., Thirupathi, A., & Liang, M. (2020). How to improve the standing long jump performance? A mininarrative review. *Applied Bionics and Biomechanics*, *2020*.

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ORIGINAL SCIENTIFIC PAPER

Assessment of Aerobic Fitness and Body Mass Index of Officers of the Nigerian Police Force in Enugu State, South East Nigeria

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Abstract

This study assessed the aerobic fitness and body mass index of officers of the Nigerian Police Force in Enugu State, Nigeria. It was a cross-sectional study and a total number of 343 police officers participated. Aerobic fitness was evaluated with a 20-metre shuttle run also known as Progressive Aerobic Cardiovascular Run (PACER) test which was used to estimate maximal oxygen uptake (VO_2max) of participants. Body Mass Index (BMI) was also measured and a proforma was used to record PACER performance, gender, age and years of service. Mean, Standard Deviation and Linear regression were used for analyses. The Statistical Package for the Social Sciences (SPSS) version 25 was used for the data analysis. The findings revealed that the police officers had a mean VO_2max of 46.01±8.644 ml/kg -1 ·minute -1. The police officers had a mean BMI of 25.68kg/m^2, which was significantly associated (<0.001) with their VO_2max. The study concluded that higher BMI is associated with decrease in VO_2max. Gender had a significant relationship with the BMI of police officers, as female officers had higher BMI while male officers had lower BMI. Age had a significant relationship with the BMI of police officers, as their higher age is associated with their higher BMI. However, officers of both genders particularly females need to engage more in physical activities to have improved aerobic capacity and have their BMI within a healthy range.

Keywords: *aerobic fitness, maximal oxygen uptake, body mass index, police officers, health, PACER*

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Introduction

Aerobic fitness and body mass index (BMI) are crucial physiologic indicators of health in human population. Globally, aerobic fitness has been on the decline, while obesity seems to be on the increase among various populations. Across nations, aerobic endurance has been reduced by about 5 per cent each decade (American Heart Association [AHA], 2013) while cases of obesity have increased worldwide over the past decades (Ortega et al., 2016). In 2013, about 50 per cent of the adult population in various nations in Oceania, North Africa and the Middle East had obesity (Ortega et al., 2016). In addition, high cases of obesity were recorded in North Ameri-

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ca and Western Europe (Ortega et al., 2016). Aerobic fitness which is an element of physical fitness is vital for daily living. It is the ability of the heart and lungs to reliably dispense oxygenated blood to working muscles, as well as the capacity of the muscles to use the oxygen delivered by the blood supply as a source of energy for physical activities (Cheng et al., 2019). To determine aerobic fitness, it is important to measure maximal oxygen uptake (VO_2max) (Mahar et al., 2018). Maximal oxygen uptake is the peak rate of oxygen utilization obtainable during an activity of growing intensity (Dlugosz et al., 2013). VO_2max is denoted either as an absolute rate in litres of oxygen per minute (L/min) or as a relative rate in millilitres of oxygen for every kilogram of body mass per minute (mL/(kg·min) (Dlugosz et al., 2013).

Maximal oxygen uptake (VO_2max) may have a negative association with BMI (Mahar et al., 2018). BMI is a ratio of an individual's weight and height (Williams et at., 2013). The formula is BMI = kg/ m2 where kg is the individual's weight in kilograms and m2 is their height in metres squared (Williams et al., 2013). The score obtained is used to determine whether an individual has a healthy weight or not. Based on World Health Organization (WHO) classification, scores of 18.5kg/m2 and below are regarded as underweight, between 18.5-24.9kg/m2 is regarded as normal weight, 25kg/m2 - 29.9kg/m2 is overweight, while scores of over 30kg/ m2 are regarded as obese (WHO, 2021). The BMI is extensively used and welcomed by scientists and researchers for prognosticating health risks. However, Luiz et al. (2016) opined that BMI does not evaluate the difference in lean weight and fat mass, but is a good tool for determining weight in a sizeable adult population. This shows that BMI may have a high degree of validity.

Various determinants may influence the BMI and aerobic fitness of individuals including police officers. According to Kind et al. (2019), BMI and aerobic fitness are influenced by several determinants, such as hereditary, gender, body weight, health status, habits, physical activity (PA) levels and age. Yi et al. (2015) had earlier reported that BMI increases with age while Forrester-Knauss and Zemp (2012) reveal that men tend to have a higher BMI than women. In support of this revelation, Vijayalakshmi et al. (2017) reported that men have an appreciable BMI than women. In terms of differences in aerobic capacity between men and women, Kenny et al. (2012) posited that male and female adults may vary in aerobic potentials as female estimates of VO_2max is about 70-75 per cent of that of the male after puberty. Libby (2021) suggests that aerobic fitness diminishes with age. This according to the author is partly a result of variation in maximal heart rate (MHR) and muscle loss associated with aging. However, the magnitude of aerobic fitness can be determined by one's PA patterns. In adults, there is a positive correspondence between equitably calculated PA and aerobic fitness, even though little is known about how PA intensity affects the magnitude of one's aerobic fitness (Bradley et al., 2019).

Research (Kind et al., 2019; Kumar, 2016) has shown that excellent aerobic fitness and BMI values are associated with buoyant health in adults. In other words, poor aerobic fitness is correlated with illness and the occurrence of diverse medical conditions, such as heart disease, diabetes, high blood pressure, and obesity (Jekal et al., 2010). In addition, Kumar (2016) posited that BMI affects aerobic fitness and that evaluating and monitoring aerobic fitness and body fat in adults is of public health significance. This is chiefly crucial for security personnel including officers of the Nigerian police force. The fitness and vigour of the security workforce including police officers may affect their performance (Friedl, 2012).

Recently, there have been increasing cases of criminality and insecurity in different parts of Nigeria, including Enugu State. This increasing incidence of insecurity in Nigeria has caused curiosity about the operation and capability of the Nigerian police force. The basic objective of BMI and aerobic fitness evaluation in the drafting of security forces is to spot individuals that are adequately adapted to the dictates of armed forces (Friedl, 2012). However, aerobic fitness and body mass are dynamic and recruited police officers may have reduced or improved indices over time in the course of their career. A study (Strauss et al., 2021) assessed the effect of aerobic fitness on lessening cardiovascular risk factors among police officers and office workers in Germany. The study found that most police officers (60%) and office workers (58%) had low levels of aerobic fitness. Furthermore, the study discovered that police officers and office workers with higher aerobic fitness levels had significantly lower values in waist circumference, body fat percentage and BMI. Unfortunately, there are currently no aerobic fitness standards for officers of the Nigerian Police Force. Therefore, given the need to obtain baseline data to better understand the BMI and the aerobic fitness standards of officers of the Nigerian police force, the study was designed to assess the BMI and the aerobic fitness standards of officers of the Nigerian police force in Enugu State, Nigeria. Specifically, the objectives were to assess the aerobic fitness, BMI, and the relationship between BMI and aerobic fitness of Nigerian Police Officers. The study hypothesized that there is no significant association between aerobic fitness status and age, gender and years of service of police officers in Enugu State, Nigeria. Also, there is no significant relationship between BMI and age, gender and years of service of police officers in Enugu State, Nigeria. This study findings would help exercise professionals, police administrations and health agencies to initiate intervention/programmes for police officers for improved aerobic fitness status and healthy BMI range.

Methods

Study design and setting

A cross-sectional study was conducted between January and March 2022 at the selected police formations in the three Senatorial Districts (Enugu North, Enugu West and Enugu East) that make up Enugu State, Nigeria. The senatorial districts are made up of Local Government Areas (LGAs). In the various LGAs, there are autonomous communities and villages.

Participants

The study participants comprised police officers. All the participants are officers under the employ of the Nigerian police force in different formations in Enugu State, Nigeria. The study included female (40.8%) and male (59.2%) officers with mean age (M = 36.50). Age was further grouped as follows; 20-29 years, 30-39 years, 40-49 years, and 50-60 years.

Sampling procedures

The sample size for the study was determined using (Yamane, 1967) sample size determination formula. We calculated a sample size of 396. The multi-stage sampling procedure was used to draw the study sample. The police formation in Enugu state was first stratified into 22 operational divisions. The second stage involved the use of a simple random sampling technique of balloting without replacement for the se-

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lection of 18 officers from each of the 22 police divisions in Enugu State. This brought the sample size to 396. However, police officers who were sick or could not make it to the test venue were excluded from the study.

Material and measures

Following the participants' consent, they were subjected to the instruments for data collection. The instrument for data collection were the 20-metres shuttle run also called Progressive Aerobic Cardiovascular Endurance Run (PACER) test, stadiometer and weighing scale. Also, a proforma was used for collection of performance data and demographic data of the participants. The PACER also known as the 20m Shuttle Run Test is a running test originated by (Leger et al., 1988) and is utilized in evaluating VO_2max which estimates aerobic fitness. Candidates of the test were first of all subjected to warm-up exercises to prepare them for the PACER test. In performing PACER, the candidates ran a 20-meter shuttle signaled by a beep sound. The test gets progressively faster until they can no longer keep up with the pace. After the test, the participants were also subjected to warm-down exercises to help them recover from the activity. This test was conducted in the morning when the participants were still alert and not exhausted from their daily activities. The tally from the PACER is the total laps perfected before voluntary fatigue. The raw tally was recorded on the scoring sheet developed by Cooper Institute. Also, the Body BMI was used to estimate the participants' weight with respect to their height. The BMI was calculated by measuring the height and weight of the police officers. The height was measured with a stadiometer while the weight was measured using a weighing scale. The weight and height measurements were taken with the participants wearing light clothing and without footwear.

Data collection procedure

The current research was developed following the Ethical Principles of the World Medical Association Declaration of Helsinki for medical research involving human subjects (World Medical Association, 2013), and the research was approved by the Research Ethics Committee of the Ministry of Health, Enugu State Nigeria (MH/MSD/REC21/234).

To obtain the participation of the officers, the research team met with the Assistant Commissioner of Police in Enugu State. After an agreement with the Assistant Commissioner of Police and Divisional Police Officers, informed consent was obtained from the officers, and it was explained to them how and when the data would be taken. Also, the research team explained the objectives of research to the participants and the latter were assured about the privacy of their data. After their consent was gotten, the researchers, engaged the officers in the PACER test, also the height and weight of the officers were measured, and they filled out the proforma to show their gender, age and years of service in the Nigerian Police. The administration protocol of PACER required that two researchers were present on every test lane and ensured that all steps of the protocol were followed. The participants engaged in the protocols they were exposed to. Out of the 396 officers drawn for the study, only 343 participated. Data of 343 participants were gotten and used for the study analyses.

Data analysis

The IBM Statistical Package for Social Sciences (SPSS) version 25.0 was used for all the statistical analyses. The standard descriptive statistics were applied to describe data patterns. Mean and standard deviation were used to analyse the VO_2max and BMI scores. The details of age, gender, BMI, and laps covered by each participant were used to calculate the VO_2max; which is a reflection of the aerobic fitness of each participant. The VO_2max values were calculated using the Quadratic Model formula developed by (Mahar et al., 2011):

VO_2max = 41.76799 + (0.49261 x PACER) – (0.00290 x PACER2) – (0.61613 x BMI) + (0.34787 x gender x age)

Where, PACER is the number of laps completed; for gender, 1 = male and 0 = female; and age is in years. The VO_2max scores were rated very poorly, poor, fair, average, good, very good and excellent. VO_2max < 35.0 (Very poor); VO_2max 35.0 – 38.3 (Poor); VO_2max 38.4 – 45.1 (Fair); VO_2max 45.2 – 50.9 (Good); VO_2max 51.0 – 55.9 (Excellent); VO_2max > 55.9 (Superior) using grading format developed by (Cooper Institute, 2005). For the BMI, the height and weight of the participants were calculated and graded using (WHO, 2021) BMI classification, where a BMI value less than 18.5kg/m2 is Underweight, BMI of 18.6-24.9kg/m2 is Normal weight, BMI of 25-29.9kg/m2 is overweight while a BMI of 30kg/m2 and above is Obese.

The normality of the data was checked through skewness, kurtosis and the Kolmogorov–Smirnov (K-S) test. Normal distribution was considered if the skewness showed values between -2 and +2, and the KS test is not significant (Bryne, 2010). The predictive capacity of VO_2max and BMI as well as their covariates (gender, age and year of service) was assessed by linear multiple regression analyses. All the tests were 2-tailed, and the probability values less than 0.05 ($p<0.05$) were considered significant.

Results

Table 1 shows the characteristics of the study participants. They included 203 male and 140 female police officers. The mean age, BMI and VO_2max of 36.50(SD=6.109),

Table 1. Characteristics of the Participants

Characteristics of Participants	n (%) M(SD)
Male	203 (59.2%)
Female	140 (40.8%)
Age	36.50(SD=6.109)
BMI (kg/m^2)	25.68(SD=3.325)
VO_2Max	46.01(SD=8.644)

Note. Aerobic fitness status (VO2max) categorization by Cooper Institute for Aerobics Research (CIAR, 2005), VO2max < 35.0 (Very poor); VO2max 35.0 – 38.3 (Poor); VO2max 38.4 – 45.1 (Fair); VO2max 45.2 – 50.9 (Good); VO2max 51.0 – 55.9 (Excellent); VO2max > 55.9 (Superior). Body Mass Index Categorization by World Health Organization (WHO, 2021), BMI<18.5(Underweight); BMI 18.5-24.9 (Normal weight); BMI 25-29.9 (Overweight); BMI > 30 (Obese).

25.68(SD=3.325) and 46.01(SD=8.644), respectively were obtained (Table 1).

Between BMI and VO_2max, the result (β= -.557 p= .000), indicates that BMI had moderate negative effect on VO_2max. which is significant. This implies that as BMI increases, VO_2max decreases (Table 2).

Table 2. Relationship between BMI and VO_2Max

Model		Standardized Coefficients (β)	Standard Error (S. E)	T	p-value
1	Constant	83.199	3.028	27.475	< .001
	BMI	-.557	0.117	-12.382	< .001

R = .557; R2 = .310; Adjusted R2 = .308; F = 153.302; Sig = < .001; a= Dependent Variance: VO_2Max; b=Independent Variance (constant): BMI

Table 3 shows that only gender had a significant relationship with the VO_2max of Police Officers. The prediction between gender and VO_2max (β = .871, p<.001) indicates that gender had a strong positive effect on V02max. which is significant. This implies that as females' V02max increases, males' VO_2max increases, though males (mean = 52.26, SD =4.05) had higher VO_2max than the females (mean = 36.96, SD =4.53) (Table 3).

Table 3. Multiple Regression of VO_2Max and Covariates

Model		Standardized Coefficients (β)	Standard Error (S. E)	T	p-value
1	Constant	38.086	.826	46.131	< .001
	Gender	.871	.468	32.661	< .001
	Years of Service	-.495	.571	-.866	.387
	Age Group	-.198	.408	-.486	.627

R = .872; R2 = .761; Adjusted R2 = .759; F = 359.195; Sig = < .001; a= Dependent Variance: VO_2Max; b=Independent Variance (constant): Gender, Years of Service, Age Group

Table 4 shows that regression between gender and BMI was obtained thus (β = -.278, p <.001), indicating that gender had low negative effect on BMI. This implies that as females' BMI which is higher (mean 26.79, SD = 3.44) increases, males' BMI (mean = 24.92, SD = 3.02) decreases. Age (B = .809, p = 0.008 < 0.05) had a significant relationship with the BMI of police officers, as their higher age is associated with their higher BMI (Table 4).

Table 4. Multiple Regression of BMI and Covariates

Model		Standardized Coefficients (β)	Standard Error (S. E)	T	p-value
1	Constant	24.815	.611	40.586	< .001
	Gender	-.278	.346	-5.209	< .001
	Years of Service	.131	.423	.309	.757
	Age Group	.809	.302	2.678	< .001

R = .336; R2 = .113; Adjusted R2 = .105; F = 14.374; Sig = < .001; a= Dependent Variance: BMI; b=Independent Variance (constant): Gender, Years of Service, Age Group

Discussion

This study was undertaken to assess the aerobic fitness and BMI of officers of the Nigerian Police Force in Enugu State South-East Nigeria. Table 1 shows that the police officers had a mean VO_2max of 46.01±8.644 ml/kg -1 ·min -1. Our finding is higher than those of Strauss et al. (2020) who observed a mean VO_2max of 34.1 ± 8.0 ml/kg -1 ·min -1 in male police officers from North Rhine-Westphalia, Germany. This shows that the police officers in Enugu state Nigeria demonstrated higher aerobic capacity than police officers in North Rhine-Westphalia, Germany. Our study also shows that police officers in Enugu state had a mean BMI of 25.68kg/m2. Our finding although similar is lower than those of Strauss et al. (2020) who observed a mean BMI of 28.0±3.2 in a German male police population. The BMI score in our finding is overweight according to WHO (2021) rating. This finding is not surprising but expected. The finding agrees with Ortega et al. (2016) who reported that more adults are becoming overweight globally. However as noted by (Luiz et al., 2016), BMI does not differentiate between lean weight and fat mass, as such does not define the composition of the body contributing more or less to the overall body weight. It is therefore important to note that the BMI scores of the police officers in our study may be due to high lean mass, as we did not measure their body composition which is a major limitation of our study. However, scientists think that adults should strive to maintain a normal weight range of 18.5kg/m2 - 24.9kg/m2 and that BMI value is a good pointer to the health of humans.

Table 2 shows that BMI has a significant relationship with the aerobic fitness status of the police officers, as their higher BMI is associated with a decrease in their maximal oxygen uptake. This finding is expected and not surprising because excess body weight has been shown to harm maximal oxygen uptake in humans. This is in line with Kind et al. (2019) assertion that maximal oxygen uptake (VO_2max) reflects an individual's aerobic fitness and may be affected by BMI. Similarly, Mahar et al. (2018) had reported earlier that there is a negative association between VO_2max and BMI. In healthy participants, the major factors that affect VO_2max includes the strength of respiratory muscles which initiate the force of contraction, the size of the airway and the elastic pressure of the lungs (Shah et al., 2022). In case of participants with high BMI, the function of respira-

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tory muscles may be impaired from the heightened resistance they must overcome and from the decreased capacity of these muscles (Shah et al., 2022).

Table 3 shows that there is a strong relationship between independent variables (gender, years of service, age group) and the dependent variable (VO_2max). The results however revealed that only gender had a significant relationship with the VO_2max of police officers. This finding is expected and is in line with the assertion of Kenny et al. (2012) that aerobic fitness can be affected by gender. The author further disclosed that men are likely to have more efficient aerobic capacity than women. Since muscle is the highest user of oxygen during physical activity, higher muscle mass in men may be partly responsible for their higher VO_2max when compared to women (Mahar et al., 2011).

Table 4 shows that the gender of police officers had a significant relationship with their BMI, as female officers had higher BMI while male officers had lower BMI. This finding is surprising because it differs from the finding of Forrester-Knauss and Zemp (2012) which reveal that men tend to have higher BMI than women in Swiss. It is also contrary to Vijayalakshmi (2017) who had reported in their findings that men have significantly higher BMI than women in India. The reason for this difference may have to do with geographical location or lifestyle and could be investigated further. This study revealed a significant relationship between age and BMI of police officers, as their higher age is associated with their higher BMI This finding is in line with Yi et al. (2015) who asserted that BMI tends to increase as one gets older in Korea. This may be due to age-related decrease in metabolic rate. However, no matter one's age, keeping a healthy weight is important and this underscores the importance of engagement in physical activities regardless of one's age. The findings of this study show that the number of years the officers have been in service does not have a significant association with their BMI.

One of the limitations of the study is that this study did not assess the daily activities of the officers which could have guided us to understand if it affected their aerobic fitness status and BMI. As such, we cannot tell if their aerobic fitness status and BMI has any association with their daily activities. Future studies should consider using a larger, randomized and more representative sample size while considering other associated factors that could have affected maximal oxygen uptake and BMI of participants. A small number of variables is another major limitation of this study. Future studies should explore anthropometric, motoric and functional parameters in a similar population. Furthermore, other means of measuring body composition, such as skinfold measurement should also be explored.

Conclusion

The findings have shown that police officers in Enugu State Nigeria had a 'good' aerobic fitness status and 'overweight' BMI. Because we did not measure body composition, we cannot categorically state that the high BMI found in the study is a result of high body fat among the population. Higher BMI is associated with a decrease in aerobic fitness. Male officers had better aerobic fitness status than female officers. Female police officers had a higher mean BMI than their male counterparts. Age and years of service did not have a significant association with aerobic fitness as represented by maximal oxygen uptake. Older officers had higher BMI values. Given the results obtained, one can conclude that this study adds data to the current database on aerobic fitness and BMI, and also on the relationship between aerobic fitness and BMI. The result indicates that more needs to be done to improve the maximal oxygen uptake (VO_2max) and BMI of police officers. Police administration and physical trainers need to do more and devise better training strategies that will impact positively the aerobic fitness and BMI of police officers. The findings indicates that it would be of high importance to encourage rigorous physical activity among police officers to increase aerobic fitness. In addition, the study results indicate that it is crucial to incorporate health-advancing initiatives, such as nutritional classes and exercise promoting programs in police training. Other physical fitness components like agility, power and flexibility are also important for police officers and should be explored.

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References

American Heart Association. (2013). *Children's cardiovascular fitness declines worldwide.* Science Daily.[Available at www.sciencedaily.com/releases/2013/11/131119112809.htm]

Bradley, S.M., Michos, E.D., & Miedema, M.D. (2019). Physical activity, fitness, and cardiovascular health. *JAMA Network Open.* 2(8), 1-10.

Bryne, B. (2010). *Structural equation modeling with AMOS. In Basic Concepts, Applications, and Programming.* New York, NY, USA: Taylor & Francis Group LLC.

Cheng, J., Chiu, C., & Su, T. (2019). Training and evaluation of human cardiorespiratory endurance based on a fuzzy algorithm. *International Journal of Environmental Research and Public Health*. 16(13), 2390.

Cooper Institute (2005). *Fitnessgram/Activitygram Test Administration Manual (4th ed.).* Champaign, IL: Human Kinetics.

Dlugosz, E.M, Chappell, M.A., & Meek, T.H., Szafrańska, P., Zub, K., Konarzewski, M., Jones, J.H.,

Bicudo, J.E., Careau, V., & Garland, T., (2013). Phylogenetic analysis of mammalian maximal oxygen consumption during exercise. *Journal of Experimental Biology*. 216(24), 4712–4721.

Forrester-Knauss, C., & Zemp, S.E. (2012). Gender differences in disordered eating and weight dissatisfaction in Swiss adults: which factors matter? *BMC Public Health*. 12(1), 1-9.

Friedl, K.E. (2012). Body composition and military performance – many things to many people. *Journal of Strength & Conditioning Research.* 26(2), 87–100.

Jekal, Y., Yun, J.E., Park, S.W., Jee S.H. & Jeon J.Y., (2010). The relationship between the level of fatness and fitness during adolescence and the risk factors of metabolic disorders in adulthood. *Korean Diabetes Journal.* 34:126-134.

Kenny, L., Wilmore, J., & Costill, D. (2012). *Physiology of Sport and Exercise (5th ed.).* USA: Courier Companies, Inc.

Kind, S., Brighenti-Zogg, S., Mundwiler, J., Schupbach, U., Leuppi, J.D., Miedinger, D., & Dieterle, T. (2019). Factors associated with cardiorespiratory fitness in a Swiss working population. *Hindawi Journal of Sports Medicine.* 1: 1-8.

Kumar, V. (2016). Cardiorspiratory fitness and body mass index in young male adults of hilly and backward area. *Inter-*

national Journal of Science and Research. 5(10), 561-563.

Leger LA, Mercier D, Gadoury C, Lambert J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Science.* 6(2), 93–101.

Libby, P., (2021). *Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine (12th ed.).* Elsevier.

Luiz, G.G., Porto, R.M., Nogueira, E.C., Nogueira, G.E., Molina, A., Luiz, F.J., & Stefanos, N.K. (2016). Agreement between BMI and body fat obesity definitions in a physically active population. *Archives of Endocrinology and Metabolism.* 60(6), 122-133.

Mahar, M.T., Guerieri, A.M., Hanna, M.S., & Kemble, C.D. (2011). Estimation of aerobic fitness from 20m multistage shuttle run test performance. *American Journal of Preventive Medicine*. 41(1), 117-123.

Mahar, M.T, Welk, G.J., & Rowe, D.A. (2018). Estimation of aerobic fitness from PACER performance with and without body mass index. *Measurement in Physical Education and Exercise Science.* 22(3), 239-249.

Nuttal, F.Q. (2015). Body Mass Index: Obesity, BMI, and health; A Critical Review. *Nutrition Today.* 50(3),117-128.

Ortega, F.B, Lavie, C.J., & Blair, S.N. (2016). Obesity and cardiovascular disease. *Circulation Research.* 118(1),1752-1770.

Shah, H., Mali, S., Rang, S., Jadhav, C., Rukadikar, A., Singh, A.K., & Shamnani, G. (2022). Effect of body mass index on cardiorespiratory parameters among medical students: a cross-sectional study. *International Journal of Physiology, Pathophysiology and Pharmacology.* 14(1), 4-9.

Strauß, M., Foshag, P., Jehn, U., Vollenberg, R., Littwitz, H., & Leischik, R. (2020). Exercise capacity, Cardiovascular-and Metabolic Risk of German Police officers in an international comparison. Research Square. https://doi.org/10.21203/rs.3.rs-84144/v1

Williams, M.H., Anderson, D.E., & Rawson, E.S. (2013). *Nutrition for health, fitness and sports (10th ed.).* New York: McGraw-Hill.

Vijayalakshmi, P., Thimmaiah, R., Reddy, S., Kathyayani, B.V., Gandhi, S., & BadaMath, S. (2017). Gender differences in body mass index, body weight perception, weight satisfaction, disordered eating and weight control strategies among Indian medical and nursing undergraduates. *Investigacion Educacion en Enfermeria.* 35(3), 276-284.

World Health Organization (2021). *Obesity and overweight fact sheet No 311.* Geneva, Switzerland. [Available at https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight]

World Medical Association (2013). World Medical Association Declaration of Helsinki; Ethical principles for medical research involving human subjects. *Journal of American Medical Association.* 310:2191-2194.

Yamane, T. (1967). *Statistics: An Introductory Analysis (2nd ed.).* New York: Harper and Row.

Yi, S.W., Ohrr, H., Shin, S.A., & Yi, J.J. (2015). Sex-age-specific association of body mass index with all cause mortality among 12.8 million Korean adults: a prospective cohort study. *International Journal of Epidemiology.* 2015; 44: 1696-1705.

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ORIGINAL SCIENTIFIC PAPER

Effect of Deep Stabilization System Training on the Shot Velocity in Professional Female Handball Players: Cross-sectional Study

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Abstract

The muscles of the deep stabilization system (DSS) affect spinal stabilization, and correct muscular coordination as a prerequisite for a centered position of the joints with optimal biomechanics of movement. Its stimulation by special exercises might lead to better performance in sports. The study verifies the effect of an 8-week intervention to activate DSS on the shot speed in a group of 15 adult elite female handball players. 30 participants were distributed to either the Control group (CG) or the Experimental group (EG). The EG involved special blocks with exercises activating DSS included in regular handball training. The CG involved only casual training. Input and output measurements included shot velocity assessment from various positions with a Stalker Sports Radar Gun. Mann-Whitney U-test was utilized for the statistical analysis with a 0.05 level of significance. The experiment showed a significant speed increase for all three tested throws. Speed increased by 3.82% for a one-handed overhead shot from the ground from a distance of 7m (free throw), 2.23% for a one-handed overhead shot from the ground after a run-up from a distance of 9m, and 2.23% for a one-handed overhead shot from a jump from a distance of 9 m by 2.38%. Specific activation exercises of DSS of the spine led to increased shot speed in handball.

Keywords: *Handball, Shot velocity, Deep stabilization system of the spine, performance, core*

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Introduction

Handball is very popular sport in the Czech Republic. Professional athletes tend to achieve better results and thus bring the game to a higher level, which is also conditioned by increasing performance. In this context, the new research studies that bring updated training methods lead to an increase in sports performance (Fritz et al., 2020, Jiang et al., 2022, Junker and Stöggl, 2019, Nuhmanni, 2022, Takahashi et al., 2019, Reed et al., 2012).

The one-handed overhead shot is most often used in handball during a gradual attack by players in backcourt positions through the opponent's defense. Shooting with a jump above the

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goal area is usually used when ending counterattacks and quick attacks on the opponent's unformed defense. Shooting with a jump above the goal area is most often used by players in the wings position or players in the backcourt position after penetrations of the defense and has the highest percentage of success of all in a gradual attack against the formed defense (Hammami et al. 2021, Martínez-Rodríguez et al., 2021, Risberg et al., 2018, Russomanno et al., 2021, Zmijewski et al., 2020.) One of the essential prerequisites for a successful shot is its high speed, increasing of which can improve the overall team results. Shot speed can be increased by many factors. Wilk et al. (2000) define it as a complex movement scheme that requires flexibility, coordination, muscle strength, synchronization of muscle units involvement, and neuromuscular adaptation. Garcia et al. (2013) state that the shot speed is affected by the shooting technique, spatiotemporal coordination of individual body segments, and muscle strength of the upper and lower limbs. Choutka et al. (1999) and Lemos et al. (2020) include, among other factors, also inborn dispositions, motor abilities, and movement skills. They summarize them as somatic, tactical, technical, fitness, and psychological determinants of sports performance.

The DSS of the spine, or the center of the body, forms the basis for all body movements, and its activation level affects playing skills. That means if the efficiency and strength of the deep stabilizers are increased, the efficiency and speed of body movements will subsequently increase (Coulombe et al., Frizziero et al., 2021, 2017, Hlaing et al., 2021, Kellis et al., 2020). The muscles of the shoulder girdle, flexors and rotators of the trunk, muscles that allow the arm to be raised above the horizontal axis of the shoulder, muscles that are used when moving the arms backward, and the muscles of the forearm and hand for gripping the ball together with the deep stabilizing muscles form the so-called muscle chain consisting of local and global stabilizers (Ammer et al., 2022, Bernacíková, 2010, Kostadinović et al., 2020, Srhoj et al., 2012). The mentioned muscles are one of the prerequisites for a movement pattern based on a kinetic chain, the components of which must work together to achieve proper movement, preventing muscle imbalance or injury (Lin et al., 2022, Manchado et al., 2017, Thurgood and Paternoster, 2014, Szczygieł et al. 2018). One factor that influences the functioning of this kinetic chain during shooting is the muscles of the DSS of the spine. Besides others, they include, the trunk and pelvic muscles, which are responsible for maintaining the stability of the spine and pelvis while helping to generate and transfer energy from the significant parts of the body to the small ones. Stability of the center of the body (so-called postural stability) is the ability of the human body to ideally distribute and control the forces acting on the skeleton not only during static standing but also during movement activities, with the help of movement and muscle tension of agonists and antagonists of the muscles of the trunk, pelvis, and lower limbs, and thereby ensuring stability even in complex movement activities, such as shooting in handball (Lin et al., 2022, Kibler et al., 2006, Rivera, 2016).

Scientific discussion on the effectiveness of activation exercises, i.e., exercises to strengthen the body center, for individual and group performance is still open (Belli et al., 2022, Esteban-García et al., 2021, Ozmen et al., 2016, Jiang et al. 2022, Kabadayı et al., 2022, Reed et al., 2012). In handball sport, Saeterbakken et al. (2011) discovered the positive effect of a six-week intervention, a targeted activation exercise, introduced twice a week to the training units of junior handball players. Further, for example, Manchado et al. (2017) observed the effect of a 10-week intervention on shot speed in handball among adult amateur players. The measurement was performed from three different positions, while the greatest improvement was recorded in the penalty throw. Other researchers verified the effect of muscle-strengthening exercises in the lumbopelvic area in adult soccer players (Stray-Pedersen, 2002) and the effect of specific strength training on the speed of the tee shot in junior golf players. (Seiler et al., 2006).

The aim of the research was to determine the effect of activation of the DSS of the spine on the shot speed in professional female handball players. In addition, we tried to verify the assumption that the experimental group will have a higher average velocity measured of all three shots in the output measurement than the control group.

Materials and Methods

Participants

The research study included 30 professional female handball players who regularly participated in the top Czech-Slovak competitions with an average age of 18.7 ± 2 years and an average time of active handball playing of 12 ± 3 years. The group's average weight was 64.2 kg ± 6 kg, and the average height 166.9 cm ± 9 cm. Before participating in the research, we obtained written informed consent from each tested person. Information about each player's medical history, age, BMI, training characteristics, injury history, experience with handball team, and performance level was recorded by personal interviews. Data on height and weight were recorded by calibrated instruments. The participants were included based on the following criteria: DSS insufficiency confirmed by clinical assessment of postural stability based on Kolar (2009). Injury-free status and experience in a handball team at a professional level for at least eight years. Participants were randomly distributed into two groups - 15 female players in the control group and 15 in the experimental group. Table 1 reports baseline comparisons (Mean±Standard deviation) of both groups.

Table 1. Baseline Characteristics

Characteristic	Experimental Group	Control Group	Sig. (p-Value)
N	15	15	-
Height [cm]	170±4.94	163.93±4.35	0.11
Weight [kg]	65.40±5.82	63.48±4.83	0.33
BMI	22.65±1.56	23.64±1.80	0.12

The teams were in the phase of the competition. The players regularly practiced 10 hours a week and played 1 championship match on the weekend. Apart from handball, all players do not intensively participate in any other physical activity. Therefore, the research was conducted during the competition period, when the training units are not dominantly focused on developing movement skills.

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Assessment

All the tested players had an organized warm-up exercises 15 minutes before the start of shot speed measurements. The warm-up included running with inserted activities, dynamic stretching, and throws with the shooting arm at sub-maximal intensity. Shot velocity was subsequently measured from three different positions and distances: a one-handed overhead shot from the ground from a distance of 7 m (7 m throw or penalty throw), a one-handed overhead shot from the ground after a run-up from a distance of 9 m, a one-handed overhead shot from a jump from a distance of 9 m. Finally, the shooting was carried out into an empty handball goal without the goalkeeper. The Stalker Sports Radar Gun Pro II radar gun with an accuracy of ± 0.1 km/h to measure the speed of the shot was utilized. The radar gun, operated manually, was placed behind the handball gate in its center at a height of 170 cm. The participants were instructed to shoot the ball with the maximum possible force and speed from the given position and aim the ball directly at the radar gun. Each player had 3 attempts with 1 minute of passive rest in between attempts. The one with the highest measured speed was recorded. Shot velocity testing was initiated one week prior to the indication for intervention and a week after its completion. The players were always informed about the measured values after each attempt. An official IHF ball was used for all shots, and the use of handball glue was allowed. The output measurement was carried out under the same conditions and with the same rules. All the obtained output data were recorded in the recording sheets during the measurement.

Training plan - intervention

The special training plan was aimed at the DSS of the spine activation under the experienced physiotherapist's supervision. Its creation was primarily based on Thurgood and Paternoster (2014) and our own experience. We created several blocks of exercises, which were implemented in the experimental group during handball training, always after the initial warm-up, for a period of 8 weeks, always twice a week. Each of these individual blocks contained 7 exercises that focused on improving the function of the kinetic chain of movement involved in throwing, so we assumed that in the center of the body, the most important for handball is an isometric and rotational movement, followed by flexion, extension, and complex movements, in a closed kinematic chain.

The training plan designed for the experimental group was divided into 3 levels. It was characterized by progressive loading, where with each level of exercise, there was an increase in the volume and intensity of the load, as well as an overall transition from simple exercises to more complex and demanding ones. The first level of exercise took place for 2 weeks and contained 4 exercise blocks. This level consisted of basic exercises that should have been mastered before moving on to the intermediate or advanced level. Each of these exercise blocks lasted for 15 minutes. The second level of exercises lasted for 3 weeks and included 6 blocks of exercises, and intermediate-level exercises were included. These exercises followed the basic exercises, but instability, movement, weight, and strength were added to engage the DSS more and increase effectiveness. The individual blocks of the second level lasted 20 minutes each. Finally, the third level of exercise took place, like the previous level, for 3 weeks, and it contained 6 blocks of exercises. Advanced-level exercises, which included complex and challenging movements, were included. Proper execution of the exercises required strength, stability, and mobility of the deep stabilization muscles. Special training blocks lasted 25 minutes.

Statistical analysis

The Shapiro-Whilk normality test was performed to identify data distributions, and in only one case, the input data did not correspond to a normal distribution. Due to this fact, we further used the non-parametric Mann-Whitney U-test. The level of statistical significance was chosen for the tests at 5%, and we also determined a substantive significance.

Results

The input and output measurement results from three shooting positions are recorded in Tables 2-4. The differences between the input and output measurements can be observed in both groups. The most significant improvement in shot velocity on average was recorded in the experimental group in the one-handed overhead shot from the ground from a 7 m distance (7 meters or penalty throw) of 3.82%, the second most significant improvement of 2.38% on average was measured in the one-handed overhead shot from a jump from a 9 m distance, the smallest average improvement was measured in the one-handed overhead shot from the ground after a run-up from a distance of 9 m, i.e., 55 by 2.23%. No improvement was observed in the control group. The complete results of both measurements for individual players are displayed in the Table 2, Table 3, and Table 4.

Table 2. One-handed overhead shooting from the ground from a 7 m distance (penalty throw)

	Experimental group			Control group		
Measurement	Input [km/h]	Output [km/h]	Difference [%]	Input [km/h]	Output [km/h]	Difference [%]
M	69.77	72.43	3.82	65.51	65.29	-0.34
SD	3.67	3.48	1.11	3.45	3.56	0.66
Variance	13.47	14.76	1.23	11.92	12.64	0.44

M – mean average , SD – Standard deviation

Table 3. One-handed overhead shooting from the ground after a run-up from a distance of 9 m

	Experimental group			Control group		
Measurement	Input [km/h]	Output [km/h]	Difference [%]	Input [km/h]	Output [km/h]	Difference [%]
M	71.77	73.34	2.23	67.83	67.77	-0.1
SD	3.87	3.47	1.43	2.74	2.96	0.94
Variance	14.97	12.07	2.04	7.5	8.77	0.88

M – mean average , SD – Standard deviation

Table 4. One-handed overhead shooting from a jump from a distance of 9 m

	Experimental group			Control group		
Measurement	Input [km/h]	Output [km/h]	Difference [%]	Input [km/h]	Output [km/h]	Difference [%]
M	72.55	74.29	2.38	67.29	67.31	0.03
SD	3.27	3.55	0.99	2.85	2.89	0.57
Variance	10.7	12.59	0.98	8.11	8.38	0.33

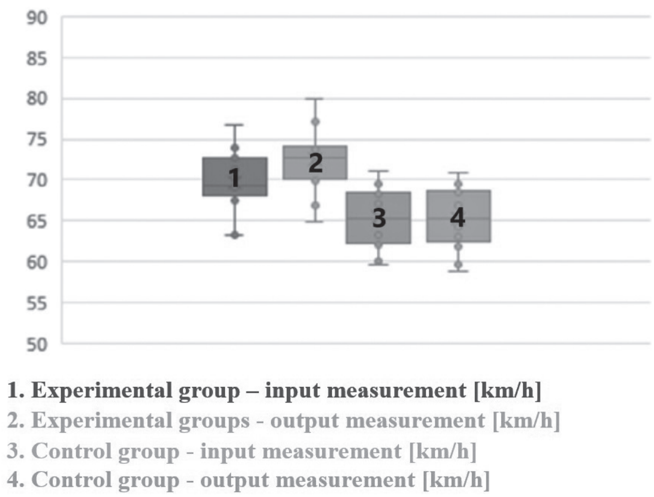
M – mean average , SD – Standard deviation

Based on the initial survey of the data, it can be concluded that the training was successful in all three tested cases. As a measure of improvement, we took the difference between the input and output measurements relative to the output according to the formula: the improvement measure is equal to the output measurement minus the input measurement minus the output measurement. Overall, according to the measured data, there was an average increase in the velocity of the shots by 2.81% in the experimental group and a slight deterioration by -0.14% in the control group, as reported in Table 5.

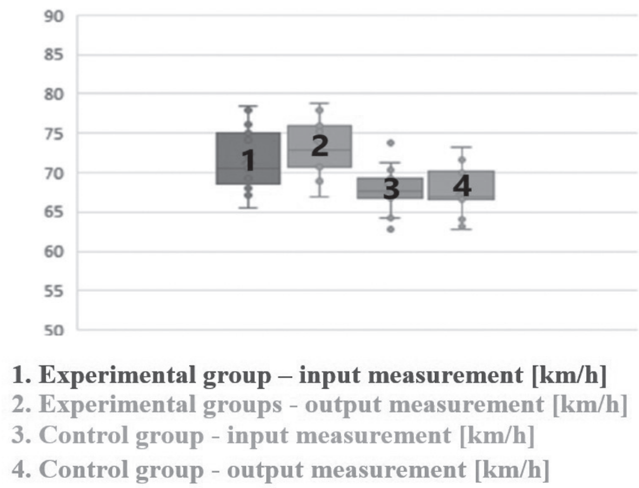
Table 5. Overall results

	Experimental group	Control group
Difference [%]	2.81	-0.14

The measured values are shown graphically in Graphs 1–3. In all three cases, an obvious increase in the average of the values of the speeds measured during the output measurement in the experimental group can be observed, compared to an almost zero shift in the values measured during the output measurement in the control group.



Graph 1. The difference between the input and output measurement shots velocity during a one-handed overhead shooting from the ground from a 7 m distance (penalty throw)



Graph 2. The difference between the input and output measurement of shot velocity during overhead one-handed shooting from a position after a run-up from a 9m distance

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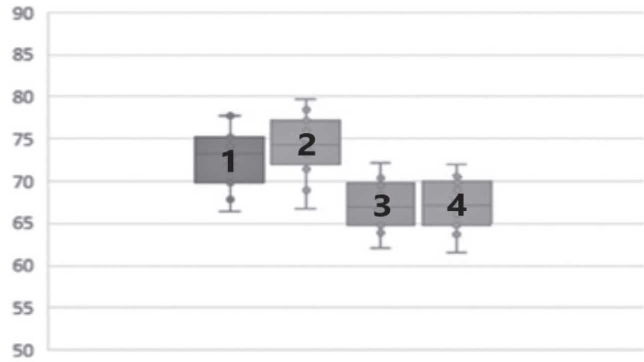

Graph 3. The difference between the input and output measurement of the velocity of the projectiles when shooting overhead one-handed from a jump from a 9 m distance

The distribution of the input data was first checked using the Shapiro-Wilk normality test. The level of statistical significance was chosen to be 5%. The test results are recorded in Table 6.

According to the performed Shapiro-Wilk normality test, we found that the input data distribution in one case does not correspond to a normal distribution. Thus, the Mann-Whitney U-test was used to test the hypotheses. The level of statistical significance for the tests was chosen to be 5%. By subsequently performing the Mann-Whitney U-test on the data set, p-values were obtained. The test results are recorded in Table 7.

Table 6. Shapiro-Wilk normality test

Throw	1		2		3	
Group	Experimental group	Control group	Experimental group	Control group	Experimental group	Control group
p-value	0.92 %	0.02 %	0.38 %	0.64 %	0.75 %	0.63 %
Normal distribution	Yes	No	Yes	Yes	Yes	Yes

Table 7. Mann-Whitney U-test

Shooting	A	B	C
p value	<0.001 (U=225. Z=82.26)	<0.001 (U=209. Z=3.98)	<0.001 (U=219. Z=4.40)

A - one-handed overhead shot from the ground from a 7 m distance (penalty throw), B - one-handed overhead shot from the ground after a run-up from a 9 m distance, C - one-handed overhead shot from a jump from a 9 m distance.

By the test, it was proven that the speed of the throw increased significantly due to the effect of 8 weeks of exercise aimed at activating the DSS muscles in all 3 types of shots. In all three investigated cases, the mean of the measurement differences was higher than the standard deviation of the differences. Therefore, differences are factually significant (Table 8).

Table 8. Factual significance

Difference in measurements [%]	Experimental Group		
Shooting	A	B	C
M	3.82	2.23	2.38
SD	1.11	1.43	0.99

M – Mean average, SD - standard deviation, A - one-handed overhead shooting from the ground from the spot from 7 m distance (penalty throw), B - one-handed overhead shooting from the ground after a run-up from a 9 m distance, C - one-handed overhead shooting from a jump from 9 m distance.

Discussion

As part of our research, we evaluated the effect of the DSS of spine activation on the shot speed in professional female handball players. In an experimental investigation, we tried to verify the effect of an 8-week intervention aimed at activating the DSS of the spine on the shot speed in a group of 30 adult female handball players who play top-level competition in the Czech Republic. The experimental group had special blocks with exercises to activate the DSS included in regular handball training.

We found that in the experimental group, after applying the center activation exercise, there was an improvement and an increase in the velocity of all shots. We did not notice any improvement in the control group. In the experimental group, the speed of the shot increased by 3.82% during the one-handed overhead shooting from the ground from a distance of 7 m (free throw), on average; the control group, on the other hand, worsened by -0.34% during the output measurement. Thus, for this shooting method, we recorded the highest rate of improvement in the experimental group out of all 3 shooting methods. In the one-handed overhead shooting from the spot after a run-up from a distance of 9 m, the experimental group improved on average by 2.23% in the final measurement; the control group worsened on average by -0.1% in the second measurement. We recorded the slightest improvement in the experimental group on average with this shooting method. From the third shooting position, the overhead one-handed jump shot from a distance of 9 m, the experimental group improved in the output measurement by 2.38%.

In contrast, the control group saw a slight improvement of 0.03%. So this was the only shooting method in which there was no deterioration in the control group, but the improvement was really small. Overall, there was an average increase in the speed of bullets by 2.81% in the experimental group, while in the control group, we noticed a slight deterioration by -0.14% on average.

The measured data were processed using mathematical-statistical methods, where the Shapiro-Wilk normality test was first used, which proved that in 1 case the data distribution did not correspond to a normal distribution, and therefore the Mann-Whitney U-test was used for subsequent data analysis. After the calculation of this test, we after performing the tests found that due to the effect of 8 weeks of exercise on the activation of the DSSS muscles, the velocity of the shots increased statistically significantly. Furthermore, in all three examined cases, the average of the measurement difference was higher than the standard deviation of the differences, and the differences can therefore be considered factually significant. Thanks to this, we were able to reject the null hypothesis and accept the assumption we made that the experimental group would have a higher speed of all three shots measured on average in the output measurement than the control group.

In the Czech Republic, we have not noticed any research devoted to this issue in handball; only Vojtěchovská's final thesis (2022) examines the effect of center activation exercises on shot speed in hockey. Some foreign authors, such as Manchado et al. (2017) and Saeterbakken et al. (2011), demonstrated in young athletes that the DSSS muscles activation indeed affects handball players' shot velocity. More specifically, for example, in the research of Manchado et al. (2017), the shooting rate of the experimental group increased on average by 4.3% after 10 weeks of DSSS muscle activation exercises 3 times per week. The authors of this study recommended following up on research with elite athletes. Compared to our results, there was a more significant improvement, which may be due to the two weeks longer duration of the intervention and the choice of exercises. Despite the solid theoretical basis supporting the use of specific training and the studies cited here to support this theory, inconsistent views still persist in the literature regarding the effect on performance or injury prediction in athletes (Danneels et al., 2001, Gorostiaga et al., 2004, Luo et al., 2022, McGill, 2001, Shelly, 2010). No or insignificant effect with regard to performance improvement in different sports disciplines may explain the poor design of the progression of selected basic exercises (Brull-Muria et al., 2021, Hibbs et al., 2008, Junker, 2019, Stanton et al., 2004). For this reason, we strictly followed the sequence of the three described exercise levels during core training. We progressed from simpler exercises to more complex ones, from static to dynamic, and from exercises in stable positions to balance.

The results of our study and the aforementioned research investigations confirm the importance of specific strength training for increasing the activation of the DSS, or strengthening the core muscles, in the training process. At the same time, they show an improvement in game performance, the key factors of which are the speed of the shot, which, together with accuracy, determines the effectiveness of performance in handball.

We found that in the experimental group, after applying exercises to activate the DSS of the spine, there was a significant increase in the speed of all three measured shots. We did not notice any improvement in the control group. A one-handed overhead shot from the ground from a distance of 7 m (penalty shot) increased the speed the most by 3.82%, a one-handed overhead shot from the ground after a run-up from a distance of 9 m increased its speed by 2.23%, and one-handed jump shots from 9m by 2.38%.

Targeted activation of the DSS muscles led to increased shot speed in handball. We recommend implementing strength training programs aimed at targeted activation of the deep stabilizers in training not only for handball but also for other team sports.

Bioethical clearance

The study was designed in accordance with the Helsinki Declaration, and conducted following the approval of the Ethics Committee of the Faculty of Education UJEP (1/2019/01).

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References

Ammer, K.; Ebenbichler, G.; Bochdansky, T. Low Back Pain—A Disease or Condition of Impaired Functional Health? Definition-Inherent Consequences for the Comprehensive Care of Back Pain Patients. BioMed 2022, 2, 270-281. https://doi.org/10.3390/biomed2020022

Belli, G.; Marini, S.; Mauro, M.; Maietta Latessa, P.; Toselli, S. Effects of Eight-Week Circuit Training with Core Exercises on Performance in Adult Male Soccer Players. Eur. J. Investig. Health Psychol. Educ. 2022, 12, 1244-1256. https://doi.org/10.3390/ejihpe12090086

Bernaciková, M., Kapounková, K., Novotný, J. et al. (2010). Házená [učební texty]. Retrieved 12. 1. 2020 from the World Wide Web: http://is.muni.cz/do/rect/el/estud/fsps/ps10/fyziol/web/sport/hry-hazena.html.

BILICI, Ömer Faruk; SELÇUK, Muzaffer. Evaluation of the Effect of Core Training on the Leap Power and Motor Characteristics of the 14-16 Years Old Female Volleyball Players. Journal of Education and Training studies, 2018, 6.4: 90-97. – není v textu

Brull-Muria, E.; Beltran-Garrido, J.V. Effects of a Specific Core Stability Program on the Sprint and Change-of-Direction Maneuverability Performance in Youth, Male Soccer Players. Int. J. Environ. Res. Public Health 2021, 18, 10116. https://doi.org/10.3390/ijerph181910116

Choutka, M., Brklová, D. & Votík, J. (1999). Motorické učení v tělovýchovné a sportovní praxi. Plzeň: Západočeská univerzita, Fakulta pedagogická.

Coulombe BJ, Games KE, Neil ER, Eberman LE. Core Stability Exercise Versus General Exercise for Chronic Low Back Pain. J Athl Train. 2017 Jan;52(1):71-72. doi: 10.4085/1062-6050-51.11.16. Epub 2016 Nov 16. PMID: 27849389; PMCID: PMC5293521.

Danneels LA, Vanderstraeten GG, Cambier DC, Witvrouw EE, Bourgois J, Dankaerts W, De Cuyper HJ. Effects of three different training modalities on the cross sectional area of the lumbar multifidus muscle in patients with chronic low back pain. Br J Sports Med. 2001 Jun;35(3):186-91. doi: 10.1136/bjsm.35.3.186. PMID: 11375879; PMCID: PMC1724339.

Esteban-García, P.; Jiménez-Díaz, J.F.; Abián-Vicén, J.; Bravo-Sánchez, A.; Rubio-Arias, J.Á. Effect of 12 Weeks Core Training on Core Muscle Performance in Rhythmic Gymnastics. Biology 2021, 10, 1210. https://doi.org/10.3390/biology10111210

Fritz B, Parkar AP, Cerezal L, Storgaard M, Boesen M, Åström G, Fritz J. Sports Imaging of Team Handball Injuries. Semin Musculoskelet Radiol. 2020 Jun;24(3):227-245. doi: 10.1055/s-0040-1710064. Epub 2020 Sep 28. PMID: 32987422.

Frizziero, A.; Pellizzon, G.; Vittadini, F.; Bigliardi, D.; Costantino, C. Efficacy of Core Stability in Non-Specific Chronic Low Back Pain. J. Funct. Morphol. Kinesiol. 2021, 6, 37. https://doi.org/10.3390/jfmk6020037

García, J. A., Sabido, R., Barbado, D. & Moreno, F. J. (2013). Analysis of the relation between throwing velocityand throwing accuracy in team-handball according to instruction. European Journal of Sport Science, 13(2), 149–154.

Gorostiaga EM, Izquierdo M, Ruesta M, Iribarren J, González-Badillo JJ, Ibáñez J. Strength training effects on physical performance and serum hormones in young soccer players. Eur J Appl Physiol. 2004 May;91(5-6):698-707. doi: 10.1007/s00421-003-1032-y. Epub 2003 Dec 24. Erratum in: Eur J Appl Physiol. 2005 Jan;93(4):507. PMID: 14704801.

Hammami M, Gaamouri N, Ramirez-Campillo R, Shephard RJ, Bragazzi NL, Chelly MS, Knechtle B, Gaied S. Effects of high-intensity interval training and plyometric exercise on the physical fitness of junior male handball players. Eur Rev Med Pharmacol Sci. 2021 Dec;25(23):7380-7389. doi: 10.26355/eurrev_202112_27434. PMID: 34919239.

Hibbs AE, Thompson KG, French D, Wrigley A, Spears I. Optimizing performance by improving core stability and core strength. Sports Med. 2008;38(12):995-1008. doi: 10.2165/00007256-200838120-00004. PMID: 19026017.

Hlaing SS, Puntumetakul R, Khine EE, Boucaut R. Effects of core stabilization exercise and strengthening exercise on proprioception, balance, muscle thickness and pain related outcomes in patients with subacute nonspecific low back pain: a randomized controlled trial. BMC Musculoskelet Disord. 2021 Nov 30;22(1):998. doi: 10.1186/s12891-021-04858-6. PMID: 34847915; PMCID: PMC8630919.

Jiang, Q.; Kim, Y.; Choi, M. Kinetic Effects of 6 Weeks' Pilates or Balance Training in College Soccer Players with Chronic Ankle Instability. Int. J. Environ. Res. Public Health 2022, 19, 12903. https://doi.org/10.3390/ijerph191912903

Junker D, Stöggl T. The Training Effects of Foam Rolling on Core Strength Endurance, Balance, Muscle Performance and Range of Motion: A Randomized Controlled Trial. J Sports Sci Med. 2019 Jun 1;18(2):229-238. PMID: 31191092; PMCID: PMC6543984.

Kabadayı, M.; Karadeniz, S.; Yılmaz, A.K.; Karaduman, E.; Bostancı, Ö.; Akyildiz, Z.; Clemente, F.M.; Silva, A.F. Effects of Core Training in Physical Fitness of Youth Karate Athletes: A Controlled Study Design. Int. J. Environ. Res. Public Health 2022, 19, 5816. https://doi.org/10.3390/ijerph19105816

Kellis E, Ellinoudis A, Intziegianni K, Kofotolis N. Muscle Thickness During Core Stability Exercises in Children and Adults. J Hum Kinet. 2020 Jan 31;71:131-144. doi: 10.2478/hukin-2019-0079. PMID: 32148578; PMCID: PMC7052719.

Kibler, W. B., Press, J. & Sciascia, A. (2006). The role of core stability in athletic function. Sports Med, 36, 189–198.

Kolář, Kostadinović S, Milovanović N, Jovanović J, Tomašević-Todorović S. Efficacy of the lumbar stabilization and thoracic mobilization exercise program on pain intensity and functional disability reduction in chronic low back pain patients with lumbar radiculopathy: A randomized controlled trial. J Back Musculoskelet Rehabil. 2020;33(6):897-907. doi: 10.3233/BMR-201843. PMID: 32675390.

Lemos LF, Oliveira VC, Duncan MJ, Ortega JP, Martins CM, Ramirez-Campillo R, Sanchez JS, Nevill AM, Nakamura FY. Physical fitness profile in elite beach handball players of different age categories. J Sports Med Phys Fitness. 2020 Dec;60(12):1536-1543. doi: 10.23736/S0022-4707.20.11104-6. Epub 2020 Jun 30. PMID: 32608936.

Lin, C.-Y.; Liu, Y.-H.; Chen, S.-M.; Cheng, S.-C.; Liu, M.-F. The Effectiveness of Group-Based Core Stability Exercise and Educational Booklet for Hospital Workers in Taiwan with Nonspecific Low Back Pain: A Preliminary Study. Int. J. Environ. Res. Public Health 2022, 19, 3324. https://doi.org/10.3390/ijerph19063324

Luo S, Soh KG, Soh KL, Sun H, Nasiruddin NJM, Du C, Zhai X. Effect of Core Training on Skill Performance Among Athletes: A Systematic Review. Front Physiol. 2022 Jun 6;13:915259. doi: 10.3389/fphys.2022.915259. PMID: 35755428; PMCID: PMC9227831.

Manchado, C., García-Riuz, J., Cortell-Tormo, J. M. & Tortosa-Martínez, J. (2017). Effect of Core Training on Male Handball Players Throwing Velocity. Journal of Human Kinetics, 56, 177–185.

Martínez-Rodríguez A, Sánchez-Sánchez J, Martínez-Olcina M, Vicente-Martínez M, Miralles-Amorós L, Sánchez-Sáez JA. Study of Physical Fitness, Bone Quality, and Mediterranean Diet Adherence in Professional Female Beach Handball Players: Cross-Sectional Study. Nutrients. 2021 Jun 2;13(6):1911. doi: 10.3390/nu13061911. PMID: 34199412; PMCID: PMC8229186.

McGill, Stuart M.. Low Back Stability: From Formal Description to Issues for Performance and Rehabilitation. Exercise and Sport Sciences Reviews: January 2001 - Volume 29 - Issue 1 - p 26-31.

Nuhmani, S. Correlation between Core Stability and Upper-Extremity Performance in Male Collegiate Athletes. Medicina 2022, 58, 982. https://doi.org/10.3390/medicina58080982

Ozmen T, Aydogmus M. Effect of core strength training on dynamic balance and agility in adolescent badminton players. J Bodyw Mov Ther. 2016 Jul;20(3):565-70. doi: 10.1016/j.jbmt.2015.12.006. Epub 2015 Dec 19. PMID: 27634079.

Reed CA, Ford KR, Myer GD, Hewett TE. The effects of isolated and integrated 'core stability' training on athletic performance measures: a systematic review. Sports Med. 2012 Aug 1;42(8):697-706. doi: 10.2165/11633450-000000000-00000. PMID: 22784233; PMCID: PMC4166601.

Risberg MA, Steffen K, Nilstad A, Myklebust G, Kristianslund E, Moltubakk MM, Krosshaug T. Normative Quadriceps and Hamstring Muscle Strength Values for Female, Healthy, Elite Handball and Football Players. J Strength Cond Res. 2018 Aug;32(8):2314-2323. doi: 10.1519/JSC.0000000000002579. PMID: 29794892; PMCID: PMC6092090.

Rivera CE. Core and Lumbopelvic Stabilization in Runners. Phys Med Rehabil Clin N Am. 2016 Feb;27(1):319-37. doi: 10.1016/j.pmr.2015.09.003. PMID: 26616187.

Russomanno TG, Lam H, Knopp M, Huang H, Stadtlander T, Lames M. Within-Match Performance Dynamics - Momentary Strength in Handball. J Hum Kinet. 2021 Jul 28;79:211-219. doi: 10.2478/hukin-2021-0073. PMID: 34401000; PMCID: PMC8336560.

Seiler, S., Skaanes, P. T. & Kirkesola, G. (2006). Effects of sling exercise training on maximal clubhead velocity in junior golfers. Medicine & Science in Sports & Exercise, 38, 286.

Shelly, M. S., Hernassi, S. & Shephard, R. (2010). Relationship between power and strength of upper a lower limb muscles and throwing velocity in male handball players. Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins) 24(6) 1480–1487.

Srhoj, V., Rogulj, N., Cavala, M., Papić, V. & Foretić, N. (2012). The influence of anthropological features on ball flight velocityin handball. Collegium Antropologicum, 36(3), 967–972.

Stray-Pedersen, J. L., Magnussen, R., Kuffel, E., Seiler, S. & Katch, F. (2006). Sling exercise training improves balance, kicking velocity and torso stabilization strength in elite soccer players. Medicine & Science in Sports & Exercise, 38(5), 243. Thurgood, G. & Paternoster, M. (2014). Core trénink: kompletní rádce pro muže i ženy, jak posílením svalů středu získat zdravější a lépe fungující tělo. Praha: Slovart.

Szczygieł E, Blaut J, Zielonka-Pycka K, Tomaszewski K, Golec J, Czechowska D, Masłoń A, Golec E. The Impact of Deep Muscle Training on the Quality of Posture and Breathing. J Mot Behav. 2018 Mar-Apr;50(2):219-227. doi: 10.1080/00222895.2017.1327413. Epub 2017 Aug 18. PMID: 28820662.

Vojtěchovská, T. Vliv aktivace hlubokého stabilizačního systému páteře na rychlost střely u hráčů ledního hokeje Diplomová práce. Univerzita Karlova, 2022.

Wilk KE, Arrigo CA. Rehabilitation of Elbow Injuries: Nonoperative and Operative. Clin Sports Med. 2020 Jul;39(3):687-715. doi: 10.1016/j.csm.2020.02.010. Epub 2020 Apr 16. PMID: 32446584.

Zmijewski P, Lipinska P, Czajkowska A, Mróz A, Kapuściński P, Mazurek K. Acute Effects of a Static Vs. a Dynamic Stretching Warm-up on Repeated-Sprint Performance in Female Handball Players. J Hum Kinet. 2020 Mar 31;72:161-172. doi: 10.2478/hukin-2019-0043. PMID: 32269657; PMCID: PMC7126248.

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Revised Maj 2021

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When preparing the final version of the manuscripts, either NEW or REVISED authors should strictly follow the guidelines. Manuscripts departing substantially from the guidelines will be returned to the authors for revision or, rejected.

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Authors should submit the manuscripts as one Microsoft Word (.doc) file.

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Format the manuscript in A4 paper size; margins are 1 inch or 2.5 cm all around. Type the whole manuscript double-spaced, justified alignment.

Use Times New Roman font, size eleven (11) point.

Number (Arabic numerals) the pages consecutively (centering at the bottom of each page), beginning with the title page as page 1 and ending with the Figure legend page.

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Apart from chapter headings and sub-headings avoid any kind of formatting in the main text of the manuscripts.

1.2. Type & Length

MJSSM publishes following types of papers:

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Original Scientific Paper

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Selcuk Akpinar[1], Stevo Popović[1,2], Sadettin Kirazci[1]

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Duffield, R., & Marino, F. E. (2007). *Effects of pre-cooling procedures on intermittent-sprint exercise performance in warm conditions. European Journal of Applied Physiology, 100*(6), 727–735. https://doi.org/10.1007/s00421-007-0468-x

Works by three to twenty authors
Nepocatych, S., Balilionis, G., & O'Neal, E. K. (2017). Analysis of dietary intake and body composition of female athletes over a competitive season. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 57–65. https://doi.org/10.26773/mjssm.2017.09.008

Works by more than twenty authors
Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A.,… Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine & Science in Sports & Exercise, 35*(4), 697–705. https://doi.org/10.1249/01.mss.0000058441.94520.32

Works by group of authors
NCD-RisC. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *Lancet*, 390(10113), 2627-2642. https://doi.org/10.1016/s0140-6736(17)32129-3

Works by unknown authors
Merriam-Webster's collegiate dictionary (11th ed.). (2003). Merriam-Webster.

Journal article (print)
Scruton, R. (1996). The eclipse of listening. *The New Criterion, 15*(3), 5–13.

Journal article (electronic)
Aarnivala, H., Pokka, T., Soininen, R., Mottonen, M., Harila-Saari, A., & Niinimaki, R. (2020). Trends in age- and sex-adjusted body mass index and the prevalence of malnutrition in children with cancer over 42 months after diagnosis: a single-center cohort study. *European Journal of Pediatrics,* 179(1), 91-98. https://doi.org/10.1007/s00431-019-03482-w

Thesis and dissertation
Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport*. [Unpublished Doctoral Dissertation]. The Florida State University.

Book
Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human Kinetics.

Chapter of a book
Armstrong, D. (2019). Malory and character. In M. G. Leitch & C. J. Rushton (Eds.), *A new companion to Malory* (pp. 144-163). D. S. Brewer.

Reference to a Facebook profile
Little River Canyon National Preserve (n.d.). *Home* [Facebook page]. Facebook. Retrieved January 12, 2020 from https://www.facebook.com/lirinps/

2.5. Tables

All tables should be included in the main manuscript file, each on a separate page right after the Reference section.

Tables should be presented as standard MS Word tables.

Number (Arabic) tables consecutively in the order of their first citation in the text.

Tables and table headings should be completely intelligible without reference to the text. Give each column a short or abbreviated heading. Authors should place explanatory matter in footnotes, not in the heading. All abbreviations appearing in a table and not considered standard must be explained in a footnote of that table. Avoid any shading or coloring in your tables and be sure that each table is cited in the text.

If you use data from another published or unpublished source, it is the authors' responsibility to obtain permission and acknowledge them fully.

2.5.1. Table heading

Table heading should be written above the table, in Title Case, and without a full stop at the end of the heading. Do not use suffix letters (e.g., Table 1a, 1b, 1c); instead, combine the related tables. *See* example:

- ✓ **Table 1.** Repeated Sprint Time Following Ingestion of Carbohydrate-Electrolyte Beverage

2.5.2. Table sub-heading

All text appearing in tables should be written beginning only with first letter of the first word in all capitals, i.e., all words for variable names, column headings etc. in tables should start with the first letter in all capitals. Avoid any formatting (e.g., bold, italic, underline) in tables.

2.5.3. Table footnotes

Table footnotes should be written below the table.

General notes explain, qualify or provide information about the table as a whole. Put explanations of abbreviations, symbols, etc. here. General notes are designated by the word Note (italicized) followed by a period.

- ✓ *Note.* CI: confidence interval; Con: control group; CE: carbohydrate-electrolyte group.

Specific notes explain, qualify or provide information about a particular column, row, or individual entry. To indicate specific notes, use superscript lowercase letters (e.g. $^{a, b, c}$), and order the superscripts from left to right, top to bottom. Each table's first footnote must be the superscript ^{a}.

- ✓ ^{a}One participant was diagnosed with heat illness and n = 19.^{b}n =20.

Probability notes provide the reader with the results of the texts for statistical significance. Probability notes must be indicated with consecutive use of the following symbols: * † ‡ § ¶ || etc.

- ✓ *P<0.05,†p<0.01.

2.5.4. Table citation

In the text, tables should be cited as full words. *See* example:

- ✓ Table 1 (first letter in all capitals and no full stop)
- ✓ ...as shown in Tables 1 and 3. (citing more tables at once)
- ✓ ...result has shown (Tables 1-3) that... (citing more tables at once)
- ✓ ....in our results (Tables 1, 2 and 5)... (citing more tables at once)

2.6. Figures

On the last separate page of the main manuscript file, authors should place the legends of all the figures submitted separately.

All graphic materials should be of sufficient quality for print with a minimum resolution of 600 dpi. MJSSM prefers TIFF, EPS and PNG formats.

If a figure has been published previously, acknowledge the original source and submit a written permission from the copyright holder to reproduce the material. Permission is required irrespective of authorship or publisher except for documents in the public domain. If photographs of people are used, either the subjects must not be identifiable or their pictures must be accompanied by written permission to use the photograph whenever possible permission for publication should be obtained.
Figures and figure legends should be completely intelligible without reference to the text.

The price of printing in color is 50 EUR per page as printed in an issue of MJSSM.

2.6.1. Figure legends

Figures should not contain footnotes. All information, including explanations of abbreviations must be present in figure legends. Figure legends should be written bellow the figure, in sentence case. *See* example:

- ✓ **Figure 1.** Changes in accuracy of instep football kick measured before and after fatigued. SR – resting state, SF – state of fatigue, *p>0.01, †p>0.05.

2.6.2. Figure citation

All graphic materials should be referred to as Figures in the text. Figures are cited in the text as full words. *See* example:

- ✓ Figure 1
- × figure 1
- × Figure 1.
- ✓ ….exhibit greater variance than the year before (Figure 2). Therefore…
- ✓ ….as shown in Figures 1 and 3. (citing more figures at once)
- ✓ ….result has shown (Figures 1-3) that... (citing more figures at once)
- ✓ ….in our results (Figures 1, 2 and 5)... (citing more figures at once)

2.6.3. Sub-figures

If there is a figure divided in several sub-figures, each sub-figure should be marked with a small letter, starting with a, b, c etc. The letter should be marked for each subfigure in a logical and consistent way. *See* example:

- ✓ Figure 1a
- ✓ …in Figures 1a and b we can…
- ✓ …data represent (Figures 1a-d)…

2.7. Scientific Terminology

All units of measures should conform to the International System of Units (SI).

Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples.

Decimal places in English language are separated with a full stop and not with a comma. Thousands are separated with a comma.

Percentage	Degrees	All other units of measure	Ratios	Decimal numbers
✓ 10%	✓ 10º	✓ 10 kg	✓ 12:2	✓ 0.056
× 10 %	× 10 º	× 10kg	× 12 : 2	× .056

Signs should be placed immediately preceding the relevant number.		
✓ 45±3.4	✓ p<0.01	✓ males >30 years of age
× 45 ± 3.4	× p < 0.01	× males > 30 years of age

2.8. Latin Names

Latin names of species, families etc. should be written in italics (even in titles). If you mention Latin names in your abstract they should be written in non-italic since the rest of the text in abstract is in italic. The first time the name of a species appears in the text both genus and species must be present; later on in the text it is possible to use genus abbreviations. *See* example:

- ✓ First time appearing: *musculus biceps brachii*
- ✓ Abbreviated: *m. biceps brachii*

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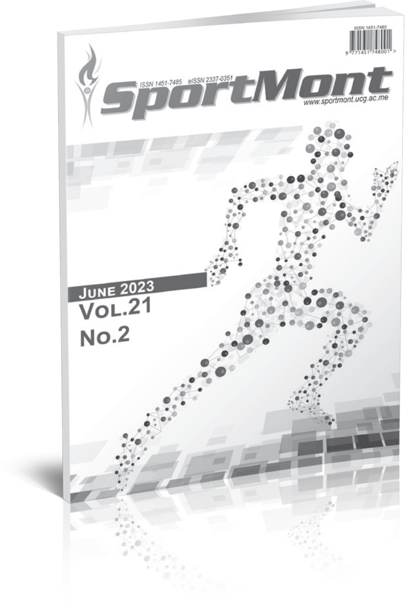

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SMJ is published three times a year, in February, June and October of each year. SMJ publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Sports Science and Medicine, as well as it can function as an open discussion forum on significant issues of current interest.

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MONTENEGRIN SPORTS ACADEMY

Founded in 2003 in Podgorica (Montenegro), the Montenegrin Sports Academy (MSA) is a sports scientific society dedicated to the collection, generation and dissemination of scientific knowledge at the Montenegrin level and beyond.

The Montenegrin Sports Academy (MSA) is the leading association of sports scientists at the Montenegrin level, which maintains extensive co-operation with the corresponding associations from abroad. The purpose of the MSA is the promotion of science and research, with special attention to sports science across Montenegro and beyond. Its topics include motivation, attitudes, values and responses, adaptation, performance and health aspects of people engaged in physical activity and the relation of physical activity and lifestyle to health, prevention and aging. These topics are investigated on an interdisciplinary basis and they bring together scientists from all areas of sports science, such as adapted physical activity, biochemistry, biomechanics, chronic disease and exercise, coaching and performance, doping, education, engineering and technology, environmental physiology, ethics, exercise and health, exercise, lifestyle and fitness, gender in sports, growth and development, human performance and aging, management and sports law, molecular biology and genetics, motor control and learning, muscle mechanics and neuromuscular control, muscle metabolism and hemodynamics, nutrition and exercise, overtraining, physiology, physiotherapy, rehabilitation, sports history, sports medicine, sports pedagogy, sports philosophy, sports psychology, sports sociology, training and testing.

The MSA is a non-profit organization. It supports Montenegrin institutions, such as the Ministry of Education and Sports, the Ministry of Science and the Montenegrin Olympic Committee, by offering scientific advice and assistance for carrying out coordinated national and European research projects defined by these bodies. In addition, the MSA serves as the most important Montenegrin and regional network of sports scientists from all relevant subdisciplines.

The main scientific event organized by the Montenegrin Sports Academy (MSA) is the annual conference held in the first week of April.

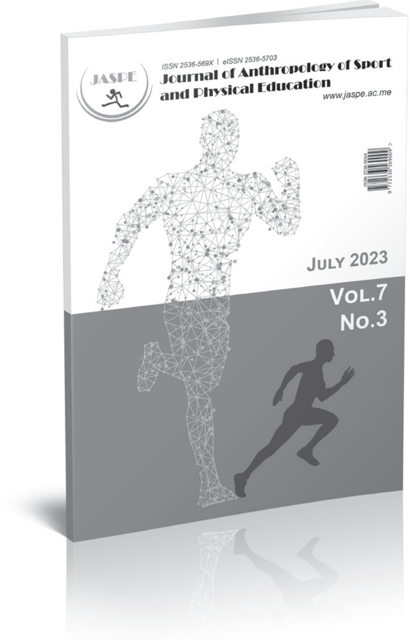
Annual conferences have been organized since the inauguration of the MSA in 2003. Today the MSA conference ranks among the leading sports scientific congresses in the Western Balkans. The conference comprises a range of invited lecturers, oral and poster presentations from multi- and mono-disciplinary areas, as well as various types of workshops. The MSA conference is attended by national, regional and international sports scientists with academic careers. The MSA conference now welcomes up to 200 participants from all over the world.

It is our great pleasure to announce the upcoming 21th Annual Scientific Conference of Montenegrin Sports Academy “Sport, Physical Activity and Health: Contemporary Perspectives” to be held in Dubrovnik, Croatia, from 18 to 21 April, 2024. It is planned to be once again organized by the Montenegrin Sports Academy, in cooperation with the Faculty of Sport and Physical Education, University of Montenegro and other international partner institutions (specified in the partner section).

The conference is focused on very current topics from all areas of sports science and sports medicine including physiology and sports medicine, social sciences and humanities, biomechanics and neuromuscular (see Abstract Submission page for more information).

We do believe that the topics offered to our conference participants will serve as a useful forum for the presentation of the latest research, as well as both for the theoretical and applied insight into the field of sports science and sports medicine disciplines.

Journal of Anthropology of Sport and Physical Education



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