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ORIGINAL SCIENTIFIC PAPER

Analysis of the Association Between Health Literacy, Physical Literacy, and Scholastic Achievement; A Preliminary Cross-Sectional Study Among High-School Students From Southern Croatia

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Abstract

Theoretically, health literacy (HL) and physical literacy (PL) should be associated with overall education, but little is known about their association with scholastic achievement. The aim of this study was to investigate whether scholastic variables relate to HL and PL among high-school adolescents. We observed 268 high school students (202 females, 66 males) who were assessed on HL using the HLS-EU47 questionnaire and PL by PLAYself questionnaire. Scholastic variables included grade point average and excused and unexcused number of absences from school. Gender-stratified correlations, cluster analysis, and discriminant canonical analysis were calculated to establish the associations between study variables. The correlations between HL and scholastic variables were generally poor, while statistically significant correlations between grade point average and HL were noted only among girls (R=0.16, p<0.05). Cluster and discriminant analyses confirmed higher HL and PL among girls who were better at school. While associations between HL and PL with scholastic achievement were generally poor, our results point to the necessity of further investigation of a problem. Hence, specific types of knowledge should be explored as possible correlates of HL and PL in adolescence.

Keywords: *adolescents, health behavior, lifestyle, pedagogy, teachers*

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Introduction

High school students are in a sensible life period (i.e., adolescence), where they adopt behaviors that determine their adult habits (de Bruin, 2012). What is more, high school students are still in compulsory education, which means that teachers and other education agents can influence their behavior and teach them how to adopt behaviors that are good for their health (Olujić & Maras, 2021). Several concepts have been considered influential in the sense of adopting positive health behaviors, including health literacy (HL) and physical literacy (PL) (Buja et al., 2020; Cairney et al., 2019).

The most common definition of HL is "HL entails people's knowledge, motivation, and competencies to access, understand, appraise and apply health information to make judg-

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ments and take decisions in everyday life concerning healthcare, disease prevention, and health promotion to maintain or improve quality of life during the life course" (Sørensen et al., 2012). Indeed, numerous studies identified the link between HL and health-related behaviors and outcomes. Namely, it was found that adolescents with high levels of HL displayed good nutritional habits, appropriate physical activity levels, not consuming alcohol and tobacco, and having a good health-related quality of life (Guo et al., 2021; Klinker et al., 2020; Qiao et al., 2021). Supportively, a recent study conducted on similar participants (i.e., high school students from Croatia) evidenced that students with better HL have a preferable lipid profile, which is an indicator of cardiovascular health (Kesic et al., 2022).

On the other side, PL can be defined as "the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engagement in physical activities for life" (Martins et al., 2021). PL is mainly connected to health outcomes through fostering participation in physical activity, which is considered one of the most important habits that positively impact health status (Caldwell et al., 2020). Moreover, PL has directly been linked to several health indicators, such as cardiorespiratory fitness and health-related quality of life (Cairney et al., 2019; Cornish et al., 2020). Recent studies on high school students found that students with better PL have higher physical activity levels (Gilic et al., 2022) and better physical fitness (Gilic et al., 2022; Sunda et al., 2022).

As HL and PL can be taught (i.e., by high school teachers), it could be expected that scholastic achievement and other school-related variables would be connected to HL and PL. In other words, we can theorize that students with better grades and fewer school absences would have better developed PL and HL skills and better health habits. Indeed, studies evidenced that students with higher grades had higher diet quality (Whatnall et al., 2019) and physical activity levels (Nelson & Gordon-Larsen, 2006; Schmitz et al., 2002). Moreover, a study conducted on adolescents from Bosnia and Herzegovina evidenced that students who are better in school (i.e., have better grades) managed to preserve their physical activity levels during the COVID-19 pandemic, which indicates that they had good PL skills and that they were aware of the health benefits of physical activity (Sekulic et al., 2021). Finally, scholastic achievement and health habits have been considered positively associated in a recent study that emphasized the importance of including HL interventions in the education system which would lead to better health outcomes of students (de Albuquerque et al., 2022).

Both HL and PL are skills that can be learned and are susceptible to changes during the educational processes in school. Considering that HL and PL are linked to positive health behaviors and outcomes, it is important to investigate whether they relate to scholastic variables in order to emphasize the importance of including them in the school curriculum. However, studies that simultaneously investigated associations between HL, PL, and scholastic variables are lacking. Thus, the aim of this research was to determine whether HL and PL are related to scholastic variables (grade point average and school absences) in high school students. We hypothesize that students with higher grade point averages and fewer school absences will have higher HL and PL levels.

Materials and Methods

Participants and Study Design

In this cross-sectional preliminary study 268 high student (202 females, 66 males) from the Southern Croatia were involved. The average age was 16.8 ± 1.3 years. The study was part of a wider research project previously initiated and approved by The Ethical Board of the University of Split, Faculty of Kinesiology, on 23rd September 2021 (EBO: 2181-205-02-01-21-0011)

The study permitted the inclusion of participants who were attending the school during the school years 2020/2021, and 2021/2022, and who were successfully tested for all variables observed (HL, PL). Students (or parents/legal guardians for those younger than 18 years of age) were invited to sign their consent to participate in the study on a form, successive to ethical approval.

Variables and Measurement

The variables in this study included gender and age (in years), HL, PL and variables of scholastic achievement.

The Croatian version of the European Health Literacy Survey Questionnaire 47 (HLS-EU-Q47) was used to assess the HL level as it was previously demonstrated to be valid among Croatian adolescents (Geets Kesic et al., 2022). The questionnaire asked 47 questions, relating to an individual's capability to acquire, process and understand basic health information and related services, and so allowing them to make appropriate health decisions or to obtain, understand, appraise and act upon it/them. A general index of HL was constructed using a 4-point Likert scale, with responses from very difficult—1 to very easy—4. The score was calculated through the formula: index = (mean – 1) × (50/3). Scoring was made on a scale of 0-50 where 0 was considered the lowest score and 50 the highest. The scoring index was separated into four sections of HL: inadequate (from 0 to 25); problematic (26–33); sufficient (34–42); excellent (43–50).

PL was assessed using self-administered tool which is a part of the Physical Literacy Assessment of Youth (PLAYself). PLAYself consists of four subscales: (i) affective and cognitive domain of PL; (ii) environment; (iii) literacy, numeracy and PL in different settings; and (iv) physical fitness (Jefferies et al., 2021). Maximum score is 100 (for subscales and for the total score) which represents the highest self-perceived PL. PLAYself was previously validated on the sample of Croatian adolescents (Gilic et al., 2022). To carry out all questionnaires (HLS-EU-Q47 and PLAYself) the platform SurveyMonkey (SurveyMonkey Inc., San Mateo, CA, USA) was used.

Scholastic achievement was assessed by academic achievement (grade point average - GPA) and school absences (excused and unexcused number of absences form school). The Constitution of the Republic of Croatia states that everyone is entitled to free compulsory education. The Ministry of Science, Education and Sport regulated the education process with the Primary and Secondary School Education Act, and the Ordinance on the Manner, Procedures and Elements of the Evaluation of the Primary and Secondary School Students (Žiljak & Baketa, 2019). Croatian education system defines two categories of grading: conduct grading – 3-point descriptive scale (poor, good, exemplary) and grade point average (GPA). GPA is calculated as the arithmetic mean of all numerical grades and it forms a scale from one to five as: insufficient/failing grade (1.00-1.99), sufficient (2.00-2.49), good (2.50-3.49), very good (3.50-4.49) and excellent (4.50-5.00). Overall school absence was the number of absences in school hours in one year.

All scholastic data was collected from the class register book in the electronic format: e-Dnevnik. E-Dnevnik represents a joint between ICT and the traditional class register book as web application. It was developed in 2011/2012 by The

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Croatian Academic and Research Network (CARNet) and its partners as the pilot-project "e-Schools". The idea was to implement ICT in education system in order to enable simpler access to different school data. One of major services developed and implemented by this project was e-Dnevnik. The advantage of use of e-Dnevnik in school practice is its simplicity to keep students records, the monitoring of student progress, the possibility of analyzing collected statistical data and quick access to information about individual student or class. The ICT integrated in e-Dnevnik, easy gives to teacher or other school staff (e.g., pedagogue) GPA and calculated absence for the individual students or for the class (Vrkić Dimić & Vidov, 2019).

Statistical Analysis

All variables were checked for normality of the distributions by Kolmogorov-Smirnov test. As a result, parametric statistics were calculated, and descriptive statistics were reported by means and standard deviations.

The analyses were done in several phases. As a preliminary (first) phase Pearson's correlation coefficients were calculated. In the second phase participants were grouped into homogenous groups on the basis of scholastic variables by multivariate cluster analysis. Specifically, the Ward's method of clustering based on Euclidian distances was used. Each participant was consequently allocated to appropriate number of clusters (homogenous groups), which was used as categorical factor in the next phases. Analysis of variance was calculated to establish the characteristics of the formed clusters. Finally, discriminative canonical analysis (DISCRA) was calculated to evaluate the multivariate differences in HL and PL among established clusters. All analyses were gender-stratified.

Statistica ver. 13.5 (Tibco Inc, Palo Alto, California, USA) was used for all analyses, and p-level of 0.05 was applied.

Results

Table 1 presents descriptive statistics for study variables as well as correlations among variables for the total sample of subjects. PL and HL were weekly correlated (5% of the common variance), while GPA was poorly but significantly correlated with HL (less than 2% of the common variance).

Descriptive statistics and correlations among variables for boys are presented in Table 2. In brief, apart from significant correlations among scholastic variables, no other coefficient reached statistical significance.

Table 1. Descriptive statistics (Mean, SD – standard deviation) and Pearson's correlations among variables – total sample

	Mean	SD	Age	PL	HL	GPA	U_Absence
Age (years)	17.03	1.39					
PL (score)	68.04	11.26	-0.02				
HL (score)	38.07	6.53	0.14*	0.25*			
GPA (score)	4.08	0.57	0.17*	0.08	0.12*		
U_Absence (school hours)	2.89	1.69	0.21*	-0.07	0.00	-0.29*	
T_Absence (school hours)	69.70	47.11	0.03	-0.03	-0.08	-0.41*	0.32*

Note: PL – physical literacy, HL – health literacy, GPA – grade point average, U_Absence – number of unexcused absences, T_Absence - number of total hours of absence, * denotes significance of $p < 0.05$

Table 2. Descriptive statistics (Mean, SD – standard deviation) and Pearson's correlations among variables – subsample of boys

	Mean	SD	Age	PL	HL	GPA	U_Absence
Age (years)	17.15	1.29					
PL (score)	68.05	11.04	0.05				
HL (score)	37.98	6.51	0.02	0.08			
GPA (score)	3.84	0.62	0.18	-0.07	0.01		
U_Absence (school hours)	3.55	2.40	0.35*	-0.12	-0.02	-0.22	
T_Absence (school hours)	71.32	48.70	0.05	0.23	-0.02	-0.33*	0.29*

Note: PL – physical literacy, HL – health literacy, GPA – grade point average, U_Absence – number of unexcused absences, T_Absence - number of total hours of absence, * denotes significance of $p < 0.05$

Table 3. Descriptive statistics (Mean, SD – standard deviation) and Pearson's correlations among variables – subsample of girls

	Mean	SD	Age	PL	HL	GPA	U_Absence
Age (years)	16.99	1.42					
PL (score)	68.03	11.36	-0.05				
HL (score)	38.10	6.55	0.18*	0.31*			
GPA (score)	4.16	0.53	0.19*	0.15*	0.17*		
U_Absence (school hours)	1.67	1.31	0.15*	-0.05	0.01	-0.27*	
T_Absence (school hours)	69.16	46.69	0.03	-0.12	-0.10	-0.46*	0.37*

Note: PL – physical literacy, HL – health literacy, GPA – grade point average, U_Absence – number of unexcused absences, T_Absence - number of total hours of absence, * denotes significance of $p < 0.05$

When calculated for girls, HL and PL were weekly but significantly correlated with GPA (less than 3% of the common variance). Generally, girls with higher GPA had better PL and HL (Table 3).

Figure 1 presents the hierarchical tree clustering of the boys according to their scholastic achievement. As evident, two homogenous groups were formed (Cluster 1 and Cluster 2), each containing a similar number of participants. Additional ANOVA evidenced better scholastic achievement in boys grouped in Cluster 1 ($p < 0.05$).

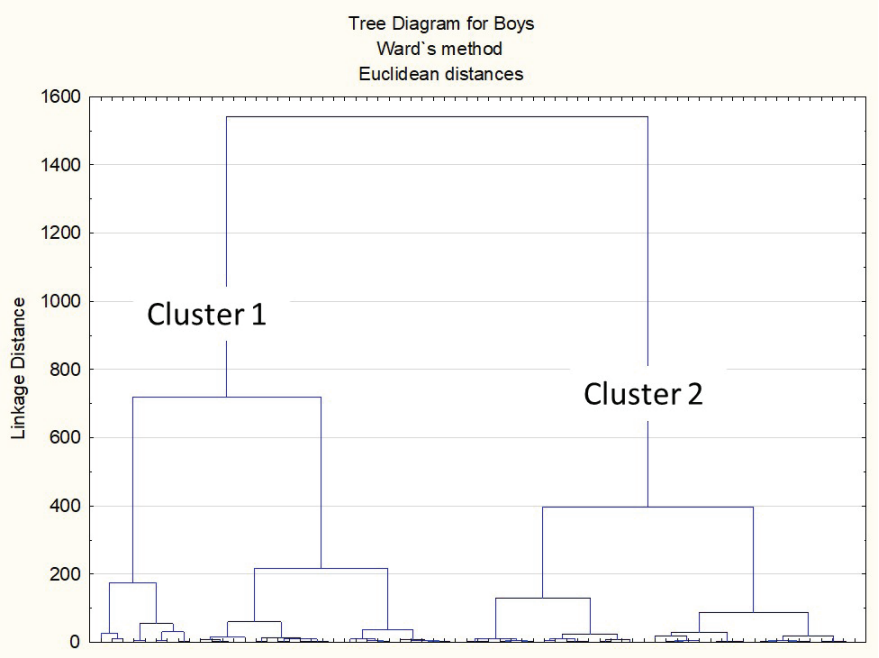

Figure 1. Multivariate clustering of boys based on scholastic variables.

Clustering of the girls on the basis of the scholastic variables is presented in Figure 2. In this subsample, three clusters were formed. ANOVA evidenced the best scholastic achievement in members of Cluster 1 ($p < 0.05$), with significant post-hoc differences between Cluster 1 and the remaining two clusters.

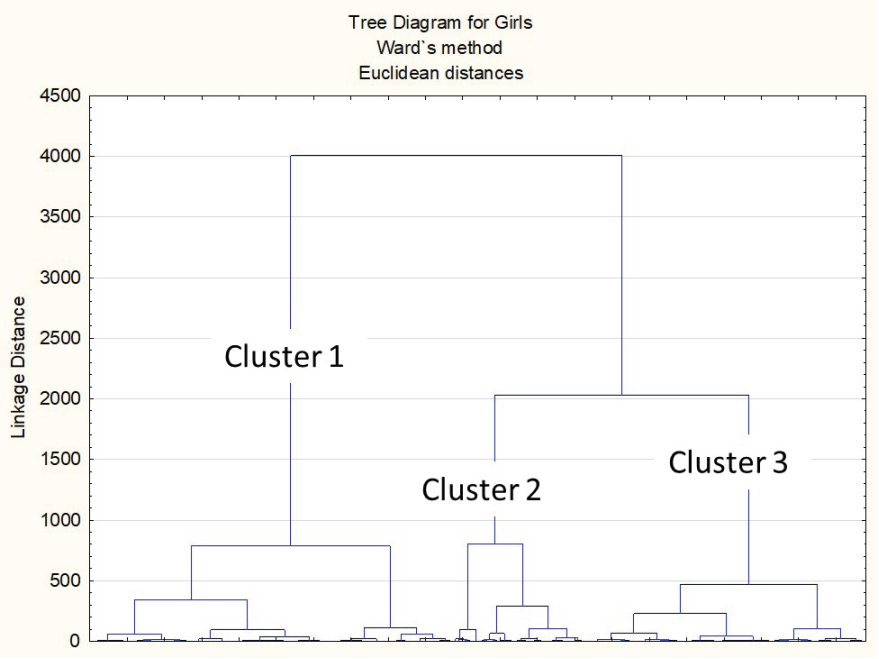

Figure 2. Multivariate clustering of girls based on scholastic variables.

DISCRA did not reveal significant differences between Clusters for boys (Table 4). However, DISCRA revealed multivariate differences amng Clusters formed on the basis of scholastic achievement in girls (Table 5). In brief, Root 1 reached statistical significance, evidencing the highest PL and HL in girls grouped in Cluster 1 (note that Cluster 1 consisted of girls who achieved the best scholastic achievement; please see previously).

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Table 4. Discriminant canonical analysis for boys – multivariate differences between clusters based on scholastic variables in health literacy (HL) and physical literacy (PL)

	Root 1
PL	0.65
HL	-0.55
Wilks Lambda	0.96
Canonical R	0.18
p-level	0.34
Centroid: Cluster 1	0.18
Centroid: Cluster 2	-0.16

Table 5. Discriminant canonical analysis for girls – multivariate differences among clusters based on scholastic variables in health literacy (HL) and physical literacy (PL)

	Root 1	Root 2
PL	0.71	-1.00
HL	0.93	-0.36
Wilks Lambda	0.94	0.98
Canonical R	0.20	0.10
p-level	0.03	0.13
Centroid: Cluster 1	0.26	0.01
Centroid: Cluster 2	-0.16	-0.10
Centroid: Cluster 3	-0.19	0.20

Discussion

The gender-stratified approach we applied herein was evidently appropriate. In brief, while scholastic factors were not significantly associated with PL and HL in boys, our analyses showed a significant association between these variables in girls. Although the correlation was generally low, the relative consistency of the associations (PL and HL were almost identically associated with scholastic factors in girls) deserves specific attention regarding study aims.

We initially hypothesized that scholastic factors would be positively associated with both observed types of literacy (PL and HL). Indeed, it was logical to expect that better scholastic achievement, despite the type of variable observed, would be an indicator of better HL and PL. To the best of our knowledge, this is one of the first investigations which directly observed mentioned relationships in southeastern Europe and almost certainly the first one on the territory of former Yugoslavia. However, previous studies in other regions support our findings (Nelson & Gordon-Larsen, 2006; Schmitz et al., 2002; Whatnall et al., 2019).

The positive association between scholastic achievement observed throughout school-grades (i.e., grade point average) with HL and PL is relatively straightforward. Namely, both PL and HL can be taught (de Albuquerque et al., 2022). Therefore, it is logical that students with better grades will have better knowledge incorporated in PL and HL questionnaires, either simply by better "general knowledge" obtained from various school subjects (i.e., biology, chemistry, physical education), or by specific learning about the topics evaluated in PL and HL questionnaires.

When it comes to a positive association between other scholastic variables we have observed (e.g., absences) with PL and HL, the explanation is relatively logical, although it doesn't seem so at first sight. Namely, scholastic factors are known to be intercorrelated. It means that students with better grades are less likely to be (frequently) absent from school. Although we didn't specifically discuss it in our study, previous research done in the territory of the former Yugoslavia consistently confirmed it (Idrizovic et al., 2015; Zubak et al., 2018). While the causality of the association between scholastic variables is not within this research's scope of this research, it will not be discussed in detail.

The findings that scholastic factors were correlated with PL and HL solely in girls is probably a result of several "mechanisms". First, the most logical explanation is related to the number of subjects and the fact that we observed three times more girls than boys. Simply statistically, the number of subjects increases the degrees of freedom and the probability and statistical significance (Huck, 2008). However, it seems that this was not the main mechanism of gender-specific associations since correlation coefficients in girls were somewhat higher than in boys (please see Results for details). Therefore, it is more likely the fact that we observed one specific educational program (vocational school, including future health professionals) resulted in (more) systematic development of all types of knowledge in girls than in boys. To support such a notion, we must mention that girls had better grades and better results in HL and PL than boys. This could imply that girls

with better grades are more aware of the importance of health and have better health information.

Despite the previous discussion, the fact that studied correlations between scholastic variables with PL did not reach statistical significance among boys deserves certain attention. Once again, the most probable reason is the specificity of the sample of participants involved in our research. Precisely, students attending vocational high schools, such as the one studied here, are known to have worse health habits (e.g., increased sedentary time and lower physical activity levels) than academic high school students (Štefan et al., 2020).

Furthermore, as authors were directly involved in working with similar students (the study's first author was a teacher, and the second author was a school principal), we can state that only a few students (particularly boys) were actively involved in sports. It is important since the sport is one of the main agents that promote physical activity levels among boys, and directly and indirectly influences health habits by fostering the development of PL (Sunda et al., 2022). Additionally, sport is the primary source of physical activity which is one of the paramount health promoting behaviours, and as such is also linked to HL (Buja et al., 2020). Thus, as boys included in our study didn't practice sports to a greater extent, it is somewhat logical that the association between scholastic variables and literacies (HL and PL) did not reach statistical significance. This result deserves special attention from the perspective of a school and especially school pedagogues.

Namely, regarding adolescents not participating in sports activities which is the primary source of developing both HL and PL, those literacies should be embedded in the school curriculum. Indeed, school-based health promotion practices and embedding HL curricula are key agents for flourishing HL in young people (Schulenkorf et al., 2021). Schools are identified as venues for promoting health and health education as schools can reach all school-aged children without regarding their economic or social background (St Leger, 2001).

Conclusion

Although our results showed relatively weak associations between scholastic achievement with HL and PL, it seems that the problem of the influence of education on HL and PL deserves attention. Namely, while correlations were significant for girls, lack of association in boys could direct future studies in evidencing correlations between specific types of knowledge with HL and PL.

The main study limitation comes from the fact that we studied one specific sample of participants, students from a vocational school in one region of Croatia. Therefore, specific biases could exist and consequently could influence the results. Therefore, adolescents from other regions and schools should be observed in future studies.

It is globally accepted that both HL and PL should be developed, especially in adolescence. Consequently, it is necessary to evaluate its correlates and implement and evaluate programs to improve PL and HL as determinants of health. Therefore, school authorities should be informed of results obtained herein, especially on the evident lack of associations between scholastic achievement, PL, and HL in high-school boys.

References

Buja, A., Rabensteiner, A., Sperotto, M., Grotto, G., Bertoncello, C., Cocchio, S., Baldovin, T., Contu, P., Lorini, C., & Baldo, V. (2020). Health Literacy and Physical Activity: A Systematic Review. *Journal of Physical Activity and Health*, *17*(12), 1259-1274. https://doi.org/10.1123/jpah.2020-0161

Cairney, J., Dudley, D., Kwan, M., Bulten, R., & Kriellaars, D. (2019). Physical Literacy, Physical Activity and Health: Toward an Evidence-Informed Conceptual Model. *Sports Medicine*, *49*(3), 371-383. https://doi.org/10.1007/s40279-019-01063-3

Caldwell, H. A. T., Di Cristofaro, N. A., Cairney, J., Bray, S. R., MacDonald, M. J., & Timmons, B. W. (2020). Physical Literacy, Physical Activity, and Health Indicators in School-Age Children. *International Journal of Environmental Research and Public Health*, *17*(15). https://doi.org/10.3390/ijerph17155367

Cornish, K., Fox, G., Fyfe, T., Koopmans, E., Pousette, A., & Pelletier, C. A. (2020). Understanding physical literacy in the context of health: a rapid scoping review. *BMC Public Health*, *20*(1), 1569. https://doi.org/10.1186/s12889-020-09583-8

de Albuquerque, J. V., Chen, Y., Moir, F., & Henning, M. (2022). School-based interventions to improve health literacy of senior high school students: a scoping review protocol. *JBI Evid enced Synthesis*, *20*(4), 1165-1173. https://doi.org/10.11124/jbies-21-00333

de Bruin, W. B. (2012). Judgment and decision making in adolescents. In *Judgment and decision making as a skill: Learning, development and evolution.* (pp. 85-111). Cambridge University Press.

Geets Kesic, M., Penjak, A., & Sekulic, D. (2022). Reliability and validity of the croatian version of the european health literacy survey questionnaire. *Montenegrin Journal of sports Science and Medicine, Abstracts from the 19th Annual Scientific Conference of Montenegrin Sports Academy "Sport, Physical Activity and Health: Contemporary perspectives": Dubrovnik, Croatia. 7-10 April 2022.*, *11*, 1.

Gilic, B., Malovic, P., Sunda, M., Maras, N., & Zenic, N. (2022). Adolescents with Higher Cognitive and Affective Domains of Physical Literacy Possess Better Physical Fitness: The Importance of Developing the Concept of Physical Literacy in High Schools. *Children (Basel)*, *9*(6). https://doi.org/10.3390/children9060796

Guo, S., Yu, X., Davis, E., Armstrong, R., & Naccarella, L. (2021). Health Literacy: An Interactive Outcome Among Secondary Students in Beijing. *Health Literacy Research and Practice*, *5*(1), e1-e14. https://doi.org/10.3928/24748307-20201117-01

Huck, S. W. (2008). *Reading Statistics and Research*. Pearson/Allyn & Bacon. https://books.google.si/books?id=y_pLAQAAIAAJ

Idrizovic, K., Zenic, N., Tahirajl, E., Rausavljevic, N., & Sekulic, D. (2015). Cigarette Smoking among 17-18 Year Old Adolescents - Prevalence and Association with Sociodemographic, Familial, Sport, and Scholastic. Factors. *Medicina Pracy*, *66*(2), 153-163. https://doi.org/10.13075/mp.5893.00104

Jefferies, P., Bremer, E., Kozera, T., Cairney, J., & Kriellaars, D. (2021). Psychometric properties and construct validity of PLAYself: A self-reported measure of physical literacy for children and youth. *Applied Physiology, Nutrition, and Metabolism*, *46*(6), 579-588.

Kesic, M. G., Savicevic, A. J., Peric, M., Gilic, B., & Zenic, N.

 DOI 10.26773/mjssm.230301

(2022). Specificity of the Associations between Indices of Cardiovascular Health with Health Literacy and Physical Literacy; A Cross-Sectional Study in Older Adolescents. *Medicina (Kaunas)*, *58*(10). https://doi.org/10.3390/medicina58101316

Klinker, C. D., Aaby, A., Ringgaard, L. W., Hjort, A. V., Hawkins, M., & Maindal, H. T. (2020). Health Literacy is Associated with Health Behaviors in Students from Vocational Education and Training Schools: A Danish Population-Based Survey. *International Journal of Environmental Research and Public Health*, *17*(2). https://doi.org/10.3390/ijerph17020671

Martins, J., Onofre, M., Mota, J., Murphy, C., Repond, R.-M., Vost, H., Cremosini, B., Svrdlim, A., Markovic, M., & Dudley, D. (2021). International approaches to the definition, philosophical tenets, and core elements of physical literacy: A scoping review. *PROSPECTS*, *50*(1-2), 13-30. https://doi.org/10.1007/s11125-020-09466-1

Nelson, M. C., & Gordon-Larsen, P. (2006). Physical activity and sedentary behavior patterns are associated with selected adolescent health risk behaviors. *Pediatrics*, *117*(4), 1281-1290. https://doi.org/10.1542/peds.2005-1692

Olujić, I., & Maras, N. (2021). Razlike u školskom uspjehu učenika osnovne škole s obzirom na pohađanje programa produženog boravka. *Nova prisutnost: časopis za intelektualna i duhovna pitanja*, *19*(2), 345-356.

Qiao, H., Wang, X., Qin, Z., Wang, N., Zhang, N., & Xu, F. (2021). The relationship between health literacy and health-related quality of life among school-aged children in regional China. *Health Quality and Life Outcomes*, *19*(1), 262. https://doi.org/10.1186/s12955-021-01895-6

Schmitz, K. H., Lytle, L. A., Phillips, G. A., Murray, D. M., Birnbaum, A. S., & Kubik, M. Y. (2002). Psychosocial correlates of physical activity and sedentary leisure habits in young adolescents: the Teens Eating for Energy and Nutrition at School study. *Preventive Medicine*, *34*(2), 266-278. https://doi.org/10.1006/pmed.2001.0982

Schulenkorf, T., Krah, V., Dadaczynski, K., & Okan, O. (2021). Addressing Health Literacy in Schools in Germany: Concept Analysis of the Mandatory Digital and Media Literacy School Curriculum. *Frontiers in Public Health*, *9*, 687389. https://doi.org/10.3389/fpubh.2021.687389

Sekulic, D., Ostojic, D., Decelis, A., Castro-Piñero, J., Jezdimirovic, T., Drid, P., Ostojic, L., & Gilic, B. (2021). The Impact of Scholastic Factors on Physical Activity Levels during the COVID-19 Lockdown: A Prospective Study on Adolescents from Bosnia and Herzegovina. *Children (Basel)*, *8*(10). https://doi.org/10.3390/children8100877

Sørensen, K., Van den Broucke, S., Fullam, J., Doyle, G., Pelikan, J., Slonska, Z., & Brand, H. (2012). Health literacy and public health: a systematic review and integration of definitions and models. *BMC Public Health*, *12*, 80. https://doi.org/10.1186/1471-2458-12-80

St Leger, L. (2001). Schools, health literacy and public health: possibilities and challenges. *Health Promotion Int*, *16*(2), 197-205. https://doi.org/10.1093/heapro/16.2.197

Sunda, M., Gilic, B., Sekulic, D., Matic, R., Drid, P., Alexe, D. I., Cucui, G. G., & Lupu, G. S. (2022). Out-of-School Sports Participation Is Positively Associated with Physical Literacy, but What about Physical Education? A Cross-Sectional Gender-Stratified Analysis during the COVID-19 Pandemic among High-School Adolescents. *Children (Basel)*, *9*(5). https://doi.org/10.3390/children9050753

Štefan, L., Sorić, M., Devrnja, A., Petrić, V., & Mišigoj-Duraković, M. (2020). One-year changes in physical activity and sedentary behavior among adolescents: the Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS). *International journal of adolescent medicine and health*, *32*(5).

Vrkić Dimić, J., & Vidov, S. (2019). E-dnevnik u školskoj praksi–mišljenja i iskustva nastavnika srednjih škola. *Acta Iadertina*, *16*(1), 0-0.

Whatnall, M. C., Patterson, A. J., Burrows, T. L., & Hutchesson, M. J. (2019). Higher diet quality in university students is associated with higher academic achievement: a cross-sectional study. *Journal of Human Nutrition and Diet*, *32*(3), 321-328. https://doi.org/10.1111/jhn.12632

Zubak, Z., Zenic, N., Ostojic, L., Zubak, I., & Pojskic, H. (2018). A Prospective Study on the Influence of Scholastic Factors on the Prevalence and Initiation of Illicit Drug Misuse in Adolescence. *International Journal of Environmental Research and Public Health*, *15*(5). https://doi.org/10.3390/ijerph15050874

Žiljak, T., & Baketa, N. (2019). Education Policy in Croatia. In Z. Petak & K. Kotarski (Eds.), *Policy-Making at the European Periphery: The Case of Croatia* (pp. 265-283). Springer International Publishing. https://doi.org/10.1007/978-3-319-73582-5_14

ORIGINAL SCIENTIFIC PAPER

Age and Sex Differences in Shot Distribution and Accuracy in International 3x3 Basketball Tournaments

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Abstract

This study aimed to (a) investigate shot distribution and accuracy in international 3x3 basketball tournaments by classifying shot attempts into three types (two-point, mid-range, and paint shots) and (b) compare them among age and sex categories (senior men, senior women, under-18 men, and under-18 women). Ninety-one games from the FIBA 3x3 World Cup 2019 and the FIBA 3x3 Under-18 World Cup 2019 were analyzed using a notational analysis method. The Mann-Whitney U test with Benjamini-Hochberg correction was used to compare shot attempts and success rates between categories. There were no sex differences in the success rates of two-point and mid-range shots ($p<0.05$). However, male teams attempted more two-point shots [senior men vs. senior women, $p<0.01$, $r = 0.40$ (medium effect size); under-18 men vs. under-18 women, $p<0.01$, $r = 0.21$ (small effect size)] and fewer mid-range shots [senior men vs. senior women, $p<0.01$, $r = 0.36$ (medium effect size); under-18 men vs. under-18 women, $p<0.01$, $r = 0.34$ (medium effect size)] than female teams. Differences between senior and under-18 teams in shot distribution were only observed in men's tournaments: senior teams attempted more two-point shots [$p<0.01$, $r = 0.25$ (small effect size)] and fewer paint shots [$p = 0.04$, $r = 0.19$ (small effect size)] than under-18 teams. Male teams were superior to female teams in terms of scoring efficiency. However, the career transition from youth to senior tournaments may be smoother for girls than boys because of the similarity in the shot selection between under-18 and senior games.

Keywords: *Basketball, 3x3, notational analysis, game-related statistics, shooting*

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Introduction

Basketball is a ball game in which two teams of five players each try to score points by shooting a ball into a basket placed 3.05 m above the floor. Making a successful shot closer to the basket is easier, but the opponent's defense can be more challenging. A successful long-range shot, especially from outside the three-point line, results in 1.5 times more points, but it requires strength (Tang & Shung, 2005) and power (Pojskić et al., 2014) as well as skills to make a long-range shot. Given the nature of the game, information on where the shots were

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attempted from and how accurate they were are essential in evaluating technical and tactical performances. A previous study has reported that shot distribution and accuracy differ among age and sex categories in elite-level games (Madarame, 2021). This type of information could provide a basis for developing optimal tactics and training programs based on the age and sex of players.

In the late 2000s, the International Basketball Federation (FIBA) began formalizing another form of basketball that uses only one basket and is played by two teams of three players (Snoj, 2021a). The new discipline was named "3x3" and became one of the Olympic sports in the Tokyo 2020 Olympic Games. There are several differences between 3x3 and 5on5 basketball games besides the number of players on the court. One of the significant differences is the points awarded for a successful shot. In 5-on-5 basketball played under the FIBA rules, two points are awarded for a shot attempted from inside the 6.75 m line and three points for a shot attempted from outside the 6.75 m line. In 3x3 basketball, however, one and two points are awarded for each situation, making long-range shots more valuable. Another difference is the time allowed from gaining possession to attempt a shot: 5-on-5, 24 s; 3x3, 12 s. The shortened shot clock in 3x3 basketball requires the offensive team to complete the offense in less time. Because of these differences, shot distribution and accuracy in 3x3 basketball may differ from those in 5-on-5 basketball.

Research in 3x3 basketball is still in its infancy, but the number of studies is growing (Conte et al., 2019; Erčulj et al., 2019; Ferioli et al., 2022; Figueira et al., 2022; Koh et al., 2012; McGown et al., 2020; Montgomery & Maloney, 2018; Ortega et al., 2021), and several of them (Erčulj et al., 2019; Ferioli et al., 2022; McGown et al., 2020) have compared shot-related statistics between men's and women's 3x3 basketball games. Erčulj et al. (2019) investigated shot distribution and accuracy in under-18 teams competing in the 2018 Youth Olympic Games. They reported that although male teams attempted more two-point shots and fewer one-point shots than female teams, male teams showed lower two-point success rates and higher one-point success rates than female teams. The findings that male teams attempted more two-point shots and fewer one-point shots than female teams are consistent with a study by Ferioli et al. (2022) that analyzed the FIBA 3x3 Europe Cup 2019, a senior tournament. While these pioneering studies should be highly valued, they have a limitation in analyzing shot distribution in basketball games: they only classified field goals into one- and two-point shots. It is well known that three-point shot attempts in the National Basketball Association (NBA) have dramatically increased since the mid-2010s. Instead of an increase in three-point shots, there has been a decrease in mid-range shots, relatively long-ranged shots within a two-point shot area (Goldsberry, 2019; Shea, 2014). This phenomenon indicates that simply classifying shot locations into two, inside and outside the three-point line, limits the analysis.

McGown et al. (2020) not only classified field goal attempts into one- and two-point shots but also investigated the number of layup shot attempts and reported no sex differences in any of the shot attempts. However, since they analyzed a domestic tournament in Australia, technical and tactical performances may differ from those in international tournaments. In addition, it should be noted that the study normalized the number of shot attempts per minute of game time. Since the number of offenses is affected by the game's pace, it is recommended to use per possession values to compare game-related statistics in basketball research (Sampaio et al., 2013; Snoj, 2021b). This recommendation would be supported by a study by Ferioli et al. (2020), which reported sex differences in the number of possessions in 3x3 basketball.

As far as the author is aware, no study has investigated shot distribution in international 3x3 tournaments for youth by classifying shot attempts into three or more shot locations. In addition, no independent study has comprehensively investigated age and sex differences in shot distribution and accuracy in international 3x3 basketball tournaments. Therefore, the aims of this study were to (a) investigate shot distribution and accuracy in international 3x3 basketball tournaments by classifying shot attempts into three types (two-point, mid-range, and paint shots) and (b) compare them among age and sex categories (senior men, senior women, under-18 men, and under-18 women).

Methods

Data collection

Data were collected from the FIBA 3x3 World Cup 2019 and the FIBA 3x3 Under-18 World Cup 2019 using a notational analysis method. The total number of games was 192 (48 in each category); however, one game in the under-18 women's tournament was excluded from the analysis because the official game footage was only available from 3:02 remaining in the game. An experienced researcher coded each play chronologically in a Microsoft Excel spreadsheet while watching the publicly accessible game footage posted on FIBA 3x3's official YouTube channel (https://www.youtube.com/fiba3x3). Field goal attempts were classified into three types depending on where they were attempted (Table 1).

Table 1. Definitions used to classify field goal attempts

Shot type	Definition
Two-point shot	A shot attempted from outside the two-point line
Mid-range shot	A shot attempted from inside the two-point line but not a paint shot
Paint shot	A shot where the shooter's last step foot or landing foot is in the paint area

If the play could not be identified from the footage, it was classified as "unclear" and excluded from the analysis. There were 14 cases classified as "unclear," but since the number was small compared to the 11,117 shots recorded, it was determined that it would not affect the result of the study. In official basketball records, if a player is fouled in the act of shooting, the shot is not recorded as a field goal attempt unless the shot goes in (International Basketball Federation, 2018). However, if more shots from a particular location are fouled, the number of shots from that location will be underestimated. Since this study aimed to determine the number of actual shot attempts from each location, the number of unsuccessful shots due to fouls was added to the field goal attempts. However, unsuccessful shots due to fouls were excluded when calculating the success rate of each location.

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Data reliability

Intra-rater reliability was tested after at least one month from the initial measurement. Eight games (two games from each category) were randomly selected using the R function "sample," and the plays were re-coded. Cohen's kappa was calculated using the R function "kappa2" in the "irr" package and was 0.985.

Data processing

Data were analyzed separately for each game's winning and losing teams. The number of shot attempts in each game was normalized to 100 possessions. Normalizing the number of shot attempts by the number of possessions is widely used in basketball research to eliminate the influence of game rhythm (Giovanini et al., 2021; Raval & Pagaduan, 2021). In addition, the duration of a 3x3 game varies from game to game because the game ends when either team scores 21 points; hence normalization is essential in 3x3 games. Instead of using an estimation formula to calculate the number of possessions, actual measurements based on the records of this study were used. An offensive rebound was considered a continuation of possession (Snoj, 2021b).

Statistical analyses

Statistical analyses were conducted using the software R version 4.0.5 for Windows (R Core Team, 2021). Beeswarm boxplots were created to visualize the data using the R function "geom_boxplot" in the "ggplot2" package and the R function "geom_quasirandom" in the "ggbeeswarm" package. The Mann-Whitney U test (the R function "wilcox_test" in the "coin" package) was used to compare shot attempts and success rates between categories. Once the p-value for each pairwise comparison was obtained, multiplicity was adjusted using the Benjamini-Hochberg method (Benjamini & Hochberg, 1995) with the R function "p.adjust" to maintain a significance level of $p<0.05$. The r-value was calculated as an effect size for the Mann-Whitney U test ($r = 0.10$-0.29, small effect size; $r = 0.30$-0.49, medium effect size; $r \geq 0.50$, large effect size) (Cohen, 1988).

Results

Comparisons of the number of shot attempts per 100 possessions

The number of two-point, mid-range, and paint shot attempts per 100 possessions are presented as beeswarm boxplots (Figure 1), and the results of pairwise comparisons are shown in Table 2.

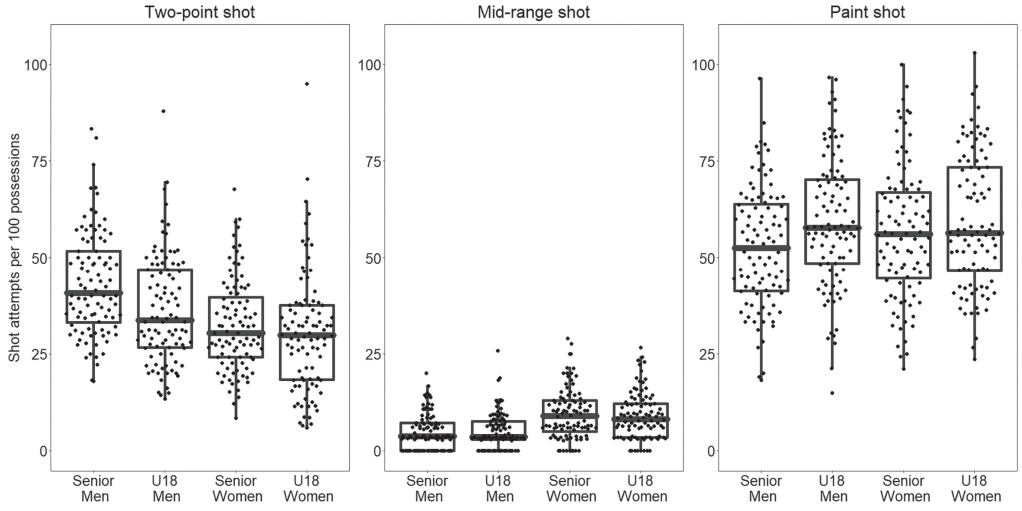

Figure 1. Beeswarm boxplots of two-point, mid-range, and paint shot attempts per 100 possessions. The dots represent the value of each team for each game.

Table 2. Results of pairwise comparisons of shot attempts per 100 possessions between categories

	Two-point shot		Mid-range shot		Paint shot	
	p	r	p	r	p	r
Senior men vs. U18 men	<0.01*	0.25†	0.86	0.01	0.04*	0.19†
Senior men vs. Senior women	<0.01*	0.40‡	<0.01*	0.36‡	0.30	0.10†
Senior men vs. U18 women	<0.01*	0.44‡	<0.01*	0.34‡	0.04*	0.18†
U18 men vs. Senior women	0.06	0.14†	<0.01*	0.36‡	0.34	0.09
U18 men vs. U18 women	<0.01*	0.21†	<0.01*	0.34‡	0.83	0.02
Senior women vs. U18 women	0.21	0.09	0.72	0.04	0.40	0.07

Note. *p<0.05, †small effect size (r = 0.10-0.29), ‡medium effect size (r = 0.30-0.49).

Male teams attempted a significantly greater number of two-point shots than female teams in both senior [$p<0.01$, $r = 0.40$ (medium effect size)] and under-18 tournaments [$p<0.01$, $r = 0.21$ (small effect size)]. Differences between senior and under-18 teams in two-point shot attempts were only observed in men's tournaments: senior teams attempted more two-point shots than under-18 teams [$p<0.01$, $r = 0.25$ (small effect size)]. In contrast to two-point shot attempts, female teams attempted a significantly greater number of mid-range shots than male teams in both senior [$p<0.01$, $r = 0.36$ (medium effect size)] and under-18 tournaments [$p<0.01$, $r = 0.34$ (medium effect size)]. Differences between

senior and under-18 teams were not observed in mid-range shot attempts (p>0.05). There were no sex differences within the same age categories in paint shot attempts (p>0.05). Similar to the results of two-point shot attempts, differences between senior and under-18 teams in paint shot attempts were only observed in men's tournaments; however, in contrast to two-point shot attempts, under-18 teams attempted more paint shots than senior teams [p = 0.04, r = 0.19 (small effect size)].

Comparisons of success rates

Figure 2 shows the beeswarm boxplots of success rates of two-point, mid-range, and paint shots; Table 3 shows the results of pairwise comparisons.

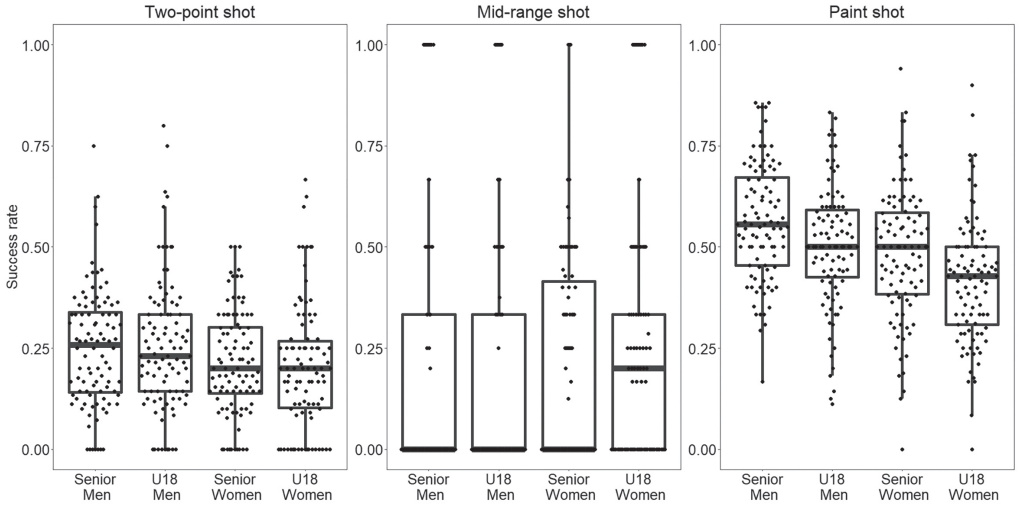

Figure 2. Beeswarm boxplots of the success rates of two-point, mid-range, and paint shot attempts. The dots represent the value of each team for each game.

Table 3. Results of pairwise comparisons of success rates between categories

	Two-point shot		Mid-range shot		Paint shot	
	p	r	p	r	p	r
Senior men vs. U18 men	0.94	0.01	0.94	0.01	<0.01*	0.19†
Senior men vs. Senior women	0.22	0.11†	0.45	0.08	<0.01*	0.24†
Senior men vs. U18 women	0.09	0.16†	0.14	0.16†	<0.01*	0.46‡
U18 men vs. Senior women	0.22	0.11†	0.45	0.09	0.45	0.06
U18 men vs. U18 women	0.09	0.16†	0.14	0.16†	<0.01*	0.31‡
Senior women vs. U18 women	0.56	0.05	0.47	0.06	<0.01*	0.24†

Note. *p<0.05, †small effect size (r = 0.10-0.29), ‡medium effect size (r = 0.30-0.49).

There were no age or sex differences in the success rate except for paint shots. Male teams showed higher paint success rates than female teams [senior men vs. senior women, p<0.01, r = 0.24 (small effect size); under-18 men vs. under-18 women, p<0.01, r = 0.31 (medium effect size)]; senior teams showed higher paint success rates than under-18 teams [senior men vs. under-18 men, p<0.01, r = 0.19 (small effect size); senior women vs. under-18 women, p<0.01, r = 0.24 (small effect size)].

Discussion

This study aimed to (a) investigate shot distribution and accuracy in international 3x3 basketball tournaments by classifying shot attempts into three types (two-point, mid-range, and paint shots) and (b) compare them among age and sex categories. There were no sex differences in the success rates of two-point and mid-range shots. However, male teams attempted more two-point shots and fewer mid-range shots than female teams. Differences between senior and under-18 teams in shot distribution were only observed in men's tournaments: senior teams attempted more two-point shots and fewer paint shots than under-18 teams.

Between-sex comparisons showed that male teams attempted more two-point shots than female teams. Previous studies have reported that male teams attempted more two-point shots than female teams in the FIBA 3x3 Europe Cup 2019 (Ferioli et al., 2022) and the 2018 Youth Olympic Games (Erčulj et al., 2019). Since similar results were obtained in several different tournaments, it can be said with considerable certainty that male teams attempted more two-point shots than female teams in recent international 3x3 tournaments. It should be noted that there is a study reporting no sex differences in shot-related statistics (McGown et al., 2020); however, the study analyzed a domestic tournament in Australia. The difference in competition levels between international and domestic tournaments may be a reason for the discrepancy.

The fact that male teams attempted more two-point shots than female teams suggests that male teams attempted fewer non-two-point shots than female teams. Previous studies have reported that male teams attempted fewer one-point shots than female teams in senior (Ferioli et al., 2022) and under-18 (Erčulj et al., 2019) international 3x3 tournaments. Unlike

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these studies, this study analyzed one-point shots separately for mid-range and paint shots. The results showed that while there were no differences in paint shot attempts between male and female teams, male teams attempted fewer mid-range shots than female teams. In many cases, male teams did not attempt a single mid-range shot in a game (senior teams, 27%; under-18 teams, 23%). In addition, some mid-range shots seemed to be attempted without intention: accidentally stepping on the two-point line or having no choice but to attempt a shot because the shot clock was about to expire. There were also cases for female teams with no mid-range shot attempts in a game, but the proportion was smaller (senior teams, 9%; under-18 teams, 8%) than male teams. As mid-range shots have come to be considered inefficient, avoiding the attempt has become prevalent in recent 5-on-5 basketball games (Goldsberry, 2019; Shea, 2014). The results of this study suggest that the trend is also seen in both men's and women's 3x3 basketball games but is especially notable in men's games.

Differences between senior and under-18 teams in shot distribution were only observed in men's tournaments: senior teams attempted more two-point shots and fewer paint shots than under-18 teams. From the scoring efficiency point of view, it is preferable to reduce mid-range shot attempts rather than paint shot attempts. However, since men's both age categories rarely attempt mid-range shots, it would not have been capable of further reducing mid-range shot attempts. A previous study on international 5-on-5 basketball has also reported that differences in shot distribution between senior and under-18 games were only observed in men's tournaments (Madarame, 2021). Therefore, women's games likely have more similarities between senior and under-18 tournaments than men's in both disciplines of basketball. It should be noted, however, that the effect size of the difference between the senior and the under-18 men's tournaments was small. Since effect sizes of sex differences observed in two-point and mid-range shot attempts were medium (except for two-point shot attempts in the under-18 tournaments), differences between age categories are likely to be smaller than between sex categories.

Age or sex differences in the success rate were only observed in paint shots. The success rate of paint shots was higher in the men's tournament than in the women's tournament and higher in the senior tournament than in the under-18 tournament. Unfortunately, these results cannot be directly compared to previous studies because success rates of paint shots in 3x3 basketball have not been reported. However, the fact that male teams showed higher success rates than female teams was consistent with a previous report on one-point success rates in under-18 games (Erčulj et al., 2019). In addition, a previous study on international 5-on-5 basketball has also reported that the success rate of two-point shots (one-point shots in 3x3 basketball) was higher in the men's tournament than in the women's tournament and higher in the senior tournament than in the under-18 tournament (Madarame, 2021).

Two-point shots require greater strength (Tang & Shung, 2005) and power (Pojskić et al., 2014) than one-point shots because of a greater distance from the basket. Therefore, it is reasonable to assume that male teams have higher success rates than female teams, and senior teams have higher success rates than under-18 teams. These assumptions are partially consistent with a previous study on international 5-on-5 basketball: the success rate of three-point shots (two-point shots in 3x3 basketball) was higher in the senior tournament than in the under-18 tournament for both sexes (Madarame, 2021). Sex differences in the success rate were not observed in the 5-on-5 study probably because differences in muscle strength and power were compensated by differences in size and weight of the balls: the ball used in women's 5-on-5 basketball is smaller and lighter than the ball used in men's 5-on-5 basketball. Unlike 5-on-5 basketball, 3x3 basketball uses balls of the same size and weight for both sexes, which may give male players an advantage over female players. However, the results of this study showed neither age nor sex differences in the success rate of two-point shots. Moreover, and surprisingly, a previous study on 3x3 basketball has reported that the success rate of two-point shots was higher in the women's tournament than in the men's tournament (Erčulj et al., 2019). Since 3x3 basketball is usually played on outdoor courts, environmental factors such as wind and light might have been a greater source of variability in the success rate of long-range shots.

A limitation in interpreting this study is that the senior and the under-18 tournaments were held in different locations. Since the games were played on outdoor courts, we cannot rule out the possibility that environmental differences may have influenced the results, especially the age comparison of success rates. While this study analyzed only one tournament per category, future studies analyzing multiple tournaments could overcome this limitation.

In conclusion, it was suggested that male teams were superior to female teams in terms of scoring efficiency. However, the career transition from youth to senior tournaments may be smoother for girls than boys because of the similarity in the shot selection between under-18 and senior games.

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References

Benjamini, Y., & Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society: Series B (Methodological)*, *57*(1), 289-300. https://doi.org/https://doi.org/10.1111/j.2517-6161.1995.tb02031.x

Cohen, J. (1988). The Effect Size: r. In *Statistical Power Analysis for the Behavioral Sciences* (pp. 77-82). Routledge.

Conte, D., Straigis, E., Clemente, F. M., Gómez, M.-Á., & Tessitore, A. (2019). Performance profile and game-related statistics of FIBA 3x3 Basketball World Cup 2017. *Biology of Sport*, *36*(2), 149-154. https://doi.org/10.5114/biolsport.2019.83007

Erčulj, F., Vidic, M., & Leskošek, B. (2019). Shooting efficiency and structure of shooting in 3×3 basketball compared to 5v5 basketball. *International Journal of Sports Science & Coaching*, *15*(1), 91-98. https://doi.org/10.1177/1747954119887722

Ferioli, D., Conte, D., Scanlan, A. T., & Vaquera, A. (2022). Technical-Tactical Demands of 3 × 3 International Basketball Games According to Game Outcome, Player Sex, and Competition Phase. *The Journal of Strength & Conditioning Research*. https://doi.org/10.1519/jsc.0000000000004282

Figueira, B., Mateus, N., Esteves, P., Dadelienė, R., & Paulauskas, R. (2022). Physiological Responses and Technical-Tactical Performance of Youth Basketball Players: A Brief

Comparison between 3x3 and 5x5 Basketball. *Journal of Sports Science & Medicine*, *21*(2), 332-340. https://doi.org/10.52082/jssm.2022.332

Giovanini, B., Conte, D., Ferreira-Junior, A., & Nascimento, V. B. (2021). Assessing the key game-related statistics in Brazilian professional basketball according to season phase and final score difference. *International Journal of Performance Analysis in Sport*, *21*(2), 295-305. https://doi.org/10.1080/24748668.2021.1881358

Goldsberry, K. (2019). Mapping the geography of the NBA. In *Sprawlball: A Visual Tour of the New Era of the NBA* (pp. 2-34). Houghton Mifflin Harcourt.

International Basketball Federation. (2018). *FIBA statisticians' manual 2018*.

Koh, K. T., Wang, C. K. J., & Mallett, C. J. (2012). Discriminating Factors between Successful and Unsuccessful Elite Youth Olympic Female Basketball Teams. *International Journal of Performance Analysis in Sport*, *12*(1), 119-131. https://doi.org/10.1080/24748668.2012.11868588

Madarame, H. (2021). Shot Distribution and Accuracy in Senior and Youth International Basketball Games: Changes over the Decade of the 2010s. *International Journal of Environmental Research and Public Health*, *18*(18), 9900. https://doi.org/10.3390/ijerph18189900

McGown, R. B., Ball, N. B., Legg, J. S., & Mara, J. K. (2020). The perceptual, heart rate and technical-tactical characteristics of 3×3 basketball. *International Journal of Sports Science & Coaching*, *15*(5-6), 772-782. https://doi.org/10.1177/1747954120930916

Montgomery, P. G., & Maloney, B. D. (2018). 3x3 Basketball: Performance Characteristics and Changes During Elite Tournament Competition. *International Journal of Sports Physiology and Performance*, *13*, 1349-1356. https://doi.org/10.1123/ijspp.2018-0011

Ortega, E., Ortín, M., Giménez-Egido, J. M., & Gómez-Ruano, M. (2021). Technical-Tactical Performance Indicators During the Phases of Play in 3x3 Basketball. *Revista de Psicologia del Deporte (Journal of Sport Psychology)*, *30*(2), 187-194. http://mail.rpd-online.com/index.php/rpd/article/view/366

Pojskić, H., Šeparović, V., Muratović, M., & Užičanin, E. (2014). The relationship between physical fitness and shooting accuracy of professional basketball players. *Motriz: Revista de Educação Física*, *20*, 408-417. https://doi.org/10.1590/S1980-65742014000400007

R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

Raval, K. M. R., & Pagaduan, J. C. (2021). Factors that Differentiate Winning and Losing in Men's University Basketball. *Montenegrin Journal of Sports Science and Medicine*. https://doi.org/10.26773/mjssm.210902

Sampaio, J., Ibáñez, S. J., & Lorenzo, A. (2013). Basketball. In T. McGarry, P. O'Donoghue, & J. Sampaio (Eds.), *Routledge handbook of sports performance analysis* (pp. 357-366). Routledge.

Shea, S. (2014). The Fundamental Principle of Efficiency. In *Basketball Analytics: Spatial Tracking* (pp. 35-62). Createspace Independent Publishing Platform.

Snoj, L. (2021a). The Rise of 3x3 and Its History. In *3x3 Basketball: Everything You Need to Know* (pp. 34-72). Meyer & Meyer Sport (UK) Ltd.

Snoj, L. (2021b). Statistical Analysis and Advanced Data Analytics. In *3x3 Basketball: Everything You Need to Know* (pp. 140-173). Meyer & Meyer Sport (UK) Ltd.

Tang, W. T., & Shung, H. M. (2005). Relationship between isokinetic strength and shooting accuracy at different shooting ranges in Taiwanese elite high school basketball players. *Isokinetics and Exercise Science*, *13*, 169-174. https://doi.org/10.3233/IES-2005-0200

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ORIGINAL SCIENTIFIC PAPER

Influence of multicomponent exercise program or self-selected physical activity on physical, mental, and biochemical health indicators of older women

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Abstract

The aim of this study was to compare physical, mental, and biochemical health indicators of 48 older women (67 ± 1 year) who practiced multicomponent exercise program (ME, n = 25) and self-selected physical activity (PA, n = 23) for 6 months. It was an observational study, which aimed to relate a prospective intervention. Displacement speed, lower limb (LL) power, functional capacity, body composition, biochemical profile, physical activity levels (PAL), sedentary behavior (SB), quality of life (QoL), and mental illness risk (MIR) were evaluated. ME presented better values compared to the PA in the gait speed (p = 0.001, large ES), aerobic capacity (p = 0.0001, large ES), agility/dynamic balance (p = 0.0001, large ES), LL flexibility (p = 0.0003, large ES), UL flexibility (p = 0.04, large ES), upper limb (UL) strength (p = 0.07, moderate ES), Total cholesterol (p = 0.009, large ES), triglycerides (p = 0.003, large ES), creatinine (p = 0.007, large ES), glycated hemoglobin (p= 0.007, large ES), and lower mean glucose value (p = 0.008, large ES). ME was more efficient than PA to improve indicators of gait speed, and functional capacity, regulate glycated hemoglobin, blood glucose, and serum creatinine. Thys study also brings practical applications for coaches, which could adapt and use creativity to develop different types of systematized ME, aiming to enhance positive adaptations in the older people at multilevel outcomes.

Keywords: *Physical exercise, Psychophysiological factors, Aging, Quality of Life*

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Introduction

From the sixth decade of life onwards, organic functions begin to decline sharply, causing a reduction in the functional independence and quality of life of older people. Reductions in bone mass, strength, and muscle mass are evident during old age, and contribute to the evolution of sarcopenia, frailty, and disability, and in more advanced cases can lead to early mortality (Cruz-Jentoft et al., 2019). During aging, body fat content increases, leading to a higher incidence of obesity (Bosello & Vanzo, 2021). In turn, excess body fat worsens the QoL of older people, because it reduces mobility and increases joint discomfort and pain. In addition to functional deterioration, obesity contributes to the advancement of dyslipidemia, hypertension, diabetes, and various types of cancer (Ling & Rönn, 2019). Beyond the physical/physiological decline, aging is also associated with the worsening of cognitive function, then, being a stronger factor to increasethe rates of mental illness (García-Goñi et al., 2021). The emergence and aggravation of mental illnesses weaken older people, impairing their interpersonal relationships and thus worsening their autonomy, independence, and QoL. Furthermore, it is known that women have a greater degree of mental suffering during old age (Kiely et al., 2019).

Strong evidence supports that physical inactivity is one of the main risk factors for the aggravation and progression of diseases both in the physical and cognitive spheres of older people (Bueno-Antequera & Munguía-Izquierdo, 2020). Physical exercise is a systematic subcategory of physical activity that produces physiological stimuli in all systems of the body through the organized increase of the variables of the training program (e.g., volume, intensity, frequency, thus providing stimuli for the improvement of capacities, strength, cardiorespiratory endurance, flexibility, balance, and cognition) (Dasso, 2019). Therefore, it is an efficient intervention to delay or even reverse some changes in physical/functional and mental health during aging (Fossati et al., 2021). Moreover, concerning physical exercise, multicomponent physical exercise programs (ME) has shown positive effects on functional capacity (Caldas, 2018; Caldas et al., 2019; Chiu & Yu, 2022; Monteiro, Bartolomeu, et al., 2019; Monteiro et al., 2022; Monteiro, Silva, et al., 2019), biochemical (Caldas, 2018; Leitão et al., 2021a), and cognitive function of older people (Wang et al., 2020).

It is also known that increasing energy expenditure through non-systematized interventions also produces improvements in the health parameters of older people (Eckstrom et al., 2020; Izquierdo et al., 2021), however, in the literature review carried out by this research, were found only studies about the effects of periodized or non-periodized resistance training interventions on functional and health parameters of older people (Coelho-Júnior et al., 2019; Vargas-Molina et al., 2022; Williams et al., 2017), and until the moment, no studies were found verifying the effects of systematized (ME) vs. non-systematized interventions, seeking can be more effective in producing improvements in physical, biochemical, and mental health/QoL of the older people. Investigating this subject would help to understand if ME is superior to other types of interventions to improve the functional, biochemical, mental, and QoL of older people.

Thus, the objective of this study was to compare physical and mental health and biochemical health indicators of older women who practice and do not practice ME.

Methods

Study Design

It was an observational study, which aimed to relate a prospective intervention. The ME group "ME" (n = 24) consisted of older women participating in the "Saúde e Vida" extension project of the Department of Physical Education of the Universidade Federal de Viçosa (UFV) who performed a periodized protocol of ME for 6 months prior to the experiment. The ME took place every Monday, Wednesday, and Friday from 7:00 am to 7:50 am.

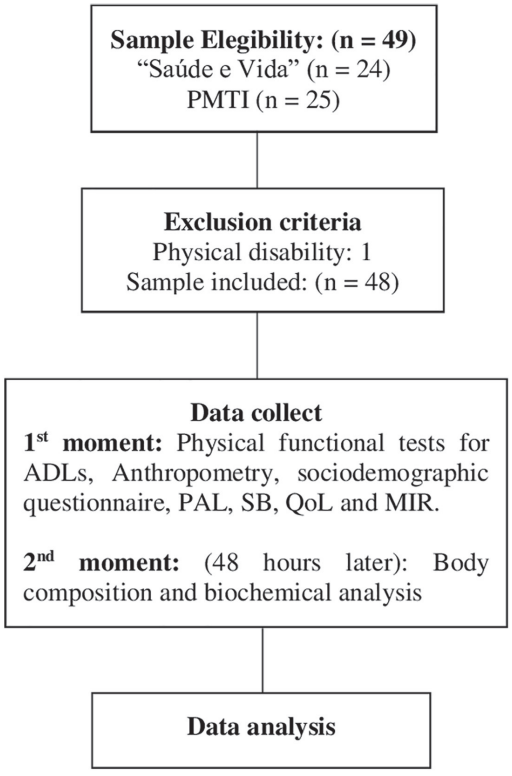

Figure 1. Flowchart of the study.

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All ME sessions included exercises that addressed the capabilities of muscle strength, cardiorespiratory endurance, flexibility, and balance/agility, performed using free weights, elastic bands, and the woman's body weight. The volume of exercises was controlled (number of sets x repetitions x execution time), as well as the complexity of the exercises performed. The training intensity was controlled by the OMNI-PSE perceived exertion scale (Borg, 2000).

The study had a control group called the self-selected physical activity group "PA" (n = 24), which consisted of older women selected from a project by the city of Viçosa MG, Municipal Project for the Third Age. PA had been participating for the last 6 months in low-intensity aerobic gymnastics, every Tuesday and Thursday from 09:00 to 09:50. The sessions consisted of typical local dance exercises, aerobic gymnastics, and group walks, with the exercise intensity self-selected by each woman. In addition, the sessions were not periodized throughout the year.

The collections were divided into 2 days. On the first day of evaluation, at the UFV sports gym, sociodemographic variables, PAL, SB, physical function in activities of daily living (ADLs), QoL, and MIR were collected (Benedetti et al., 2004; Chachamovich et al., 2008; de Jesus Mari & Williams, 1986; Rikli & Jones, 2013). On the second day of evaluation, 48 hours after the first, a densitometry test was performed to assess body composition, and blood was collected for analysis of biochemical variables at the UFV Health Division.

Inclusion criteria included women aged 60 years or older, who maintained at least 70% attendance in their respective physical exercise programs, and who had no physical, functional, or cognitive limitations that prevented them from participating in the collections. The exclusion criteria were older women who did not maintain the minimum attendance of 70% of the training or who presented some clinical impediment to participating in the collections. The sample and collection eligibility process is described in the flowchart in Figure 1 below.

The volunteers gave their consent to participate in the study. The project was approved by the Ethics Committee in Research with Human Beings of the Federal University of Viçosa (UFV) (CAAE: 60303716.1.0000.5153). All study procedures were conducted by properly trained people, considering the specificity of each task.

Data Collect

The monitors of the "Saúde e Vida" project were trained to apply the instruments used in the research. The evaluators who applied the QoL instruments and MIR underwent specific training carried out by a psychologist from the Psychosocial Division of the UFV.

The outcomes of interest in the study were defined based on physical function variables in ADLs, anthropometrics and body composition, biochemical profile, blood pressure and resting heart rate, PAL, SB, QoL, and MIR (Chachamovich et al., 2008; de Jesus Mari & Williams, 1986; HÉLIO JÚNIOR, 2016a).

Lower extremities' physical function

10 m walk test (W10m): A distance of 10 meters was defined between two cones. The evaluator started the stopwatch as soon as the evaluated person crossed the starting line. The evaluator encouraged the subject to walk the 10 meters in a straight line as quickly as possible, being allowed to decelerate only after the final cone. As soon as the evaluated person crossed the line of the last cone, the evaluator stopped the stopwatch. Three attempts were performed with a one-minute interval between each one, and the shortest time for completion was recorded. The stopwatch used was accurate to 0.01 seconds. Maximum walking speed was determined by dividing the distance covered by the time spent and adopting the test standardization according to the Latin American Development Group for Maturity (Dantas & de Souza Vale, 2004).

To assess the LL power, the 5 times sit-to-stand test (STS) was used. The test was carried out in a standardized 0.49 m highchair. The evaluator started the stopwatch when the subject lost contact with the chair, and the subject performed five repetitions as quickly as possible. The evaluator stopped the timer at the end of the fifth repetition as soon as the evaluated person sat down in the chair for the fifth time. The evaluator encouraged each woman throughout the test to ensure that she was performing the movement at maximum speed and preserving the technique. Two attempts were performed with an interval of 60 seconds between each one, and the shortest time was recorded (Alcazar et al., 2018). The stopwatch used was accurate to 0.01 seconds. The average speed of movement of the LL (1), the average power (2), and the relative power of the LL (3) were obtained through the STS results (seconds) and anthropometric measurements of body mass (Kg), height (m), chair height (m), and gravity acceleration (g = 0.9 m/s^{-2}). These are described in the respective equations below:

$$\text{STS mean velocity} = \frac{[Height\ x\ 0{,}5 - Chair\ height\ ]}{Five\ STS\ time\ x\ 0{,}1}$$

$$\text{STS mean force} = \frac{Body\ mass\ x\ 0{,}9\ x\ g\ [Height\ x\ 0{,}5 - Chair\ height\ ]}{Five\ STS\ time\ x\ 0{,}1}$$

$$\text{STS mean power} = \frac{Body\ mass\ x\ 0{,}9\ x\ g\ [Height\ x\ 0{,}5 - Chair\ height\ ]}{Five\ STS\ time\ x\ 0{,}1}$$

Functional Capacity

For the evaluation of functional capacity, the Senior Fitness Test battery (Rikli & Jones, 2013) was used, which combines the following tests:

(1) 6-minute walk: a rectangular course of 50 meters was set up, delimited by cones every 5 meter. The subject was instructed to walk as fast as possible for 6 minutes. At the end of the test, the distance traveled in meters was recorded.

(2) Sit to stand: the subject was positioned standing in front of a chair 43 cm high. At the evaluator's signal, the subject performed the movement of sitting and standing as many times as possible for 30 seconds, and the number of repetitions was recorded. The stop-watch used was accurate to 0.01 seconds.

(3) Arm Curl: the evaluated was seated in a chair 43 cm high, holding a 2 kg dumbbell. At the evaluator's signal, the subject performed as many elbow flexions and extensions as possible for 30 seconds, and the number of repetitions was recorded. The stopwatch used was accurate to 0.01 seconds.

(4) Time up and go (TUG): the evaluated was seated in a chair 43 cm high, facing a cone positioned at 2.44 m. At the evaluator's signal, the subject walked as fast as possible around the cone and returned to the starting position. Two attempts were made and the shortest time was recorded. The stopwatch used was accurate to 0.01 seconds.

(5) Sit and reach: the evaluated was seated in a chair 43 cm high, barefoot, with one leg extended. The subject was instructed to reach the toes with the hands together. The distance (in cm) between the tips of the fingers, hands, and soles of the feet was recorded. The positive distance was assigned when the older women surpassed the foot, null distance (equal

to zero) when she placed her hands on the foot, and negative distance when she did not reach the foot.

(6) Back Scratch: With one hand over her shoulder, the subject tried to reach the other hand placed below, attempting to find the fingers or place one hand on the other, behind her back. The distance (in cm) between the tips of the middle fingers was recorded. The positive distance was assigned when the older woman placed one hand over the other, null distance (equal to zero) when she touched one hand to the other, and negative distance when her hands did not meet.

Body composition

Body mass was measured with a precision of 0.1 kg, using an electronic scale of Bioimpedance up to 150 kg, Omron HBF® - 514 brands. The subjects were barefoot and wearing light clothes. Height was measured using a Sanny® brand stadiometer with a precision of 1 mm, in which the women were in an upright position with their feet together, and the stadiometer arm was positioned at the vertex (highest point of the head) of the older women. The Body Mass Index (BMI) was calculated using the ratio: body mass (kg)/height² (m).

Waist and hip circumferences were measured using a tape measure with an accuracy of 1 mm. Through the waist and hip measurements, the waist-hip ratio (WHR): waist circumference/hip circumference was obtained. Cut-off points ≥ 0.80 were considered for increased cardiometabolic risk for females (Barroso et al., 2020).

For the evaluation of body composition, the densitometry method by double X-ray absorption (DEXA) was used, and the Lunar Prodigy Advance DXA System device (analysis version: 13.31) was manufactured by GE Medical, model 8743, Madison, WI, USA. Through it, bone mineral density (BMD) of the lumbar spine (L1 –L4) and femoral neck, lean mass, and body fat were measured. The total appendicular muscle mass (AMM) (Kg) was verified; upper limb muscle mass (ULM) plus lower limb muscle mass (LLM) and relative appendicular mass (AMM/Height): upper limb muscle mass (MMSS) + lower limb muscle mass (LLM/Height). AMM < 15 kg and AMM/Height < 5.5 kg/m were considered as the risk cut-off point for low muscle mass. All evaluations with DEXA were performed at the UFV Health Division by the same technician.

Biochemical analyses

Biochemical analyses were performed at the Clinical Analysis Laboratory of the UFV. For blood collection, the older women fasted for 12 hours and did not perform physical exercises for at least 24 hours prior to the exam following laboratory protocols. Total cholesterol, triglycerides, glycated hemoglobin, mean fasting glucose, urea, creatinine, and albumin were measured.

Physical Activity Level

The long-form International Physical Activity Questionnaire (IPAQ) was used, adapted, and validated for the Brazilian older population (Benedetti et al., 2004). The instrument was applied in the form of an individual interview. To classify the PAL through the IPAQ, three categories were used, adopting the criteria suggested by the Guidelines for data processing and analysis of the International Physical Activity Questionnaire. The categories adopted were:

(1) High - those who perform vigorous-intensity activity for at least 3 days, reaching a minimum total physical activity of at least 1500 METs/minutes/week, or; those who perform 7 or more sessions per week of any combination of these activities, achieving a minimum of 3000 METs/minutes/week.

(2) Moderate - those who perform 3 or more days of vigorous activity of at least 20 minutes a day or; those who perform at least 5 days or more of moderate-intensity activity or walking for at least 30 minutes a day or; those who performed 5 or more sessions per week of any combination of walking, moderate or vigorous-intensity activities, completing a minimum of 600 METs/minutes/week.

(3) Low - those not included in either of the two aforementioned categories.

Sedentary behavior

The Longitudinal Aging Study Amsterdam – Sedentary Behavior Questionnaire (LASA-SBQ) was proposed by (Visser & Koster, 2013a). The instrument consists of 10 questions to assess SB (sitting or lying down), comprising "snooze" activities (nap); "reading"; "saying a prayer or listening to music"; "watching television" (TV); "use the computer"; "hobbies"; "administrative activities"; "talk" (speak); "transportation" and "going to church or theater", determining the time spent in hours and minutes of a typical weekday (Monday to Friday) and a typical weekend day, adapted and validated for the Brazilian older population proposed by (HÉLIO JÚNIOR, 2016a).

Quality of Life

The assessment of QoL was performed by applying the Portuguese version of the WHO QoL scale - version for the older population (WHOQOL-OLD) adapted and validated for Brazil (Chachamovich et al., 2008).

Mental illness risk

The SRQ-20 (Self-Reporting Questionnaire) questionnaire was used to assess MIR, validated for Brazilian patients (de Jesus Mari & Williams, 1986). The questionnaire contains 20 dichotomous questions (yes or no), and when the subject presents seven or more positive answers, it means the presence of the MIR. For the application of the questionnaire, the evaluators were trained by a psychologist from the psychosocial division of the UFV.

Statistical analysis

Initially, the normality assumption was verified using the Shapiro-Wilk test. Data that presented a normal distribution were described as mean and standard error, and data that did not present a normal distribution were described as median and interquartile range. Normal data were submitted to Levene's test for homogeneity of variances and then the T-test for independent samples was applied. For normal and non-normal continuous data, the effect size was calculated using Cohen's r. For the analysis of nominal independent variables, the chi-square test was used for two simple proportions (X^2). Additionally, were performed a covariance analysis (ANCOVA), aimed to exclude possible covariates that could influence the differences between groups. For the ANCOVA model, were considered as covariates, the "older woman's age" and the "total training minutes" of both groups during the 24 weeks of intervention. Regarding the "total training minutes", was

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not possible to perform the analysis, because there was found multicollinearity between the covariate "total training minutes" and the independent variable (IV) "training group", characterizing a direct effect of the total training minutes in the training type, then, due to these disruptions in the statistical assumption, only the "older woman's age" was included in the ANCOVA model. For the effect size in the ANCOVA model were used the eta partial square (η2). To calculate the relative frequencies of dichotomous categorical variables between groups, the chi-square test of independence (X^2) was used to assess the existence or not of a correlation between the group and the subjects' MIR. For the post-hoc analysis, the limits of standardized residuals were adjusted according to the new alpha, and through that, the limits of – 2.49 and 2.49 were considered so that significance between any of the comparisons was considered. The effect size for the categorical variables was calculated using Cramér's V. The results are presented in tables and figures. All statistical analysis were performed using the R, programming language. The effect sizes cut-offs were 0.10 = small, 0.30 = moderate, and 0.50 = large were defined according to the second cut-off points (Cohen, 2013). The significance level adopted was $p < 0.05$ (Field et al., 2012).

Results

Regarding the results of ANCOVA, was possible to identify that "older woman's age" cause a statistically significant influence in only creatinine, f (1) 7.099, p = 0.001, small ES, η2 = 0.13, in which were found a positive interaction between group and gender, where the PA present statistically significant higher age than ME (ME: 64 ± 4 years old; PA: 68.5 ± 5.0 years old). Table 1 shows the anthropometric and body composition characteristics of the ME group and the PA group. Only a trend toward greater lean mass was found in ME compared to PA (p = 0.07, moderate ES, r = 0.48). There was no difference between the groups in the other variables (p > 0.05).

Table 2 shows the test results for the assessment of functional capacity, physical function, and ADLs between ME and PA. It was observed that ME had a shorter mean gait time than the PA (ME: 4.77 ± 0.1 seconds vs. PA: 5.26 ± 0.1 seconds; p = 0.001, large ES, r = 0.50). However, no difference was observed for LL power between groups (p > 0.05). It was observed that ME had a higher average aerobic capacity than PA (ME: 604 ± 8.07 meters vs PA: 551 ± 9.46 meters; p = 0.0001, large ES, r=1). ME had a shorter mean time for agility/dynamic balance than PA (ME: 5.01 ± 0.8 seconds vs. PA: 7 ± 0.11 seconds; p = 0.0001, large ES, r = 0.68). ME had a mean closer to positive values in UL flexibility than PA (ME: -1.74 ± 1.8 cm vs. PA: -9.56 ± 1.8 cm; p = 0.0003, large ES, r = 1). ME had a higher median LL flexibility PA [(ME: 5.5 (10) cm vs PA: 0 (9) cm, p = 0.004, large ES, r = 1)]. No differences were found between the average repetitions of the UL (ME: 23 ± 1 repetitions vs PA: 21 ± 0 repetitions) and between the average

Table 1 - Comparison of anthropometric variables of older women practicing multicomponent physical exercise or self-selected physical activity.

	ME	PA	p^t	r
Age (Years)	67.4 ± 1.1	68.1 ± 0.9	0.62	0.09
Height (m)	1.55 ± 0.1	1.52 ± 0.1	0.88	0.40
Body weight (Kg)	67.3 ± 1.62	67.7 ± 1.8	0.88	0.02
IMC (Kg/m)	27.9 ± 0.7	29.1 ± 0.7	0.26	0.20
Waist circumference (cm)	89.5 ± 2.3	89.8 ± 1.7	0.90	0.02
Waist/hip ratio	0.85 ± 0.014	0.87 ± 0.01	0.26	0.02
Body fat (%)	41.4 ± 0.9	41.5 ± 1.1	0.94	0.01
Lean mass (Kg)	36 ± 0.6	34.3 ± 0.4	0.07	0.48
AMM (Kg)	15.1 ± 0.3	15.3 ± 0.4	0.63	0.10
AMM (Height^2)	6.2 ± 0.1	6.64 ± 0.1	0.10	0.35
BMD/L1-L4 (g/cm^2)	1.06 ± 0.03	1.05 ± 0.04	0.92	0.02
BMD/femoral neck (g/cm^2)	0.926 ± 0.02	0.974 ± 0.02	0.22	0.21

Note. Data are means and standard deviation, median and standard error; p^t: p-value; r: effect size; m: meters; Kg: kilograms; Kg/m: kilograms per meter; cm: centimeters; %: Body fat %: body fat percentage; Height^2: height squared; g/cm^2: grams per square centimeter.

Table 2 - Comparison of functional capacity, physical function in ADLs, and biochemical markers of older women who practiced multicomponent physical exercise or self-selected physical activity.

	ME	PA	p^t	p^w	r
Senior Fitness test					
6 min walk	604 ± 8.0	551 ± 9.4	0.0001***	NA	1
Arm curl	23 ± 1	21 ± 1	0.07	NA	0.31
Sit to stand	18 ± 1	18 ± 1	0.97	NA	0.0
Time up and go	5.01 ± 0.12	7 ± 0.11	0.0001***	NA	0.68
Sit and reach	5.5 (10)	0 (9)	NA	0.004***	1.0
Back Scratch	- 1.7 ± 1.8	- 9.5 ± 1.8	0.003 ***	NA	0.49

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Table 2 - Comparison of functional capacity, physical function in ADLs, and biochemical markers of older women who practiced multicomponent physical exercise or self-selected physical activity.

	ME	PA	p^t	p^w	r
LE physical function					
W10m (s)	4.7 ± 0.1	5.26 ± 0.1	0.001**	NA	0.50
Five-time STS (s)	5.25 ± 0.12	5.45 ± 0.15	0.32	NA	0.18
UL Mean velocity (m/s)	0.76 ± 0.009	0.75 ± 0.01	0.41	NA	0.14
LL Mean force (N/m)	389 ± 9.7	384 ± 10.3	0.72	NA	0.08
LL Mean power (W)	462 ± 11.8	456 ± 13.7	0.73	NA	0.06

Note. Data are means and standard deviation, median and standard error. p^t: p-value for the independent t-test; p^w: p-value for the Wilcoxon test; r: effect size; NA: not applicable; *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$; s: seconds; UL: upper limbs; LL: lower limbs; m/s: meters per second; N/M: Newtons meter; W: watts; W/kg: watts per kilogram; mg/dl: milligram per deciliter; g/dl: gram per deciliter; % percentage value.

repetitions of the LL in both groups (ME: 18 ± 1 repetitions vs PA: 18).

Table 3 shows the results of the biochemical tests, the biochemical tests of the older women of ME and PA, as well as the percentage of older women outside the reference values established according to the standards of the update of the Brazilian Directive on Dyslipidemia and Prevention of Arteriosclerosis (Faludi et al., 2017), and the Guidelines of the Brazilian Society of Diabetes (Forti et al., 2020). It is possible to observe that ME had a higher mean value of total cholesterol than PA (ME: 201, ± 7.14 mg/dl vs PA: 171 ± 8.45 mg/dl; p = 0.009, large ES, r = 0.61), as well as a higher percentage of subjects outside the reference values (ME: 60% vs PA: 46%). The ME had lower mean triglycerides than the PA [(ME: 104 (75) mg/dl vs PA: 130 (76) mg/dl, p = 0.003, large ES, r = 1)]. The ME had a lower median creatinine than the PA [(ME: 0.77 (0.1) mg/dl vs PA: 0.89 (0.15) mg/dl; p = 0.007, large ES, r = 1)], and the PA presented one subject above the reference values.

In addition, it was possible to observe that ME had a lower mean value of glycated hemoglobin than PA (ME: 5.81 ± 0.04 mg/dl vs PA: 6.17 ± 0.11 mg/dl; p = 0.007, large ES, r = 0.57). As for the glycated hemoglobin test, ME also had a lower percentage of diabetic women than PA [(ME: n = 3 (12%) vs PA: n = 7 (29%))]. Similarly, it was possible to observe that ME had a lower mean fasting glucose value than PA (ME: 120 ± 1.4 mg/dl vs PA: 130. ± 3 mg/dl; p = 0.008, large ES, r = 0 .78), and the ME had a lower percentage of older women above normoglycemic values than the PA (ME: 36% vs PA: 67%). However, no differences were observed between the groups for the albumin variables, and urea $p > 0.05$.

Table 3 - Comparison of functional capacity, physical function in ADLs, and biochemical markers of older women who practiced multicomponent physical exercise or self-selected physical activity.

Biochemical analyses	ME	PA	p^t	p^w	r	ME % Out.	PA % Out.
Trilgycerids (mg/dl)	104 (75)	130 (76)	NA	0.50	1	7 (28%)	10 (42%)
Albumin (g/dl)	4.3 (0.30)	4.2 (0.40)	NA	0.17	32.4	1 (4%)	0 (0%)
Creatinine (mg/dl)	0.77 (0.07)	0.89 (0.15)	NA	0.007**	1	0 (0%)	1 (4%)
Urea (mg/dl)	33.9 ± 1.36	33.8 ± 2.02	0.99	NA	0	5 (20%)	5 (21%)
glycated Hemoglobin (%)	5.81 ± 0.04 **	6.17 ± 0.11	0.007**	NA	0.57	3 (12%)	7 (29%)
Mean fasting glucose (mg/dl)	120 ± 1.37**	130. ± 3.29	0.008**	NA	0.78	9 (36%)	16 (67%)

Note. Data are means and standard deviation, median and standard error; p^t: p-value for the independent t-test; p^w: p-value for the Wilcoxon test; r: effect size; % Out: values of biochemical tests that are outside the values reference; NA: not applicable; *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$; mg/dl: milligram per deciliter; g/dl: gram per deciliter; % percentage value.

Table 4 shows the results of the assessment of PAL, SB, and QoL. It is possible to observe that there was no statistically significant difference in PAL between the groups $p > 0.05$, (ME: 13% vs PA: 0%), moderate PAL (ME: 50% vs PA: 54 %) and high PAL (ME: 36% vs PA: 45%). The results in table 4 reveal that there was no difference between the groups in the SB measured on weekdays and weekends $p > 0.05$. There were no differences between the medians of the groups in the global QoL and in the facets of sensory functioning, autonomy, past, present, and future activities, social participation, death and dying, and intimacy ($p > 0.05$). However, it was possible to observe that the women in ME presented more satisfactory values in each facet than the women in PA, for sensory functioning/very good classification (ME: 25% vs. PA: 10%), autonomy/very good classification (ME: 50% vs PA: 35%) and intimacy/good rating (ME: 64% vs PA: 45%). Regarding the MIR measured by the SRQ-20, no significant differences were observed for older women with seven or more positive responses between the groups [(older women with MIR in ME: n = 4 (15%) vs. older women with MIR in the PA: n = 3 (14%); $p > 0.01$)]. In addition, figure 2 below summarizes the study results.

Discussion

The objective of this study was to compare physical and mental health indicators of older who practiced ME practitioners (ME) and older women who practiced self-selected physical activity (PA). The main findings showed no differences in body composition, PAL, SB, MIR, and QL between the groups, however, ME showed better results in aerobic capacity, agility/dynamic balance, the flexibility and strength of UL and LL, gait speed, lower glycated hemoglobin, lower

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Table 4 - Comparison of physical activity levels, sedentary behavior, and quality of life of older women who practiced multicomponent physical exercise or self-selected physical activity.

PAL	ME	PA	X^2	gl	p	V
Down	3 (11%)	0 (0%)	0.96	1	0.32	0.05
Moderate	15 (54%)	12 (55%)	2.82	1	1	0.10
High	10 (3%)	10 (45%)	0.16	1	0.68	0.02
	ME	PA	p^t	p^w	r	NA
SB - week days (min)	360 (136)	375 (148)	NA	0.96	1	NA
SB - weekends (min)	360 (190)	326 (310)	NA	0.09	1	NA
	ME	PA	p^w	df	p^w	r
Global QoL	97.5 (8.25)	95 (10)	374	55	0.61	1
Sensory functinoning	19 (2.25)	18 (2)	358	55	0.43	1
Autonomy	15.5 (2)	15 (2)	339	55	0.27	1
Past, presente, and futures activ.	16 (2.25)	16 (2)	410	55	0.94	1
Social participation	16 (2)	16 (0)	357	55	0.42	1
Death and dying	16.5 (5)	17 (2)	429	55	0.71	1
Intimacy	16 (2.25)	15 (2)	355	55	0.41	1
MIR						
	Positives	Negatives	X^2	gl	p^{x2}	V
ME	4	23	0.003	4	> 0.01	0.002
PA	4	24				

Note. Data are medians and interquartile ranges, and absolute values. PAL: physical activity levels; SB: sedentary behavior; QoL: quality of life, MIR: mental illness risk; X^2: chi-square test; df: degrees of freedom; % percentage value; p^t: p-value for the independent t-test; p^w: p-value for the Wilcoxon test; p^{x2}: p-value for the chi-square test; r: effect size; V: size of the Cramer's V effect.

fasting glucose, and lower creatinine levels, and these adaptations occurred with large ES in the major part of the results. Despite these results, one factor that must be pointed out was the multicollinearity between the "total minutes of training" with the "training group", revealing a direct association of the time spent training with the training group, which means that possibly, the higher total number of minutes also should contribute in part for the better results in the ME.

On the other side, PA of the study neither did a systematized physical exercise program nor performed higher intensity aerobic and resistance exercises during any moment of the program, which brings poor power to induce some significant adaptations in the sample (WHO, 2020). Despite our findings in this study, the evidence regarding the benefits of periodized or non-periodized exercise in the health parameters of older people is still inconclusive, which some trials reveal positive effects of periodized exercise training such as resistance training (Coelho-Júnior et al., 2019), or in combined training (Bertazone et al., 2022). In contrast, other trials have shown non-significant differences between periodized or non-periodized methods, such as in resistance training trials (Conlon et al., 2016), as well as in combined (Tozetto et al., 2022), or aerobic training (Strohacker et al., 2015).

One important point that differed in this study was that training sessions in PA were not only non-periodized, but also the older women did not perform the exercises with any kinds of overloads (i.e., dumbbells, kettlebells, elastic bands), resistance exercises, nor continuous aerobic training, thus, characterizing a poorly intervention. Therefore, PA was not considered as a control group by the researcher due to its characteristics of group classes, and not because of the type of movements, which little characterized a type of intervention. In this sense, having an idea of the higher discrepancies among the training organization and intensity between groups, the higher total number of minutes in the training sessions of the ME must not be interpreted as one big influencing factor.

Regarding functional capacity outcomes, was possible to verify that ME showed better results, with large ES in aerobic capacity, agility/dynamic balance, the flexibility of UL and LL, and gait speed than the PA The ME was performed systematically in the subjects evaluated in the present study was capable of producing a stimulus that allows positive adaptations to occur in functionality parameters and biochemical variables of the older people. In addition, looking at the characteristics of the two interventions was perceived that being a training methodology that produces stimuli at the level of various physical capacities such as strength, resistance aerobic activity, balance, and flexibility, the systematized character causes the magnitude of the stimuli to progressively increase in volume, intensity, and complexity, which from an adaptive point of view is positive in combating the advance of the aging process (Izquierdo et al., 2021).

In the present study, there was no significant difference in the PAL between ME and PA, with similar percentage values in the three PAL categories between the groups. A positive fact found in both groups was the similar number of older women with low PAL classification (ME: 13% vs PA: 0%), showing that although there were no differences, the body movement provided by both practices made it possible for the older women to reduce the risk of physical inactivity. The literature reports the importance of adequate PAL, as it helps to control a healthy weight, which in turn is associated with reduced risk of cardiovascular diseases and several non-communicable chronic diseases, such as diabetes, hypertension, and chronic kidney disease(Gaesser & Angadi, 2021), thus, reinforcing the

idea that at least some body movement is essential to prevent metabolisms deregulations and damages (Zając-Gawlak et al., 2021).

Regarding the SB measured on weekdays and weekends, no difference was observed between the groups. Both groups did not exceed 450 minutes (7.5 hours) of SB on weekdays and weekends, a raw value that was lower than the one found in the study of (Galvão et al., 2018), who analyzed a sample of 473 older people from both sexes, and noticed that the group of physically inactive older women aged 60-69 presented a value of 680 minutes (11.3 hours).

These SB findings point to a beneficial effect of both systematic physical exercise and physical activity in reducing SB in older women, revealing that regardless of the nature of the physical practice, there is a reduction in SB. These findings are interesting from a cardiometabolic point of view, however, just observing the SB reduction in an isolation manner may not be an ideal option, as it is also necessary to consider other benefits, such as functionality, independence, and QoL that each type of exercise provides the older people (Fanning et al., 2022). Interestingly, the groups did not differ in some variables, and these results may have been due to the similar PAL and SB that the older women of both groups presented, showing that although one group performed ME, the similarity in the total volume of ours of PAL and SB between groups may be in part a plausible explanation why this occurred, but is not possible to make this statement due to the lack of additional analysis investigating the association of the different expositions in the non-differences between groups.

In the present study, no significant differences were found in the body composition of the two experimental groups, however, a tendency ($p = 0.07$) for greater lean mass was found in ME to PA. The ME performed systematically is capable of inducing progressive stimulus on various components of physical fitness, and among them is body composition. Increasing muscle mass in older people is essential to prevent the onset and progression of sarcopenia, disability, and frailty, thus enabling them to maintain their independence throughout life (Barros et al., 2021).

During the aging process, it is common for metabolic imbalances to occur that lead to the development of dyslipidemia, which contributes to the emergence and worsening of cardiovascular diseases, obesity, hypertension, and diabetes. In addition, there is a decline in physical fitness and functional capacity, thus reducing QoL and the well-being of older people (Nishikawa et al., 2021). Evidence shows that ME performed in a periodized manner can improve the lipid profile, control glycemic levels, improve the balance between protein synthesis and degradation in muscle, as well as regulate blood pressure and improve cardiovascular fitness (Li et al., 2022).

In the current study, it was observed that ME presented significantly lower, and with larger ES glycated hemoglobin and fasting glucose than PA, indicating the positive effects of ME performed in a periodized manner on the glycemic levels of the older people. Exercise plays an important role in glycemic regulation, through the activation of the GLUT-4 receptor translocation mechanism to the cell membrane, causing an increase in glucose uptake from the bloodstream, thus controlling glycemic levels, which is a positive factor to reduce the risk of diabetes, targets in organ damage, metabolic syndrome and cardiovascular diseases (Kanaley et al., 2022).

With aging, there is a reduction in kidney function, and in more severe cases it can lead to chronic kidney disease, and when there are high levels of urea and creatinine and low levels of serum albumin, it is an indicator of problems in kidney function (Evans et al., 2022). The results of this study revealed that ME had significantly lower values, with large ES in the serum creatinine levels when compared to PA, which revealed a beneficial effect of ME performed in a periodized manner on the parameter of renal function in older women. Physical exercise regulates the renal function of older people, through one of the main mechanisms, which is the improvement of the glomerular filtration rate, and this mechanism improves the functioning of the kidneys and helps in the prevention and treatment of chronic kidney disease (Wu et al., 2022). A counterpoint of this analysis was that the group B age showed a positive interaction with the higher creatinine, revealing that the higher ages in PA also contributed to the significantly higher levels of creatine. During the oldest ages is more common to observe a worsened renal function, due to the natural process of cellular senescence, so, in this sense, the little high age of PA (ME: 64 ± 4 years old; PA: 68.5 ± 5 years old) could influence the higher creatinine levels (McClure et al., 2017).

No differences were found between the values of QoL between the groups, both groups presented high QoL classification, which proved to be a positive factor for both ME and PA. In the literature, the importance of group exercise is reported to improve the QoL older people, as several psychosocial aspects are stimulated, and this is positive in the sense of increasing the feelings of companionship, friendship, strengthening good feelings, and self-esteem of the older people (Ferreira et al., 2022). Considering the MIR, no differences were found between the groups, represented by a low incidence of MIR in ME with 15%, and PA with 14%. Therefore, it is known that the energy expenditure caused by body movement both present in physical activity and physical exercise is capable of modulating several biochemical mechanisms, such as increased endorphins release and reduced inflammation levels, being an important preventive factor against the development and aggravation of MIR (Hartmann et al., 2021).

Study limitations and perspectives

The study has several such as the lack of a control group that did not perform any type of physical exercise, as well as the retrospective character, which did not possibility analyze pre and post-intervention, which could be to explain better the effects of the two types of interventions, and the lack of dietary control of the older women. Another limitation of this study that must be pointed out is the total number of minutes spent in each training group enrolled in the intervention, in which ME presented a higher number of minutes than group B (ME: 3,600 minutes; PA: 2,400 minutes), which should contribute the better results in favor of the ME. Despite these differences in total time spent in training, as cited above, PA performed at very low intensity and besides, being non-periodized, it was also noted as non-systematized physical exercise types, preconizing slow speeds of walking and dancing in a comfortable intensity perception, without previous ordination or programation, which also were accompanied by the researcher, which characterized the physical activities practiced in the PA, having a low powerful to stimulate some positive effects in functional/ biochemical, variables, and QoL of the older women (very similar with a control group). As perspectives, is expected future studies with better and more elabo-

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rated experimental designs, such as controlled and randomized controlled trials, comparing ME and PA, are important to understand how the different training variables e.g., volume, intensity, frequency, duration, equalizing or not this variables, thus maying understanding and measure more precisely the influence of these different confounding factorsin the physical and mental health responses of the different aged and health condition groups, such as independent older people and frail elderly people. Thus, it will help to clarify the extent to which periodized interventions can be more efficient than non-periodized interventions for the physical and mental health of older people.

Conclusion

The results indicate that the practice of PA is similar to ME for elevating PAL levels of older women. However, through ME brought greater benefits in parameters such as gait speed, functional capacity (aerobic capacity, agility, dynamic balance, flexibility of UL and LL), and biochemistry (fasting glucose, glycated hemoglobin, and creatinine). Despite the differences in the total amount of training minutes between groups, the ME presented large ES in the major results, at least, initially, being positive for stimulating the variables that presented better outcomes. This study also brings practical applications for coaches, which could adapt and use creativity to develop different types of systematized ME, aiming to enhance positive adaptations in older people at multilevel outcomes.

References

Alcazar, J., Losa-Reyna, J., Rodriguez-Lopez, C., Acha, A., Rodríguez-Mañas, L., Ara, I., García García, F., & Alegre, L. (2018). The sit-to-stand muscle power test: An easy, inexpensive and portable procedure to assess muscle power in older people. *Experimental Gerontology*, *112*. https://doi.org/10.1016/j.exger.2018.08.006

Barros, M. P. de, Bachi, A. L. L., Santos, J. de M. B. D., Lambertucci, R. H., Ishihara, R., Polotow, T. G., Caldo-Silva, A., Valente, P. A., Hogervorst, E., & Furtado, G. E. (2021). The poorly conducted orchestra of steroid hormones, oxidative stress and inflammation in frailty needs a maestro: Regular physical exercise. *Experimental Gerontology*, *155*, 111562. https://doi.org/10.1016/j.exger.2021.111562

Barroso, W. K. S., Rodrigues, C. I. S., Bortolotto, L. A., Mota-Gomes, M. A., Brandão, A. A., & Feitosa, A. D. M. (2020). Diretrizes Brasileiras de Hipertensão Arterial–2020. *Arq Bras Cardiol*, 0–0.

Benedetti, T. B., Mazo, G. Z., & Barros, M. de. (2004). Aplicação do questionário internacional de atividades físicas para avaliação de mulheres idosas: Validade concorrente e reprodutibilidade teste-reteste. *Rev Bras Cienc e Mov*, *12*(1), 25–34.

Bertazone, T. M. A., Medeiros, L. H. de L., Oliveira, C. I. de, Bueno Junior, C. R., & Stabile, A. M. (2022). Periodized combined training in physically active overweight women over 50 years. *Motriz: Revista de Educação Física*, *28*. https://doi.org/10.1590/S1980-657420220009721

Borg, G. (2000). Escala CR10 de Borg. *Escalas de Borg para a dor e esforço percebido. São Paulo: Manole*, 43–47.

Bosello, O., & Vanzo, A. (2021). Obesity paradox and aging. *Eating and Weight Disorders: EWD*, *26*(1), 27–35. https://doi.org/10.1007/s40519-019-00815-4

Bueno-Antequera, J., & Munguía-Izquierdo, D. (2020). Exercise and Depressive Disorder. *Advances in Experimental Medicine and Biology*, *1228*, 271–287. https://doi.org/10.1007/978-981-15-1792-1_18

Caldas, L. R. dos R. (2018). *Efeitos de 12 semanas de treinamento multicomponente sobre a saúde de idosas*.

Caldas, L. R. dos R., Albuquerque, M. R., Araújo, S. R. de, Lopes, E., Moreira, A. C., Cândido, T. M., Carneiro&#8208, & Júnior, M. A. (2019). Dezesseis semanas de treinamento físico multicomponente melhoram a resistência muscular, agilidade e equilíbrio dinâmico em idosas. *Rev. bras. ciênc. esporte*, 150–156.

Chachamovich, E., Fleck, M. P., Trentini, C., & Power, M. (2008). Brazilian WHOQOL-OLD Module version: A Rasch analysis of a new instrument. *Revista de Saúde Pública*, *42*, 308–316.

Chiu, T.-Y., & Yu, H.-W. (2022). Associations of multicomponent exercise and aspects of physical performance with frailty trajectory in older adults. *BMC Geriatrics*, *22*(1), 559. https://doi.org/10.1186/s12877-022-03246-6

Coelho-Júnior, H. J., de Oliveira Gonçalvez, I., Sampaio, R. A. C., Sewo Sampaio, P. Y., Cadore, E. L., Izquierdo, M., Marzetti, E., & Uchida, M. C. (2019). Periodized and non-periodized resistance training programs on body composition and physical function of older women. *Experimental Gerontology*, *121*, 10–18. https://doi.org/10.1016/j.exger.2019.03.001

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Routledge.

Conlon, J. A., Newton, R. U., Tufano, J. J., Banyard, H. G., Hopper, A. J., Ridge, A. J., & Haff, G. G. (2016). Periodization Strategies in Older Adults: Impact on Physical Function and Health. *Medicine and Science in Sports and Exercise*, *48*(12), 2426–2436. https://doi.org/10.1249/MSS.0000000000001053

Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A. A., Schneider, S. M., Sieber, C. C., Topinkova, E., Vandewoude, M., Visser, M., Zamboni, M., & Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2. (2019). Sarcopenia: Revised European consensus on definition and diagnosis. *Age and Ageing*, *48*(1), 16–31. https://doi.org/10.1093/ageing/afy169

Dantas, E. H. M., & de Souza Vale, R. G. (2004). Protocolo GDLAM de avaliação da autonomia funcional. *Fitness & Performance Journal*, *3*, 175–182.

Dasso, N. A. (2019). How is exercise different from physical activity? A concept analysis. *Nursing Forum*, *54*(1), 45–52. https://doi.org/10.1111/nuf.12296

de Jesus Mari, J., & Williams, P. (1986). A validity study of a psychiatric screening questionnaire (SRQ-20) in primary care in the city of Sao Paulo. *The British Journal of Psychiatry*, *148*(1), 23–26.

Eckstrom, E., Neukam, S., Kalin, L., & Wright, J. (2020). Physical Activity and Healthy Aging. *Clinics in Geriatric Medicine*, *36*(4), 671–683. https://doi.org/10.1016/j.cger.2020.06.009

Evans, M., Lewis, R. D., Morgan, A. R., Whyte, M. B., Hanif, W., Bain, S. C., Davies, S., Dashora, U., Yousef, Z., Patel, D. C., & Strain, W. D. (2022). A Narrative Review of

Chronic Kidney Disease in Clinical Practice: Current Challenges and Future Perspectives. *Advances in Therapy*, *39*(1), 33–43. https://doi.org/10.1007/s12325-021-01927-z

Faludi, A. A., Izar, M. C. de O., Saraiva, J. F. K., Chacra, A. P. M., Bianco, H. T., Afiune Neto, A., Bertolami, A., Pereira, A. C., Lottenberg, A. M., & Sposito, A. C. (2017). Atualização da diretriz brasileira de dislipidemias e prevenção da aterosclerose–2017. *Arquivos brasileiros de cardiologia*, *109*(2), 1–76.

Fanning, J., Nicklas, B. J., & Rejeski, W. J. (2022). Intervening on physical activity and sedentary behavior in older adults. *Experimental Gerontology*, *157*, 111634. https://doi.org/10.1016/j.exger.2021.111634

Ferreira, J. P., Duarte-Mendes, P., Teixeira, A. M., & Silva, F. M. (2022). Effects of combined training on metabolic profile, lung function, stress and quality of life in sedentary adults: A study protocol for a randomized controlled trial. *PloS One*, *17*(2), e0263455. https://doi.org/10.1371/journal.pone.0263455

Field, A., Miles, J., & Field, Z. (2012). *Discovering statistics using R*. Sage publications.

Forti, A. C., Pires, A. C., Pittito, B. A., Gerchman, F., Oliveira, J. E. P., & Zajdenverg, L. (2020). Diretrizes da Sociedade Brasileira de Diabetes 2019-2020 [Internet]. *São Paulo: Clannad*.

Fossati, C., Torre, G., Vasta, S., Giombini, A., Quaranta, F., Papalia, R., & Pigozzi, F. (2021). Physical Exercise and Mental Health: The Routes of a Reciprocal Relation. *International Journal of Environmental Research and Public Health*, *18*(23), 12364. https://doi.org/10.3390/ijerph182312364

Gaesser, G. A., & Angadi, S. S. (2021). Obesity treatment: Weight loss versus increasing fitness and physical activity for reducing health risks. *IScience*, *24*(10), 102995. https://doi.org/10.1016/j.isci.2021.102995

Galvão, L., Tribess, S., Meneguci, J., Santos, E., Santos, R., Dórea, V., Virtuoso Junior, J., & Santos, D. (2018). *Valores normativos do comportamento sedentário em idosos*. *6*, 70–73. https://doi.org/10.17648/aces.v6n2.3137

García-Goñi, M., Stoyanova, A. P., & Nuño-Solinís, R. (2021). Mental Illness Inequalities by Multimorbidity, Use of Health Resources and Socio-Economic Status in an Aging Society. *International Journal of Environmental Research and Public Health*, *18*(2), E458. https://doi.org/10.3390/ijerph18020458

Hartmann, T. E., Robertson, C. V., Miller, T. D., Hunter, J. R., & Skein, M. (2021). Associations between exercise, inflammation and symptom severity in those with mental health disorders. *Cytokine*, *146*, 155648. https://doi.org/10.1016/j.cyto.2021.155648

HÉLIO JÚNIOR, J. (2016a). *Validação do Questionário LASA-SBQ para medida do comportamento sedentário em idosos brasileiros*.

HÉLIO JÚNIOR, J. (2016b). *Validação do questionário LASA-SBQ para medida do comportamento sedentário em idosos brasileiros*.

Izquierdo, M., Merchant, R. A., Morley, J. E., Anker, S. D., Aprahamian, I., Arai, H., Aubertin-Leheudre, M., Bernabei, R., Cadore, E. L., Cesari, M., Chen, L.-K., de Souto Barreto, P., Duque, G., Ferrucci, L., Fielding, R. A., García-Hermoso, A., Gutiérrez-Robledo, L. M., Harridge, S. D. R., Kirk, B., … Singh, M. F. (2021). International Exercise Recommendations in Older Adults (ICFSR): Expert Consensus Guidelines. *The Journal of Nutrition, Health & Aging*, *25*(7), 824–853. https://doi.org/10.1007/s12603-021-1665-8

Kanaley, J. A., Colberg, S. R., Corcoran, M. H., Malin, S. K., Rodriguez, N. R., Crespo, C. J., Kirwan, J. P., & Zierath, J. R. (2022). Exercise/Physical Activity in Individuals with Type 2 Diabetes: A Consensus Statement from the American College of Sports Medicine. *Medicine and Science in Sports and Exercise*, *54*(2), 353–368. https://doi.org/10.1249/MSS.0000000000002800

Kiely, K. M., Brady, B., & Byles, J. (2019). Gender, mental health and ageing. *Maturitas*, *129*, 76–84. https://doi.org/10.1016/j.maturitas.2019.09.004

Leitão, L., Marocolo, M., de Souza, H. L. R., Arriel, R. A., Vieira, J. G., Mazini, M., Figueiredo, T., Louro, H., & Pereira, A. (2021a). Multicomponent Exercise Program for Improvement of Functional Capacity and Lipidic Profile of Older Women with High Cholesterol and High Triglycerides. *International Journal of Environmental Research and Public Health*, *18*(20), 10731. https://doi.org/10.3390/ijerph182010731

Leitão, L., Marocolo, M., de Souza, H. L. R., Arriel, R. A., Vieira, J. G., Mazini, M., Figueiredo, T., Louro, H., & Pereira, A. (2021b). Multicomponent Exercise Program for Improvement of Functional Capacity and Lipidic Profile of Older Women with High Cholesterol and High Triglycerides. *International Journal of Environmental Research and Public Health*, *18*(20), 10731. https://doi.org/10.3390/ijerph182010731

Li, Y., Gao, Y., Hu, S., Chen, H., Zhang, M., Yang, Y., & Liu, Y. (2022). Effects of multicomponent exercise on the muscle strength, muscle endurance and balance of frail older adults: A meta-analysis of randomised controlled trials. *Journal of Clinical Nursing*. https://doi.org/10.1111/jocn.16196

Ling, C., & Rönn, T. (2019). Epigenetics in Human Obesity and Type 2 Diabetes. *Cell Metabolism*, *29*(5), 1028–1044. https://doi.org/10.1016/j.cmet.2019.03.009

McClure, M., Jorna, T., Wilkinson, L., & Taylor, J. (2017). Elderly patients with chronic kidney disease: Do they really need referral to the nephrology clinic? *Clinical Kidney Journal*, *10*(5), 698–702. https://doi.org/10.1093/ckj/sfx034

Monteiro, A. M., Bartolomeu, R. F., Forte, P., & Carvalho, J. (2019). The Effects of three different types of training in functional fitness and body composition in older women. *Journal of Sport and Health Research*, *3*(11), 289–304.

Monteiro, A. M., Rodrigues, S., Matos, S., Teixeira, J. E., Barbosa, T. M., & Forte, P. (2022). The Effects of 32 Weeks of Multicomponent Training with Different Exercises Order in Elderly Women's Functional Fitness and Body Composition. *Medicina (Kaunas, Lithuania)*, *58*(5), 628. https://doi.org/10.3390/medicina58050628

Monteiro, A. M., Silva, P., Forte, P., & Carvalho, J. (2019). The effects of daily physical activity on functional fitness, isokinetic strength and body composition in elderly community-dwelling women. *Journal of Human Sport and Exercise*, *14*(2), Art. 2. https://doi.org/10.14198/jhse.2019.142.11

Nishikawa, H., Asai, A., Fukunishi, S., Nishiguchi, S., & Higuchi, K. (2021). Metabolic Syndrome and Sarcopenia. *Nutrients*,

 DOI 10.26773/mjssm.230303

13(10), 3519. https://doi.org/10.3390/nu13103519

Rikli, R. E., & Jones, C. J. (2013). Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. *The Gerontologist*, *53*(2), 255–267. https://doi.org/10.1093/geront/gns071

Strohacker, K., Fazzino, D., Breslin, W. L., & Xu, X. (2015). The use of periodization in exercise prescriptions for inactive adults: A systematic review. *Preventive Medicine Reports*, *2*, 385–396. https://doi.org/10.1016/j.pmedr.2015.04.023

Tozetto, W. R., Leonel, L. dos S., Turnes, T., & Del Duca, G. F. (2022). Effects of linear periodization of combined training on quality of life of adults with obesity: A blind randomized controlled trial. *Scientific Reports*, *12*(1), Art. 1. https://doi.org/10.1038/s41598-022-06461-8

Vargas-Molina, S., García-Sillero, M., Romance, R., Petro, J. L., Jiménez-García, J. D., Bonilla, D. A., Kreider, R. B., & Benítez-Porres, J. (2022). Traditional and Undulating Periodization on Body Composition, Strength Levels and Physical Fitness in Older Adults. *International Journal of Environmental Research and Public Health*, *19*(8), 4522. https://doi.org/10.3390/ijerph19084522

Visser, M., & Koster, A. (2013a). Development of a questionnaire to assess sedentary time in older persons—A comparative study using accelerometry. *BMC Geriatrics*, *13*, 80. https://doi.org/10.1186/1471-2318-13-80

Visser, M., & Koster, A. (2013b). Development of a questionnaire to assess sedentary time in older persons—A comparative study using accelerometry. *BMC Geriatrics*, *13*, 80. https://doi.org/10.1186/1471-2318-13-80

Wang, X., Wang, H., Ye, Z., Ding, G., Li, F., Ma, J., & Hua, W. (2020). The neurocognitive and BDNF changes of multicomponent exercise for community-dwelling older adults with mild cognitive impairment or dementia: A systematic review and meta-analysis. *Aging*, *12*(6), 4907–4917. https://doi.org/10.18632/aging.102918

WHO. (2020). *WHO guidelines on physical activity and sedentary behaviour*. https://www.who.int/publications-detail-redirect/9789240015128

Williams, T. D., Tolusso, D. V., Fedewa, M. V., & Esco, M. R. (2017). Comparison of Periodized and Non-Periodized Resistance Training on Maximal Strength: A Meta-Analysis. *Sports Medicine (Auckland, N.Z.)*, *47*(10), 2083–2100. https://doi.org/10.1007/s40279-017-0734-y

Wu, L., Liu, Y., Wu, L., Yang, J., Jiang, T., & Li, M. (2022). Effects of exercise on markers of inflammation and indicators of nutrition in patients with chronic kidney disease: A systematic review and meta-analysis. *International Urology and Nephrology*, *54*(4), 815–826. https://doi.org/10.1007/s11255-021-02949-w

Zając-Gawlak, I., Pelclová, J., Groffik, D., Přidalová, M., Nawrat-Szołtysik, A., Kroemeke, A., Gába, A., & Sadowska-Krępa, E. (2021). Does physical activity lower the risk for metabolic syndrome: A longitudinal study of physically active older women. *BMC Geriatrics*, *21*(1), 11. https://doi.org/10.1186/s12877-020-01952-7

ORIGINAL SCIENTIFIC PAPER

Anthropometric Characteristics and Specific Functional Swimming Capacities in Youth U12 Water Polo Players

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Abstract

Introduction: Water polo is a physically high-demanding team sport, therefore players' physical abilities and anthropometric characteristics are important factors to achieve a good level of quality in technical-tactical actions. The aim of this study was to determine the association of the chronological age with the anthropometric characteristics and specific functional swimming capacities in youth U12 male water polo players. Methods: There were 170 youth U12 water polo players who attended the Croatian Water Polo Federation training camps included in this cross-sectional study. Measurements included anthropometric characteristics and specific functional swimming capacities. Results: Players were divided according to their chronological age: Q1 (January-March) – 59 players (34.7%), Q2 (April-June) – 35 players (20.6%), Q3 (July-September) – 46 players (27.1%) and Q4 (October-December) – 30 players (17.6%). Older players born in Q1 presented higher values of body height and weight than their younger peers born in Q4 (Q1 165.96±7.88 cm vs. Q4 159.46±5.44 cm, P=0.001; Q1 60.14±13.99 kg vs. Q4 51.35±7.09 kg, P=0.023), while there were no statistically significant differences in specific functional swimming tests between different age groups. Discussion: Contrary to what was hypothesized, older water polo players presented only better anthropometric characteristics than their younger peers, probably due to the biological maturity influence on functional skills, as well as small range of chronological age differences. Conclusion: Such data might provide an understanding of the general and specific water polo player's development process, which should be considered by coaches of youth players to improve their skills as a result of developing better training programs.

Keywords: *water polo, chronological age, development, swimming, performance*

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Introduction

Water polo is a physically high-demanding team sport characterized by exchange of activities with different energy load while players constantly move through the field in the water. In such environment players use different swimming intensity, receiving, dribbling and passing the ball, as well as shooting accurately on the goal. Additionally, they use different techniques to accomplish many complex technical-tactical actions while wrestling with the opponents (Smith, 1998, Botonis et al., 2015, Sekulić et al., 2016). Several authors indicated physical abilities and anthropometric characteristics as important factors to achieve a good level of quality in technical-tactical actions, both for young and adult water polo players, especially considering constant physical contact during the game (Kondrič et al., 2012, Uljević et al., 2013, Sekulić et al., 2016, Gardasevic et al., 2017, Kontić et al., 2017, Melchiorri et al., 2017, Viero et al., 2020). Greater body height and longer extremities also allow players to reach for the ball more easily, to shoot and to perform blocks more efficiently (Idrizović et al., 2014, Dimitrić et al., 2022). It is well known that water polo players' anthropometric characteristics are highly related with high performance levels, influencing intensive offensive and defensive actions in each playing position (Ferragut et al., 2011, Kondrič et al., 2012). Along with body size, swimming capacity is also related to the general performance level of youth water polo players in a game (Kontić et al., 2017, Melchiorri et al., 2017, Vasiljevic et al., 2021). Since in recent years, water polo as a game has become more dynamic, the transition from offense to defense is faster increasing the frequency of situational parameters, player contacts are stronger and there are more frequent transitions from horizontal to vertical body position (Kovačević, 2012, Uljević et al., 2021). Consequently, to reach higher level of general performance in the game, youth water polo players need to develop high swimming capacity (Kontić et al., 2017, Melchiorri et al., 2017).

Other than anthropometric characteristics and physical abilities, the complex process of growth and maturation must be considered for young athletes to ensure suitable training and competition routines. The players' initial development processes require deeper theoretical and practical knowledge, which might help to improve the training process and early identification of talented players (Escalante et al., 2013, Chirico et al., 2021). Chronological age is the traditional strategy to categorize young athletes appropriately for their level of development (Lloyd et al., 2014, Giudicelli et al., 2021). Growth is the process of increasing body size in whole or in parts, while biological maturation refers to physiological and cognitive development towards adulthood. Maturational events have an established order in which they happen but the moment when they occur and their duration have vast variability between individuals, even at the same age, affecting the physical, technical and psychological performance of young athletes (Malina et al., 2004, Lloyd et al., 2014, Giudicelli et al., 2021). In sports where strength, power and speed are extremely important and physical contact is inevitable, more mature individuals who are usually taller and heavier show better results in motor, physical and functional evaluations compared with their peers in chronological age (Ford et al., 2011, Till et al., 2014, Luna-Villouta et al., 2021). Such differences usually disappear when late-maturing athletes reach higher levels of maturation at the end of adolescence or in the beginning of adulthood (Malina et al., 2004, Lloyd et al., 2014).

Considering the importance of the chronological age and maturity, as well as functional development of youth water polo players, the aim of this study was to determine the association of the chronological age (see Methods section for details) with the anthropometric characteristics and specific functional swimming capacities in youth U12 male water polo players.

Methods

Subjects

This cross-sectional study included 170 youth water polo field players (goalkeepers were excluded due to the small number and different specific functional swimming tests conducted) who attended the Croatian Water Polo Federation (CWPF) training camp from the season 2015/2016 until 2020/2021 at the age of 12 (U12), representing the initial selection. The CWPF training camps are selective, developmental programs on-going for past 10 years, organized by the head coach-leader of the CWPF training camps, supported by 8-12 licensed water polo coaches who participated in all training activities assuring professional supervision of it. The training camps lasted for four days, with seven specific technical-tactical training sessions adjusted to the development level of youth players. All players who attended training camps had over two years of competitive practice. They trained regularly with their own teams with an average of 5 training sessions per week, lasting approximately for two hours and they participated in the highest league for their age group, playing between 20 and 30 games each season. The players were divided according to their chronological age in four groups: Q1 – those who were born in the first quarter of the year (January-March), Q2 – those who were born in the second quarter of the year (April-June), Q3 – those who were born in the third quarter of the year (July-September) and Q4 – those who were born in the fourth quarter of the year (October-December), respectively. Written informed consent was obtained from parents / legal guardians, with the study being approved by the Ethical Committee of the University of Split School of Medicine, Split, Croatia (N.: 2181-198-03-04-19-0053).

Measurements and variables

In this study a battery of tests performed included anthropometric characteristics' measurements and specific functional swimming tests. Anthropometric variables included body height and weight which were measured using a stadiometer and a digital scale, respectively, while the subjects wore only swimming trunks. Body Mass Index (BMI) was calculated as body weight (kg) divided by height squared (m^2). Water polo players' functional capacities were assessed by specific functional swimming tests including 25 m front crawl, 50 m front crawl, 100 m front crawl, 400 m front crawl, 25 m ball dribbling, 25 m eggbeater kicking, 25 m front crawl legs kicking. The players were timed with hand-held digital stopwatch (Longines, Saint-Imier, Switzerland) performing various distances and styles in 25-m swimming pool, starting at the sound signal from the water. They were allowed to push-off the wall at the start and after the turn, but a flip turn was not allowed. They were instructed to swim at maximum speed for each test. For 25 m dribbling the ball players were instructed to dribble the ball from wall to wall of the swimming pool, without throwing it and to touch the wall with one hand. Eggbeater kick is a cyclical movement and it consists of alternating the circular, asymmetric, continuous movements of the legs, an alternat-

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ing circumduction of the hips accompanied by knee flexion/extension and medial to lateral rotation, producing an upward force and maintaining players afloat in a vertical position. Upper limbs are kept free, giving the opportunity to do technical movements with or without the ball (passing, throwing, tackling an opponent, wrestling, catching or intercepting passes, and blocking shots on goal) remaining vertical or moving in any direction while in a vertical position (Uljevic et al., 2013). For testing 25 m eggbeater kicking players were instructed to swim in semi-horizontal body position with legs only, using eggbeater kick, while hands were neutralized with the ball, and head over the water surface.

Statistical analysis

Data analyses were performed using statistical software MedCalc for Windows (Microsoft Corp., Redmond, WA, USA), version 19.4. (MedCalc Software, Ostend, Belgium). Continuous data were presented as mean±standard deviation or whole number and percentage for categorical variables. The Kolmogorov-Smirnov test was used to assess normality of data distribution. Although data were not normally distributed according to the Kolmogorov-Smirnov test, it showed favorable distribution on Q-Q plots. Differences in anthropometric characteristics and specific functional swimming capacities of youth U12 water polo players according to the chronological age were tested using Kruskal-Wallis test with the post-hoc analysis. Additionally, Pearson's correlation coefficient analysis was performed to determine a relationship between chronological age, anthropometric characteristics and results of specific functional swimming tests, while multiple regression analysis was performed to determine the association between selected independent variables (anthropometric characteristics, specific swimming tests) with the chronological age of water polo players (dependent variable). The statistical significance was set at $P<0.05$.

Results

There were 170 youth U12 water polo players, divided according to their chronological age / the quarter of the year they were born in as follows: Q1 (January-March) – 59 players (34.7%), Q2 (April-June) – 35 players (20.6%), Q3 (July-September) – 46 players (27.1%) and Q4 (October-December) – 30 players (17.6%). Data about their baseline anthropometric characteristics and specific functional swimming capacities are presented in Table 1.

Table 1. Baseline characteristics of youth U12 water polo players

Chronological age (N=170)	N (%)
Age categories (quarter)	
Q1	59 (34.7)
Q2	35 (20.6)
Q3	46 (27.1)
Q4	30 (17.6)
Anthropometric characteristics (N=170)	**Mean ± SD**
Body height (cm)	163.27±7.51
Body mass (kg)	56.69±12.31
Body mass index (kg/m^2)	21.13±3.47
Specific functional swimming capacities	**Mean ± SD**
Front crawl, 25 m (s) N=143	16.45±1.14
Front crawl, 50 m (s) N=169	36.44±5.74
Front crawl, 100 m (s) N=140	79.91±5.29
Front crawl, 400 m (s) N=169	373.59±35.95
Front crawl leg kicks, 25 m (s) N=108	27.99±8.28
Eggbeater, 25 m (s) N=108	28.38±5.64
Dribbling, 25 m (s) N=170	17.73±1.48

Data are presented as mean±standard deviation or as whole numbers and percentage. Q1 – players born in the first quarter of the yeat (January-March); Q2 – players born in the second quarter of the year (April-June); Q3 – players born in the third quarter of the year (July-September); Q4 – players born in the fourth quarter of the year (October-December). Eggbeater - swimming in semi-horizontal body position with legs only, using eggbeater kick (cyclical movement consisting of alternating the circular and continuous movements of the legs, an alternating circumduction of the hips accompanied by knee flexion/extension and medial to lateral rotation, producing an upward force and maintaining players afloat in a vertical position), while hands were neutralized with the ball, and head over the water surface. Dribbling - dribbling the ball from wall to wall of the swimming pool, without throwing it and touching the wall with one hand.

Older players born in Q1 presented higher values of body height and weight than their younger peers born in Q4 (Q1 165.96±7.88 cm vs. Q4 159.46±5.44 cm, P=0.001; Q1 60.14±13.99 kg vs. Q4 51.35±7.09 kg, P=0.023), while there were no statistically significant differences in specific functional swimming tests between different age groups (Table 2).

In Table 3, the Pearson's correlation coefficient between chronological age, anthropometric characteristics and specific functional swimming capacities of youth U12 water polo players can be seen.

There were no strong correlations between tested variables. Although P was significant for the correlation between the age categories and body height (r=-0-333, P=0.001) and

Table 2. Comparison of anthropometric characteristics and specific functional swimming capacities of youth U12 water polo players according to the chronological age

Chronological age	Q1 N=59	Q2 N=35	Q3 N=46	Q4 N=30	P
Anthropometric characteristics (N=170)					
Body height (cm)	165.96±7.88[c,d]	164.21±7.28[d]	161.47±7.04[a]	159.46±5.44[a,b]	0.001
Body mass (kg)	60.14±13.99[d]	57.13±13.53[a,d,e]	55.33±10.37	51.35±7.09[a]	0.027
Body mass index (kg/m^2)	21.61±3.53	21.12±4.23	21.13±3.14	20.21±2.74	0.299
Specific functional swimming tests					
Front crawl, 25 m (s) N=143	16.30±1.12	16.51±0.99	16.50±1.12	16.63±1.37	0.626
Front crawl, 50 m (s) N=169	36.31±2.61	36.59±2.37	36.51±1.68	36.42±2.96	0.643
Front crawl, 100 m (s) N=140	80.17±5.64	79.94±5.27	79.99±4.23	79.21±6.32	0.880
Front crawl, 400 m (s) N=169	374.13±30.59	381.18±59.25	370.65±18.79	368.20±29.51	0.778
Front crawl leg kicking, 25 m (s) N=108	27.63±2.98	27.50±2.26	28.58±2.60	28.37±3.50	0.404
Eggbeater kicking, 25 m (s) N=108	28.57±2.50	28.49±1.98	28.30±2.10	28.02±2.90	0.941
Dribbling, 25 m (s) N=170	17.55±1.53	17.97±1.45	17.60±1.40	17.98±1.55	0.474

Data are presented as mean±standard deviation. *Kruskal-Wallis test with the post-hoc analysis; P < 0.05. [a] comparison with Q1 (P < 0.05). [b] comparison with Q2 (P < 0.05). [c] comparison with Q3 (P < 0.05). [d] comparison with Q4 (P < 0.05). Eggbeater - swimming in semi-horizontal body position with legs only, using eggbeater kick (cyclical movement consisting of alternating the circular and continuous movements of the legs, an alternating circumduction of the hips accompanied by knee flexion/extension and medial to lateral rotation, producing an upward force and maintaining players afloat in a vertical position), while hands were neutralized with the ball, and head over the water surface. Dribbling - dribbling the ball from wall to wall of the swimming pool, without throwing it and touching the wall with one hand.

body weight (r=-0.254, P=0.002), as well as between body height and certain specific functional swimming tests (25 m crawl r=-0.388, P<0.001; 50 m crawl r=-0.323, P=0.001; 100 m crawl r=-0.226, P=0.016; 25 m dribbling r=-0.356, P=0.001), correlation coefficient r showed weak or low correlation (Table 3).

Table 3. Pearson's correlation coefficient between chronological age, anthropometric characteristics and specific functional swimming capacities in youth U12 water polo players

	Body height (cm)		Body weight (kg)		BMI (kg/m^2)		Age (Q)	
	r	P	r	P	r	P	r	P
Age (Q)	-0.333	<0.001	-0.254	0.00	-0.131	0.119		
Front crawl, 25 m (s)	-0.388	<0.001	-0.107	0.203	0.078	0.353	0.102	0.224
Front crawl, 50 m (s)	-0.323	<0.001	-0.047	0.578	0.117	0.169	0.022	0.781
Front crawl, 100 m (s)	-0.226	0.016	0.081	0.397	0.218	0.021	-0.053	0.567
Front crawl, 400 m (s)	-0.113	0.184	0.011	0.897	0.070	0.406	-0.073	0.349
Dribbling, 25 m (s)	-0.356	<0.001	-0.013	0.122	0.036	0.674	0.070	0.362
Front crawl leg kicking, 25 m (s)	-0.139	0.152	0.055	0.575	0.149	0.122	0.130	0.179
Eggbeater kicking, 25 m (s)	-0.182	0.060	0.099	0.306	0.235	0.015	-0.084	0.385

*Significant correlation between variables, P < 0.05. BMI – body mass index; Q – quarter of the year players were born in. Eggbeater - swimming in semi-horizontal body position with legs only, using eggbeater kick (cyclical movement consisting of alternating the circular and continuous movements of the legs, an alternating circumduction of the hips accompanied by knee flexion/extension and medial to lateral rotation, producing an upward force and maintaining players afloat in a vertical position), while hands were neutralized with the ball, and head over the water surface. Dribbling - dribbling the ball from wall to wall of the swimming pool, without throwing it and touching the wall with one hand.

The statistical significance maybe was reached due to the large sample size (more than 100 subjects), and it has little practical importance (Taylor, 1990). Multiple regression analysis did not show any predictive value of chronological age as a dependent variable on anthropometric characteristics and specific functional swimming capacities (independent variables) in youth U12 water polo players.

The association between age-group water polo players' specific motor / swimming abilities and their anthropometric indices are provided in Table 4, showing no predicting value of

Table 4. Multiple regression analysis showing the predictive status of chronological age for the specific swimming abilities and anthropometric indices in youth U12 water polo players (N=170)

	β coefficient	SE	P*
Front crawl, 25 m (s)	0.103	0.179	0.564
Front crawl, 50 m (s)	-0.002	0.097	0.980
Front crawl, 100 m (s)	-0.313	0.037	0.530

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Table 4. Multiple regression analysis showing the predictive status of chronological age for the specific swimming abilities and anthropometric indices in youth U12 water polo players (N=170)

	β coefficient	SE	P*
Front crawl, 400 m (s)	-0.023	0.003	0.554
Dribbling, 25 m (s)	-0.007	0.109	0.951
Body height (cm)	-0.267	0.085	0.247
Body weight (kg)	-0.132	0.113	0.595
Body mass index (kg/m^2)	0.352	0.111	0.263
Least squares multiple regression			
Coefficient of determination R^2	0.256		
R^2-adjusted	0.213		
Multiple correlation coefficient	0.391		
Residual standard deviation	1.089		

the chronological age for the specific swimming abilities and anthropometric indices in youth U12 water polo players.

Discussion

With regard to the study aims, there are three most important findings. First, older youth players' born in Q1 chronological age category had significantly higher values of the body height and weight than their younger peers. Second, there were no significant differences between players in different chronological age categories in their specific functional swimming capacities, although we have hypothesized differently. Third, chronological age showed low correlation with the body height and weight, while there were no correlations between chronological age and specific functional swimming capacities. Other than moderate correlations between body height and 25 m front crawl and 25 m dribbling the ball, other specific functional swimming test showed low or no correlations with anthropometric variables.

Many previous studies showed tested swimming capacities as valid predictors of players' achievements, specifically between qualitatively different groups of players (for example national team players vs. lower performance level) (Falk et al., 2004, Uljević et al., 2021, Dimitrič et al., 2022, Kovačević et al., 2022). In this study the results did not discriminate older players over their younger peers in any conducted functional tests, but one should consider their chronological age as prepubescent, therefore differences between them were not prominent yet. We can only speculate that in older age of the puberty and intensive physical maturation differences in anthropometric characteristics and specific functional swimming capacities between older and younger players might be more distinguished. Still, one should be precautious in initial selection of youth water polo players based on showed results because besides functional and motor skills which are desirable to be well developed, many other skills such as general and specific endurance, agility, accuracy, coordination, reaction time, speed, cognitive skills, anticipation and decision-making time, game intelligence etc. contribute to the development of an elite water polo player. Youth water polo players with dominant anthropometric characteristics and well-developed specific functional swimming capacities have good predispositions to develop other important aspects of technical-tactical and situational demands of water polo game in order to become a successful elite water polo player, although in tested age group they had not yet reached the highest levels of motor skills and abilities on which decision-making abilities are based (Malina et al., 2004).

The knowledge of youth specific functional swimming capacities and their chronological, as well as biological development in water polo, using a multivariate approach might improve developmental program processes in youth water polo and might assist in role assignments between different playing positions in water polo teams. Such approach might also help in selection of appropriate game strategy and tactics, according to the capabilities of the selected players. Contrary to what was hypothesized in this study, older water polo players presented only better anthropometric characteristics, while their specific functional swimming capacities were similar to their younger peers, probably due to the biological maturity influence on functional skills, as well as small range of chronological age differences (Lopez-Plaza et al., 2021). Considering the observed anthropometric differences showed in the current study, an individualized training programs based on growth and development of young players is highly suggested.

Even if the current study included a multivariate approach to youth water polo performance, it has the limitation of presenting a different number of players per each age category, as well as small chronological age differences between groups, the players involved all belonged to the same age group, resulting with small or no differences in measured variables. Longitudinal studies on different age groups are therefore highly suggested for further analysis.

Conclusion

Data from the current study contribute to the specific knowledge about youth water polo players' anthropometric characteristics, as well as their performance of specific functional swimming capacities in pre-puberty developmental phase. Such data might provide an understanding of the general and specific water polo player's development process, which should be considered by coaches of youth players to improve their skills as a result of developing better training programs. Specific functional swimming capacities can be best trained because they are more modifiable, while the anthropometric characteristics should be sought in the process of identification and selection of talented players (height, arm span, extremities length). Still, those variables can only serve as possible prerequisites for the development of successful

water polo player along with well-developed agility, speed, accuracy, coordination, game intelligence, cognitive skills and anticipation.

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References

Smith, H.K. (1998). Applied physiology of water polo. *Sports Med.* 26, 317-334.

Botonis, P.G.; Toubekis, A.G.; Platanou, T.I. (2015). Physiological responses of water-polo players under different tactical strategie. *J Sports Sci. Med.* 14, 84-90.

Sekulic, D.; Kontic, D.; Esco, M.R.; Zenic, N.; Milanovic, Z.; Zvan, M. Sport-Specific Conditioning Variables Predict Offensive and Defensive Performance in High-Level Youth Water Polo Athletes. (2016). *J. Strength Cond. Res.* 30, 1316-1324.

Viero, V.; Triossi, T.; Bianchi, D.; Campagna, A.; Melchiorri, G. Physical and performance variables for talent identification in water polo. (2020). *J. Sports Med. Phys. Fit.* 60, 1309-1316.

Kondrič, M.; Uljević, O.; Gabrilo, G.; Kontić, D.; Sekulić, D. (2012). General anthropometric and specific physical fitness profile of high-level junior water polo players. *J. Hum. Kinet.* 32, 157-165.

Gardasevic, J.; Rasidagic, F.; Krivokapic, D.; Corluka, M.; Bjelica, D. Stature and Its Estimation Utilizing Arm Span Measurements in Male Adolescents from Federation of Bosnia and Herzegovina Entity in Bosnia and Herzegovina. (2017). Monten. *J. Sports Sci. Med.* 6, 37-44.

Kontic, D.; Zenic, N.; Uljevic, O.; Sekulic, D.; Lesnik, B. Evidencing the association between swimming capacities and performance indicators in water polo: A multiple regression study. (2017). *J. Sports Med. Phys. Fit.* 57, 734-743.

Melchiorri, G.; Viero, V.; Triossi, T.; Padua, E.; Bonifazi, M. Shuttle swimming test in young water polo players: Reliability, responsiveness and age-related value. (2017). *J. Sports Med. Phys. Fit.* 57, 1456-1463.

Vasiljevic, I.; Aleksandrovic, M.; Corluka, M.; Jeleskovic, E. Differences in Anthropometric Characteristics and Body Composition of Water Polo Players in the 2019 World Junior Championship. (2021) *Sport. Mont.* 19, 103-108.

Uljevic, O.; Spasic, M.; Sekulic, D. Sport-specific motor fitness tests in water polo: Reliability, validity and playing position differences. (2013). *J. Sports Sci. Med.* 12, 646-654.

Idrizovic, K.; Uljevic, O.; Spasic, M.; Sekulic, D.; Kondric, M. Sport specific fitness status in junior water polo players–Playing position approach. (2014). *J. Sports Med. Phys. Fitness.* 55, 596-603.

Dimitric, G.; Kontic, D.; Versic, S.; Scepanovic, T.; Zenic, N. Validity of the Swimming Capacities and Anthropometric Indices in Predicting the Long-Term Success of MaleWater Polo Players: A Position-Specific Prospective Analysis over a Ten-Year Period. (2022). *Int. J. Environ. Res. Public Health.* 19, 4463.

Ferragut, C.; Abraldes, J.A.; Vila, H.; Rodriguez, N.; Argudo, F.M.; Fernandes, R.J. (2011). Anthropometry and Throwing Velocity in Elite Water Polo by Specific Playing Positions. *J. Hum. Kinet.* 27, 31-44.

Kovačević, N. (2012). Intenzifikacija energetskog treninga u vaterpolu. Zbornik radova 21. ljetna škola kineziologa Republike Hrvatske. Poreč, Croatia, pp. 292-297.

Uljević, O.; Kovačević, N.; Rukavina, I.; Kontić, D. (2021). Differences among selected and no-selected male water polo players in morphological characteristics and physical fitness capacity. In Proceedings of the 9th International Scientific Conference on Kinesiology. Opatija, Croatia, p. 867.

Escalante, Y.; Saavedra, J.M.; Tella, V.; Mansilla, M.; García-Hermoso, A.; Dominguez, A.M. (2013). Differences and discriminatory power of water polo game-related statistics in men in international championships and their relationship with the phase of the competition. *J. Strength Cond. Res.* 27, 893-901.

Chirico, E.; Tessitore, A.; Demarie, S. (2021). Physiological swimming test for water polo players in the last twenty years: A systematic review. *J. Sports Med. Phys. Fitness.* 62(7):921-930.

Lloyd, R.S.; Oliver, J.L.; Faigenbaum, A.D.; Myer, G.D.; Croix, M.B.A.D.S. (2014). Chronological Age vs. Biological Maturation: Implications for exercise programming in youth. *J. Strength Cond. Res.* 28, 1454-1464.

Giudicelli, B.B.; Luz, L.G.O.; Sogut, M.; Sarmento, H.; Massart, A.G.; Júnior, A.C.; Field, A.; Figueiredo, A.J. (2021). Chronological Age, Somatic Maturation and Anthropometric Measures: Association with Physical Performance of Young Male Judo Athletes. *Int. J. Environ. Res. Public Health.* 18, 6410.

Malina, R.M.; Bouchard, C.; Bar-Or, O. (2004). *Growth, Maturation, and Physical Activity, 2nd ed.* Human Kinetics: Champaign, IL, USA.

Luna-Villouta, P.; Paredes-Arias, M.; Flores-Rivera, C.; Hernández-Mosqueira, C.; Souza de Carvalho, R.; Faúndez-Casanova, C.; Vásquez-Gómez, J.; Vargas-Vitoria, R. (2021). Anthropometric Characterization and Physical Performance by Age and Biological Maturation in Young Tennis Players. *Int. J. Environ. Res. Public Health*. 18, 10893.

Ford, P.; De Ste Croix, M.; Lloyd, R.; Meyers, R.; Moosavi, M.; Oliver, J.; Till, K.;Williams, C. (2011). The longterm athlete development model: Physiological evidence and application. *J. Sports Sci.* 29, 389-402.

Till, K.; Cobley, S.; Hara, J.O.; Cooke, C.; Chapman, C. (2014). Considering maturation status and relative age in the longitudinal evaluation of junior rugby league players. *Scand. J. Med. Sci. Sports.* 24, 569-576.

Taylor, R. (1990). Interpretation of the correlation coefficient: A basic review. *J Diagn. Med. Sonogr*. 6(1):35-39.

Falk, B.; Lidor, R.; Lander, Y.; Lang, B. (2004). Talent identification and early development of elite water-polo players: a 2-year follow-up study. *J Sports Sci.* 22, 347-55.

Lopez-Plaza, D.; Borges, P.J.; Alacid, F.; Argudo, F.M. Influence of maturity status on morphology, grip and throwing speed in young elite water polo players. (2021) *J. Sports Med. Phys. Fit.* 61, 1441–1447.

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ORIGINAL SCIENTIFIC PAPER

Reintegration Program for Professional Football Players after Grade 2 Hamstring Injuries

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Abstract

Hamstring strains are among the most common injuries in soccer, with an increased risk of recurrence. There are three stages in injuries: 1 Diagnosis, 2 Physiotherapy – Rehabilitation, 3 Reintegration. The present study investigated the reintegration actions (return to play – RTP) for eight professional footballers (Super League 1) after hamstring strain. Eight professional soccer players who had hamstring injuries with Grade 2 strain were measured and evaluated. Two measurements were taken before and after injury. The first measurement involved maximum effort field tests of 30, 40, 50 and 60 meters in a straight line without a ball, using global positioning system (GPS) devices placed on the athletes for the interpretation and evaluation of their results. The second measurement aimed to evaluate the maximum strength of the eight players before and after their injury, using squats, bench presses and leg curl exercises on the machine. The statistical analysis included descriptive and inductive statistics (paired t-test). Analysis of the data collected showed that all soccer players had higher performance in the measurements taken after injury, both in speed and in maximal strength. In conclusion, following the appropriate rehabilitation and reintegration, the eight athletes were not affected by their injury and managed to return to competitive action (RTP) without recurrence and maximizing their performance.

Keywords: *Reintegration, injury, hamstrings, footballer, rehabilitation*

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Introduction

Hamstring injuries are common in many sports including football (Kujala et al., 1997). Strain is the typical pattern of injury and results from excessive stretching of the muscle, often during sprinting or jumping (Slavotinek et al., 2010). More than 70% of football players injure their hamstrings during sprints (Skling et al., 2014). Failure to properly rehabilitate – reintegrate or an early return can lead to a relapse and a lost season (Mendez et al., 2022). It has been investigated that the majority of training and competitive actions in intermittent sports like football occur within 5-30m (Carling et al., 2016). They evaluated speed using a 30-meter sprint test with speed measured at 10 meters, 20 meters and 30 meters (Altmann et al., 2019). However, the speed at distances of 40, 50 and 60 meters has not been investigated. These distances 40,50,60 meters can occur in football firstly, in actions during the game by the fullbacks, who have to attack and return to their position back in defense in case the ball is lost, and secondly,

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when central defenders in static situations are advanced to score and have to run quickly back into defense in case of a counter attack by the opposing team. For the above reasons our players were also subjected to the 40,50 and 60 meters speed tests. (Diagnosis, which is stage 1, is performed on players to determine the severity of the injury and make a proper evaluation. This is usually done clinically with either magnetic resonance imaging (MRI) or ultrasound. This is very important as a first step to have an accurate knowledge of the extent of the injury and the length of time the player will be absent from active play (Schneider-Kolsky et al., 2006). Furthermore, MRI offers a detailed analysis of the injury and is the preferred method for elite athletes in an attempt to prevent re-injury for those players who may return to training prematurely (Mendiguchia J et al., 2011).

The second stage, concerning physical therapies to be followed by football players, consists of proper management to relieve the pain and for the gradual healing of the torn muscle (Cohen – Bradley et al., 2007). With stage 2 the players should have fully gained full range of motion of their limb. With another diagnostic test to confirm that the muscle has healed they are ready for stage 3, rehabilitation (Askling et al., 2007). High intensity total distance and sprints are extremely important factors in the reintegration stage for returning football players to a better condition than they were before the injury (Mohr et al., 2003). Therefore, the amount of high intensity running combined with lower limb maximum strength training can be considered indicators of increased performance after a hamstring injury (Tol et al., 2014).

Therefore, with appropriate/correct rehabilitation and reintegration, professional footballers restore their high performance standards and maximize them by returning to better physical fitness than before (Sherry & Best, 2004).

About the mechanisms, hamstring injuries occur in sport activities requiring sprinting, cutting movements, acceleration efforts and extreme stretch movements (Schache et al., 2012). However, within the hamstring muscular complex it is important to split the injury mechanisms into biceps femoris (BF), semimembranosus (SM), and semitendinosus (ST) muscles lesions. The hamstring muscular complex during the running biomechanics is active from the beginning of the mid-swing phase until the terminal stance phase (Drezner et al., 2003). During this period of time, the BF is the muscle that undergoes the most elongation, equal to approximately 12% of its rest length. In the same phase, the SM is the flexor muscle producing the most important strength peak and absorbing the most important parts of the power production (Schache et al., 2012). For these reasons, the BF and SM injuries are substantially different. In other words, the BF injury mechanism is mainly based on an overstretching event, while the SM injuries are mainly based on a strength/power overproduction (Askling et al.,2007). This led to the aim of the present study, which was the investigation of the reintegration actions (return to play – RTP) through an appropriate individual program and tests, for eight professional footballers (Super League 1) after grade 2 hamstring strain.

Methods

The study sample consisted of eight professional football players (Super League 1) who had suffered a grade 2 strain in the first half of the 2020-2021 season. Three were midfielders, two were strikers, one was a winger, one was a central defender and one was a fullback. Before being injured, the players were subjected to the following tests: speed field test using GPS at 30, 40, 50 and 60 meters, and biceps unipedal flexions with maximum force of 1RM on the leg curl machine. Depending on the position they were competing in, the players had to cover specific high intensity meters in the speed field test (Bayer et al., 2018). At the beginning of stage 1 of the players' injury, the team's orthopedic doctor performed an MRI and ultrasound scans to accurately determine the extent of the injuries. They were evaluated and determined by the orthopedic doctor to be grade 2 contusions with muscle fiber tears. At the end of stage 2 and before the start of stage 3, which involves reintegration, the same diagnostic tests (MRI and ultrasound scans) were performed again to determine if there was muscle healing and if the athletes were ready to begin reintegration.

The initial tests were performed after preparation as s baseline measurement and a benchmark. The time period from injury to return to competitive action was the same for all players. You cannot know when a player will be injured. So the players had the same recovery time and were evaluated in the same time period after their injury. The results are comparable because there was no focus on the time between the initial measurement and the injury, for the reason that an injury cannot be predicted.

The eight professional football players had no previous injuries, so they were selected and not excluded from the study. 1 Midfielder: age 33, height 1.85, weight 78, BMI 22, 79. 2 Midfielder: age 29, height 1.82, weight 75, BMI 22, 64. 3 Midfielder: age 25, height 1.71, weight 65, BMI 22, 23.

4 Striker: age 21, height 1.86, weight 77, BMI 22, 26. 5 Striker: age 29, height 1.88, weight 80, BMI 22, 63. 6 Winger: age 24, height 1.79, weight 75, BMI 23, 41. 7 Central defender: age 27, height 1.93, weight 80, BMI 21, 75. 8 Fullback : age 26, height 1.74, weight 67, BMI 22, 13.

Inclusion: The football players included in the study participated in all training sessions, had playing time in official matches and had no serious injuries in the previous season. Exclusion: The football players excluded from survey did not participate in all training sessions, had no playing time in official matches and had serious injuries in the previous season.

Speed field test using GPS

For the purposes of the test, the midfielders had to cover a total distance of 600 meters at very high intensity (VHI Drills / maximal intent), 3 sets of 30 meters – 3 sets of 40 meters – 3 sets of 50 meters – 4 sets of 60 meters. There was a break of 30-40 seconds between the repeats and a 3-minute break between sets. The footballers competing in the attack had to cover a total distance of 720 meters at very high intensity (VHI Drills / maximal intent), 5 sets of 30 meters – 3 sets of 40 meters – 3 sets of 50 meters – 5 sets of 60 meters. There was a break of 30-40 seconds between the repeats and a 3-minute break between sets. The lateral striker had to cover a total distance of 720 meters at very high intensity (VHI Drills / maximal intent), 5 sets of 30 meters – 3 sets of 40 meters – 3 sets of 50 meters – 5 sets of 60 meters. There was a break of 30-40 seconds between the repeats and a 3-minute break between sets. The central defender had to cover a total distance of 540 meters at very high intensity (VHI Drills / maximal intent), 3 sets of 30 meters – 3 sets of 40 meters – 3 sets of 50 meters – 3 sets of 60 meters. There was a break of 30-40 seconds between the repeats and a 3-minute break

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between sets. The lateral defender had to cover a total distance of 720 meters at high intensity (VHI Drills / maximal intent), 5 sets of 30 meters – 3 sets of 40 meters – 3 sets of 50 meters – 5 sets of 60 meters. There was a break of 30-40 seconds between the repeats and a 3-minute break between sets.

Table 1 shows the distances (meters) covered by our football players during matches and the average high-intensity distance (speed over 18 km km/h) covered during a match at the professional level depending on the position of each player. We selected our study's speed limits according to our team's GPS data.

Table 1. High Intensity Distances (Meters) Covered by our football Players during Matches

Player position	Average – level of our professional team
Central Defenders	430 meters
Fullbacks	680 meters
Central Midfielders	580 meters
Wide Midfielders	740 meters
Attackers	620 meters
Average	630 meters

Maximum test measurement 1RM

The football players underwent the prescribed 1RM maximum force measurement for one exercise in the training program, the leg curl exercise. Prior to the 1RM test all participants followed a standard warm-up routine of one set of 10 repetitions with approximately 50% of the sub maximal loads to follow, using the correct movement technique. To determine the sub maximal force loads, a progressive increase in kilograms was performed for each exercise until the football players were unable to complete a repetition with correct technique. A 3-5 minute break was given between sets. 1RM was achieved between 4-5 attempts. All measurements were performed with a fixed body position, using the same resistance equipment, by the same trainer (Śliwowski et al., 2015).

Reintegration stage (training process)

During the 3rd stage of their injury, the reintegration stage, all eight players followed a program which lasted 11 days, and on the 12th day they started training with the rest of the team. The program, described in Table 2, represents a very high intensity progression during rehabilitation of a grade 2 hamstring strain injury, taking into account an average very high intensity game profile of 630 meters (Very High Intensity Distance).

Table 2. Reintegration Program (Ferreira et al., 2018)

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12
0-10% Match Average	N/A	30% Match Average	N/A	N/A	60% Match Average	N/A	N/A	60% Match Average	N/A	N/A	
0-63m without sprint distance	N/A	190m without sprint distance	N/A	N/A	380m touching sprint distance	N/A	N/A	630m achieving maximum speed	N/A	N/A	
VHI Exploratory Technical Drills / W Length below 30m to avoid covering considerable amount of VHI distances but allowing the player to achieve it if comfortable.	OFF	VHI Drills 2x (4x30m) in 5sec. + 1x40m in 6 sec. 30sec active / passive rest between repetitions and 3 min between sets.	OFF	OFF	VHI Drills 2x(4x40m) in 6 sec. + 2x50m in 6sec + 2x40m in 5sec– achieve sprint speed. 30sec active/ passive rest between repetitions and 3 min between sets.	OFF	OFF	VHI Drills w/ maximal intent. 2x(3x50m) in 8sec + 1x50m in 7sec + 1x(4x60m) in 10sec + 1x(3x60m) in 8sec. 30-40sec active/ passive rest between repetitions and 3 min between sets.	OFF	OFF	Start Training with the team
Core Stability	Recovery Strategies Unloading Legs	Legs Maximum Strength Training 85%.	Upper-Body	Core Stability	Recovery Strategies Unloading Legs	Upper-Body	Core Stability	Legs Maximum Strength Training 85%.	Upper-Body	Core Stability	

Statistical Analysis

Kolmogorov-Smirnov and Shapiro-Wilk normality tests were performed. There was equal distribution so a paired correlation test was performed. There was a correlation between the values. In the 1st, 3rd, 5th, 7th variable, the 30, 40, 50 and 60-meter distances, a paired t-test was used to test whether there was a difference between the maximum kilometer speed before and after the strain. In the 2nd, 4th, 6th, 8th variable, the 30, 40, 50 and 60-meter distances, a paired t-test was used to test whether there was a difference between the time before and after the strain. In the 9th variable, the 1RM maximum force test, a paired t-test was used to ascertain whether there was a difference between the maximum left hamstring strength before and after the strain. In the 10th variable, the 1RM maximum force test, a paired t-test was used to ascertain whether there was a difference between the maximum right hamstring strength before and after the strain.

Results

30 meters

The results showed a significant statistical difference between the maximum mileage for the 30-meter distance before and after the strain, t (7) = 5.694, p = .001. Pre-injury performance of the football players ranged from 19.00 to 22.00 km/h maximum speed. Post-injury with proper rehabilitation the players achieved higher values ranging from 20.00 to 23.00 km/h maximum speed. All the players had higher maximum speed (km/h) in their post-injury test of 30 meters. Figure 1 shows the difference between the maximum speed (km/h) for the 30 m distance before and after the injury.

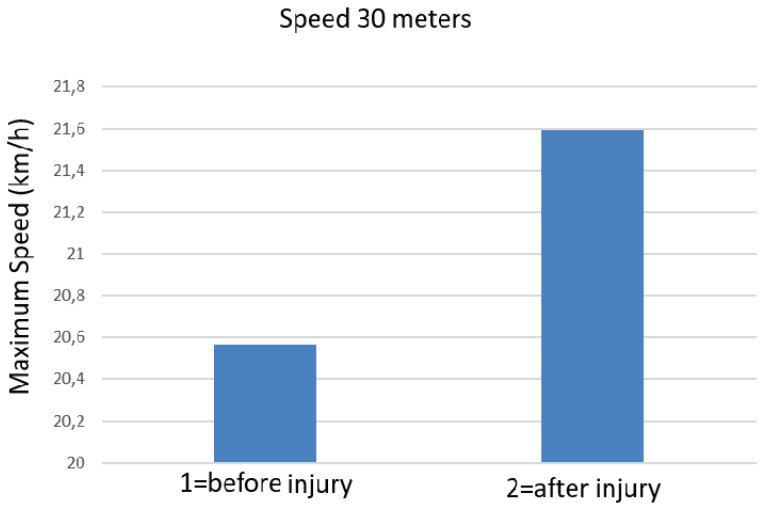

Figure 1. 30-meter distance test before and after injury.

The results showed a significant statistical difference between the times for the 30-meter distance before and after the strain, t (7) = 5.916, p = .001. Pre-injury performances of the football players ranged from 5 to 5.60 seconds. Post-injury we found that players achieved lower times ranging from 4.70 to 5.30 seconds. All the players had better times in the 30- meter run.

40 meters

The results showed a significant statistical difference between the maximum mileage for the 40-meter distance before and after the fracture, t (7) = 6.328, p = .001. Pre-injury performance of the football players ranged from 20.00 to 22.00 km/h maximum speed . Post-injury with proper rehabilitation players achieved higher values ranging from 21.00 to 27.00 km/h maximum speed. All the football players had higher maximum speed (km/h) in their post-injury test of 40 meters. Figure 2 shows the difference between the maximum speed (km/h) for the 40-meter distance before and after the injury.

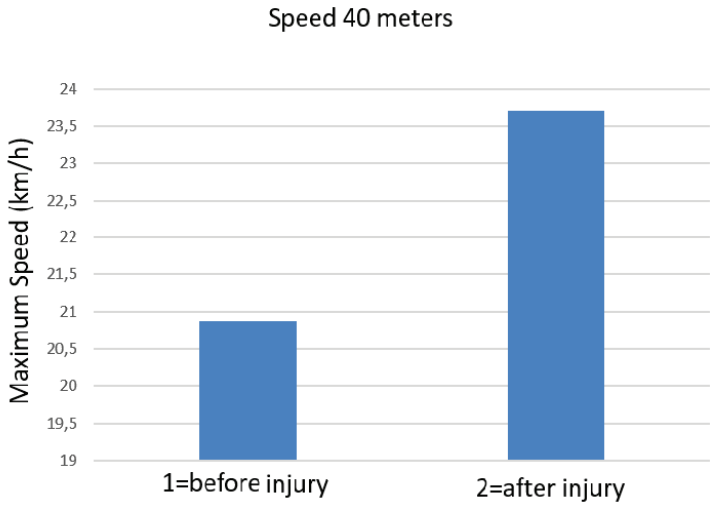

Figure 2. 40-meter distance test before and after injury.

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The results showed a significant statistical difference between the times for the 40-meter distance before and after the strain, t (7) = 8.147, p = .001. Pre-injury performance of the football players ranged from 6.60 to 7.29 seconds. Post-injury we found that players achieved lower times ranging from 5.50 to 6.75 seconds. All the players had better time in the 40-meter run.

50 meters

The results showed a significant statistical difference between the maximum mileage for the 50-meter distance before and after the strain, t (7) = 11.434, p = .001. Pre-injury performance of the football players ranged from 20.50 to 22.50 km/h maximum speed. Post-injury with proper rehabilitation players achieved higher values ranging from 23.00 to 28.00 km/h maximum speed. All the footballers had higher maximum speed (km/h) in their post-injury test of 50 meters. Figure 3 shows the difference between the maximum speed (km/h) for the 50-meter distance before and after the injury.

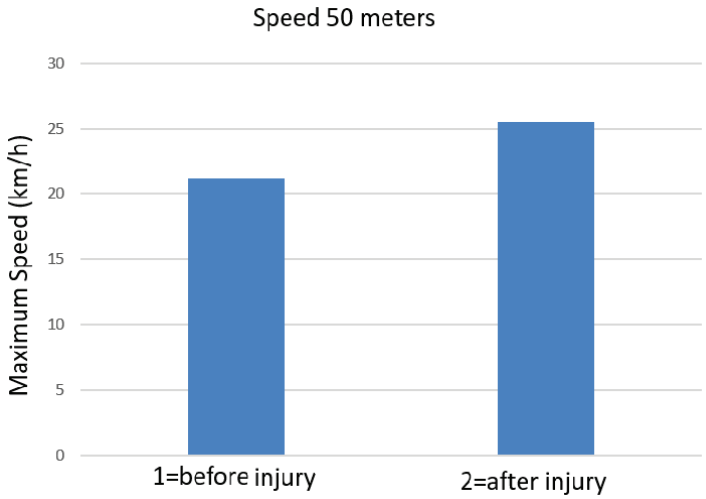

Figure 3. 50-meter distance test before and after injury.

The results showed a significant statistical difference between the times for the 50-meter distance before and after the strain, t (7) = 15.809, p = .001. Pre-injury performances of the football players ranged from 8.10 to 8.80 seconds. Post-injury we found that the players achieved lower times with values ranging from 6.50 to 7.75 seconds. All the players had better time in the 50-meter test.

60 meters

The results showed a significant statistical difference between the maximum mileage for the 60-meter distance before and after the strain, t (7) = 11.259, p = .001. Pre-injury performance of the football players ranged from 20.40 to 21.60 km/h maximum speed. Post-injury with proper rehabilitation players achieved higher values ranging from 23.00 to 28.00 km/h maximum speed. All the players had higher maximum speed (km/h) in their post-injury test of 60 meters. Figure 4 shows the difference between the maximum speed (km/h) for the 60-meter distance before and after the injury.

The results showed a significant statistical difference between the times for the 60-meter distance before and after the strain, t(7) = 16.269, p = .001. Pre-injury performance of the football players ranged from 10 to 10.60 seconds. Post-injury we found that football players achieved lower times ranging from 7.80 to 9.20 seconds. All the players had better times in the 60-meter test.

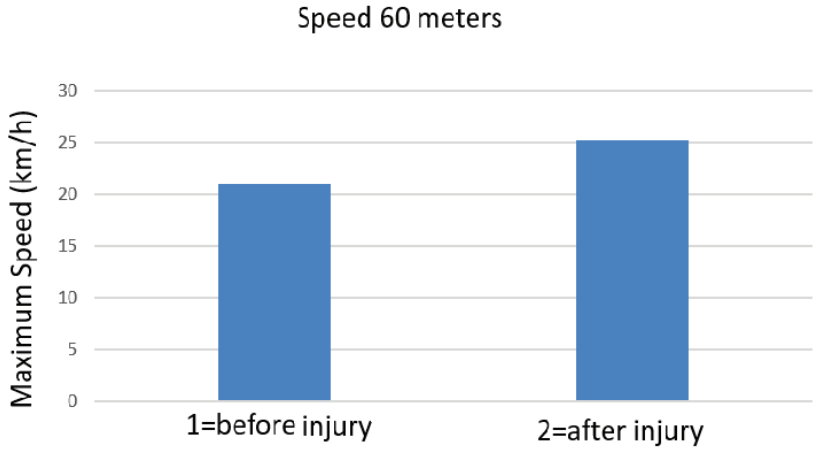

Figure 4. 60-meter distance test before and after injury.

Max Test 1RM

The results showed a significant statistical difference between maximal left hamstring strength before and after

the strain, t (7) = 4.369, p = .001. Pre-injury performance of the football players ranged from 20 to 40 kg. After injury and appropriate rehabilitation the players achieved higher values ranging from 25 to 45 kg. All of the players had greater peak strength on their tests (1RM) post-injury, so they had better results after injury.

Discussion

The eight professional football players in all variables had better results in both high intensity runs measured using GPS and maximum power. At 30 meters the footballers achieved better times and higher maximum speed (km/h) in their post-injury tests. At 40 meters the footballers also achieved better times and higher maximum speed (km/h) in their post-injury tests. In the 50-meter tests, the footballers also achieved better results in time and maximum speed after the injury than before. The same was true for the 60-meter speed tests. In the right hamstring maximum strength test all footballers had a higher maximum strength in their tests (1RM) after injury. In the left hamstring maximum strength test (1RM) the players also achieved better values after injury than before injury. So the footballers showed an improvement after the injury compared to before.

We believe that this improvement occurred due to the right, appropriate and individualized program tailored to each player's needs that they followed according to the position they played during rehabilitation. With proper rehabilitation and reintegration they recovered to a better level than they were before, improved their weaknesses and finished the season without a relapse or new injury. We believe that prior to the injury the players had deficits in the specific muscle group of the hamstrings. This was the reason they were injured and missed part of the season with a grade 2 strain. Some studies, such as (Woods et al., 2020), disagree with our results: the return of football players to competitive activity after a hamstring strain was not associated with similar high-speed running performance. The deficits observed in high-speed running may be present for many players following a hamstring strain (Orchard et al., 2005).

Brooks et al. (2006) found recurrent injuries in the same places, with recurrences at a rate of 23%. This means that something in the whole rehabilitation – reintegration process did not go as it should, leading to frequent recurrences of the hamstring injuries. According to another study (Mendiguchia 1 et al., 2014), the performance of players with a history of hamstring strain was worse after injury than before injury, with a frequent rate of recurrence. Moreover 67% of hamstring injuries in professional football show a post-injury deficit of more than 10%. So it seems that rehabilitation programs are not working properly because if they were there would be no deficit or atrophy. All the ratios would be at the percentages they should be (Tol et al., 2014).

In contrast, there were also studies that agreed with ours. They showed that the rehabilitation program they followed not only prevented injuries but also improved the players' performance at high speeds (Jiménez-Rubio et al., 2019). Another study (Skling et al., 2013) showed potential improvements compared to pre-injury performance in maximum speed, sprinting and high-intensity running. The footballers returned healthy 6 weeks after injury. Another study, however (Mendiguchia J et al., 2011), reports that the players returned neither better nor worse after the injury. According to this study, the football players returned to the exact same pre-injury performance after the rehabilitation – reintegration program.

Although the strong point of the present study is the high level of the athletes who were examined and applied the program (Super League 1 professional football players), the results must be interpreted with caution and a number of limitations should be borne in mind. The first limitation is that the sample of the present study was too small. Only eight players were subjected to the tests and followed the reintegration program. Further research is needed with a much larger sample, although this is difficult to achieve when professional players and professional teams are involved. The second limitation of the present study is the distance used to assess and evaluate the players during the reintegration program tests (average high-intensity distance of 630 m at a speed of more than 18 km/h). These distances, as Table 1 shows, were obtained according to data from tests of high-level European professional teams. However, Greece does not belong to the highest class of European professional teams. Obviously, given this limitation, there is a need for research on each individual country group in order to ensure the representativeness of the sample in the European population and make the results of the statistical analysis specific to each country group. Thirdly, it should be noted that the subjective assessment of the participants (subjective assessment of their readiness to return to the team's competitive activities), using specific self-evaluation questionnaires, was not taken into account. Thus further research is needed with this supplementary element in mind, in order to gather even more information on the players' readiness to return to the competitive activities of a team and the overall efficiency of a reintegration program. Indeed, many professional football teams consider eccentric exercises for the hamstrings the most important for preventing injuries to these muscles (Thorborg et al., 2012). In the injured players, atrophy was observed in the injured limb, once again highlighting the need to strengthen the whole body during the rehabilitation stage and also after the injury, when the players return to training with the rest of the team (Ekstrand J et al., 2015). It is also recommended to increase the number of sets on the injured limb until it is in full balance with the other limb. This is the only way to avoid recurrences or new injuries in the future (Bayer, et al., 2018).

Although there is a great deal of research on the reintegration of footballers into their previous sporting activity, very few studies concern high-level athletes or professional footballers playing in a country's top league (Brughelli et al., 2010).

Conclusions

According to our study, the eight professional football players in all variables had better results in both maximum strength tests and the different speeds they were subjected to. More specifically, in the 30,40,50,60 meters speed tests that we investigated in our team, the players improved their physical performance than before their injury according to the results. Importantly they didn't present any new injuries. We believe that this is because the rehabilitation program helped them to improve their physical condition and reach a higher level than before their injury, training globally (for all major muscle groups) and more effectively. All the players came back in the second half of the season with the right rehabilitation –

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reintegration at a better level than they had been previously, and finished the season healthy. There was no recurrence or new injury in these players for at least six months. They also played many minutes in official team games, demonstrating the effectiveness of the rehabilitation – reintegration program we implemented. Of course this particular issue needs further research, 40,50,60 meters speed tests could be researched more by other scientists, to see more results and whether they agree or disagree with our research.

References

Altmann, S., Ringhof, S., Neumann, R., Woll, A., & Rumpf, M. C. (2019). Validity and reliability of speed tests used in soccer: A systematic review. PloS one, 14(8), e0220982.

Askling, C. M., Tengvar, M., Saartok, T., & Thorstensson, A. (2007). Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings. *Clin. J. Sports Med*., *35*(2), 197-206. https://doi.org/10.1177/0363546506294679.

Bayer, M.L., Hoegberget-Kalisz, M., Jensen, M.H., Olesen, J.L., Svensson, R.B., Couppé, C., & Kjaer, M. (2018). Role of tissue perfusion, muscle strength recovery, and pain in rehabilitation after acute muscle strain injury: A randomized controlled trial comparing early and delayed rehabilitation. *Scand. J. Med. Sci. Sports*, *28*(12), 2579–2591. https://doi.org/10.1111/sms.13269.

Brooks J.H., Fuller C.W., Kemp S.P., & Reddin D.B. (2006). Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am. J. Sports Med*., *34*(8),1297-1306. https://doi.org/10.1177/0363546505286022.

Brughelli M., Cronin J., Mendiguchia J., Kinsella D., & Nosaka K. (2010). Contralateral leg deficits in kinetic and kinematic variables during running in Australian rules football players with previous hamstring injuries. *J. Strength Cond. Res.*, *24*(9), 2539–2544.

Carling C, Bradley P, McCall A, Dupont G. Match-to-match variability in high-speed running activity in a professional soccer team. *J Sports Sci.* 2016 Dec;34(24):2215–23. [PubMed] [Google Scholar]

Cohen S.B., & Bradley J.P. (2007). Acute proximal hamstring rupture. *J. Am. Acad. Ortho. Surg*., *15*(6), 350-355. https://doi.org/10.5435/00124635-200706000-00004.

Drezner JA. Practical management: hamstring muscle injuries. Clin J Sport Med 2003;13(01):48–52

Ekstrand, J., Hagglund, M., & Walden, M. Epidemiology of muscle injuries in professional football (soccer) (2011). *Am. J. Sports Med.*, *39*(6), 1226–1232. https://doi.org/10.1177/0363546510395879.

Ekstrand, J., Walden, M., & Hagglund, M. (2016). Hamstring injuries have increased by 4% annually in men's professional football, since 2001: A 13-year longitudinal analysis of the UEFA Elite Club injury study. *Br. J. Sports Med*., *50*(12), 731–737. https://doi.org/10.1136/bjsports-2015-095359.

Jiménez-Rubio, S., Navandar, A., Rivilla-García, J., Paredes-Hernández, V., & Gómez-Ruano, M. Á. (2019). Improvements in match-related physical performance of professional soccer players after the application of an on-field training program for hamstring injury rehabilitation. *Journal of Sport Rehabilitation*, *29*(8), 1145-1150. https://doi.org/10.1123/jsr.2019-0033.

Kujala U.M., Orava S, & Järvinen M. (1997). Hamstring injuries: current trends in treatment and prevention. *Sports Med.*, *23*(6), 397-404. https://doi.org/10.2165/00007256-199723060-00005.

McCall, A., Carling, C., Davison, M., Nedelec, M., Le Gall, F., Berthoin, S., & Dupont, G. (2015). Injury risk factors, screening tests and preventative strategies: A systematic review of the evidence that underpins the perceptions and practices of 44 football (soccer) teams from various premier leagues. Br. *J. Sports Med., 49*(9), 583–589. https://doi.org/10.1136/bjsports-2014-094104.

Mendez-Villanueva, A., Nuñez, F. J., Lazaro-Ramirez, J. L., Rodriguez-Sanchez, P., Guitart, M., Rodas, G. Martin-Garetxana, I., Lekue, J., Di Salvo, V., & Suarez-Arrones, L. (2022). Knee flexor eccentric strength, hamstring muscle volume and sprinting in elite professional soccer players with a prior strained hamstring. *Biology*, *11*(1), 69. https://doi.org/10.3390/biology11010069.

https://doi.org/10.1519/JSC.0b013e3181b603ef.

Mendiguchia J, & Brughelli M. (2011). A return-to-sport algorithm for acute hamstring injuries. *Phys. Ther. Sport, 12*(1), 2–14. https://doi.org/10.1016/j.ptsp.2010.07.003.

Mendiguchia, J., Samozino, P., Martinez-Ruiz, E., Brughelli, M., Schmikli, S., Morin, J. B., & Mendez-Villanueva, A. (2014). Progression of mechanical properties during on-field sprint running after returning to sports from a hamstring muscle injury in soccer players. International journal of sports medicine, *35*(08), 690-695. https://doi.org/10.1055/s-0033-1363192.

Mohr M, Krustrup P, & Bangsbo J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *J. Sports Sci.,21*(7), 519-528. https://doi.org/10.1080/0264041031000071182.

Orchard J, Best T.M., & Verrall G.M. (2005). Return to play following muscle strains. *Clin. J. Sport Med*., *15*(6), 436-441. https://doi.org/10.1097/01.jsm.0000188206.54984.65.

Schache AG, Dorn TW, Blanch PD, Brown NA, Pandy MG. Mechanics of the human hamstring muscles during sprinting. Med Sci Sports Exerc 2012;44(04):647–658

Schneider-Kolsky M.E., Hoving J.L., Warren P, & Connell D.A. (2006). A comparison between clinical assessment and magnetic resonance imaging of acute hamstring injuries. *Am. J. Sports Med*., *34*(6), 1008-1015. https://doi.org/10.1177/0363546505283835.

Sherry M.A., & Best T.M. (2004). A comparison of 2 rehabilitation programs in the treatment of acute hamstring strains. *J. Orthop. Sports Phys. Ther*., *34*(3), 116-125. https://doi.org/10.2519/jospt.2004.34.3.116.

Skling C.M., Tengvar M., Tarassova O., & Thorstensson A. (2014). Acute hamstring injuries in Swedish elite sprinters and jumpers: a prospective randomised controlled clinical trial comparing two rehabilitation protocols. *Br. J. Sports Med.*, *48*(7), 532-539. https://doi.org/10.1136/bjsports-2013-093214

Slavotinek J.P. (2010). Muscle injury: the role of imaging in prognostic assignment and monitoring of muscle repair. *Semin. Musculoskelet Radiol.,14*(2), 194-200. https://doi.org/10.1055/s-0030-1253160.

Śliwowski R., Jadczak Ł., Hejna R., & Wieczorek A. (2015). The Effects of Individualized Resistance Strength Programs on Knee Muscular Imbalances in Junior Elite Soccer Players. *PLoS ONE, 10*(12), e0144021. https://doi.org/10.1371/journal. pone.0144021

Thorborg K. (2012). Why hamstring eccentrics are hamstring essentials. *Br. J. Sports Med., 46*(7), 463–465. https://doi.org/10.1136/bjsports-2011-090962.

Tol, J. L., Hamilton, B., Eirale, C., Muxart, P., Jacobsen, P., & Whiteley, R. (2014). At return to play following hamstring injury the majority of professional football players have residual isokinetic deficits. *Br. J. Sports Med., 48*(18), 1364-1369. https://doi.org/10.1136/bjsports-2013-093016.

Van Der Horst, N., Backx, F. J. G., Goedhart, E. A., & Huisstede, B. M. (2017). Return to play after hamstring injuries in football (soccer): a worldwide Delphi procedure regarding definition, medical criteria and decision-making. *Br. J. Sports Med., 51*(22), 1583-1591. https://doi.org/10.1136/bjsports-2016-09720630.

Woods, C., Hawkins, R. D., Maltby, S., Hulse, M., Thomas, A., & Hodson, A. (2004). The Football Association Medical Research Programme: an audit of injuries in professional football—analysis of hamstring injuries. *Br. J. Sports Med.*, *38*(1), 36-41. https://doi.org/10.1136/bjsm.2002.002352.

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ORIGINAL SCIENTIFIC PAPER

Does complex contrast training induce higher physical fitness improvement in stronger compared to weaker individuals?

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Abstract

This study compared the effects of complex contrast training (CCT) on measures of physical fitness in stronger compared to weaker individuals. Forty-one participants were initially recruited for relative strength assessment in the back squat. Thereafter, 26 participants were purposively assigned to either a stronger group (CCT-ST; relative strength ≥1.75; n = 12) or a weaker group (CCT-WK; relative strength <1.55; n = 14). Physical fitness tests were assessed pre- and post-six weeks of CCT training. Tests included 30-m sprint for speed, standing long jump and countermovement jump for power, and isokinetic peak torque of the knee flexors and extensors for strength. ANOVA revealed a significant effect of time for all dependent variables (all p <0.001, ηp2 = 0.83 – 0.89 [large]). Post-hoc tests indicated significant performance improvements within-group for CCT-ST (all p <0.001, Hedge's g = 0.27 – 0.98 [small to moderate], %Δ = 3.0 – 16.4) and CCT-WK (all p <0.001, Hedge's g = 0.37 to 1.34 [small to large], %Δ = 3.1 – 17.4) for all dependent variables. No group-by-time interaction was found for the included variables. In conclusion, CCT intervention provided similar effects on the assessed measures of physical fitness in both stronger as well as weaker active individuals. Therefore, CCT can be an effective training strategy to improve physical fitness among active individuals irrespective of their relative strength.

Keywords: *Plyometric exercise, human physical conditioning, resistance training, muscle strength, exercise, athletic performance*

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Introduction

Complex training is a method to improve physical fitness attributes such as speed, explosive strength, maximal strength among various population groups (e.g., soccer, active adults) (Sáez de Villarreal et al., 2013; Thapa et al., 2021; Thapa et al., 2022). This training method utilizes both high-load low-velocity activity (e.g., heavy resistance exercises) (Spineti et al., 2016) and low-load high-velocity activity (e.g., plyometric exercises) (Ramirez-Campillo et al., 2022; Thapa, Kumar, & Sharma, 2020) in the same session, and specifically targets

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both the force as well as the velocity component within the force-velocity spectrum (Cormier et al., 2022). Indeed, there are four possible sequencing of the aforementioned high-load and low-load activities within a single session and recently Cormier et al. (2022) have clarified the terminology used to describe each combination. For example, when a high-load exercise is performed first and subsequently followed by a low-load exercise in a set-by-set fashion, it is termed complex contrast training (CCT). Other combinations include the high-load exercise sets to be completed first followed by the low-load exercise sets (i.e., complex descending training) and vice-versa (i.e., complex ascending training) or French contrast training which is a subset of CCT (Cormier et al., 2022).

Among the aforementioned exercise sequencing combinations, CCT is suggested to benefit by the means of two different mechanisms. Firstly, the optimization of the force-velocity spectrum using high-load (low velocity) and low-load (high velocity) exercises, and secondly, the post-activation performance enhancement (PAPE) (Blazevich & Babault, 2019), which improves the performance of low-load activity due to the potentiating effect of the heavy-load activity (Thapa, Kumar, Kumar, et al., 2020), thereby enhancing the CCT outcomes. The PAPE is additionally associated with increased muscle temperature, muscle/cellular water content, alteration in the motor pattern, or post-activation potentiation (Blazevich & Babault, 2019). The post-activation potentiation is the enhancement in the muscle force (up to ~28 seconds) due to phosphorylation of the myosin light chain in type II fibers. It is suggested that the high-load activity stimulates the Ca2+ into the myoplasm, activating the myosin light chain kinase which phosphorylates the light chains, thereby promoting the actin-myosin cross-bridges (Blazevich & Babault, 2019; Cormier et al., 2022; Sale, 2002).

Furthermore, Cormier et al. (2020) reported the CCT to be more effective in improving maximal strength, vertical jump, and sprinting ability compared to complex descending training, suggesting that the PAPE promotes added neuromuscular adaptations through CCT compared to another complex training sequencing (i.e., complex descending training). Indeed, the most important training considerations for CCT (Cormier et al., 2022) are often based on acute studies conducted on PAPE. For example, the long-term adaptations to CCT intervention on stronger versus weaker individuals (i.e., based on their initial strength) are often speculated with findings obtained from PAPE-based acute studies (Carter & Greenwood, 2014; Cormier et al., 2022). Although these speculations are based on sound rationale on how stronger individuals exhibit greater potentiation compared to weaker individuals (Seitz et al., 2014; Suchomel et al., 2016), intervention-based CCT studies are warranted to confirm whether such mechanisms affect long-term adaptations.

Moreover, a previous study by Cormie et al. (2010) reported no influence of baseline relative strength level on the magnitude of performance improvement after ballistic power training. For example, similar improvement was observed in stronger versus weaker individuals for 30 m linear sprint time (effect size 0.65 versus 0.76) (Cormie et al., 2010). Although, whether such findings observed with ballistic power training will apply to CCT intervention needs further confirmation. Therefore, this study aimed to compare the effects of CCT intervention on 30 m linear sprint, standing long jump (SLJ), countermovement jump with arm swing (CMJA) height, and peak torque of both legs during unilateral isokinetic tests (i.e., leg extension and flexion) of stronger compared to weaker individuals. Based on the available literature (Seitz et al., 2014; Suchomel et al., 2016), we hypothesized significant improvement in the dependent variables in the stronger compared to the weaker group.

Methods

Participants

The required sample size to conduct the study was estimated using statistical software (G*power; University 130 of Düsseldorf, Düsseldorf, Germany). The following variables were included in the a priori power analysis: study design, two groups; two measurements; alpha error <0.05; nonsphericity correction =1; correlation between repeated measures = 0.5; desired power (1-ß error) = 0.80; effect size (f) of 0.33 based on a previous study that investigated the effects of relative strength (i.e., stronger versus weaker individuals) after power training on 30 m linear sprint performance (Cormie et al., 2010).

The results of the a priori power analysis indicated that a minimum of 11 participants would be needed for each group to achieve statistical significance for 30 m linear sprint performance. Thereafter, 41 male participants were initially recruited for relative strength assessments in the back squat. Based on a previous study (Seitz & Haff, 2016), a total of 26 participants were finally selected who were grouped into stronger (i.e., relative strength ≥1.75; n = 12) or weaker individuals (i.e., relative strength <1.55; n = 14). Fifteen participants were excluded with a relative strength of <1.75 to ≥1.55 in order to establish two distinct experimental groups. Eligibility criteria for this study required participants to be university students who were actively participating in the conditioning program offered as a part of the course curriculum for a minimum duration of five hrs per week, had a minimum of one year of resistance training experience, and were free from lower limb injuries six months before the study. The demographics of the participants are presented in Table 1. The potential risks and benefits of this study were explained to the participants before the study. Thereafter, informed consent forms were signed by participants. The local ethical committee of Rashtriya Raksha University approved this study.

Table 1. Participant demographics for stronger and weaker groups.

	CCT-Stronger	CCT-Weaker	p-value
Age (yrs)	20.7 ± 2.0	21.0 ± 1.88	0.667
Height (cm)	170.8 ± 7.4	177.5 ±7.7	0.032
Body Mass (kg)	61.9±6.4	68.0±7.0	0.031
1RM squat (kg)	112.9 ± 11.3	95.4±7.5	<0.001
Relative strength (kg/kg)	1.8 ± 0.1	1.4±0.1	<0.001

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Procedure

Before the start of the intervention, familiarization sessions were conducted for the CCT exercises and testing procedures to reduce the learning effects. Demographic data were collected and one-repetition maximum (1RM) tests for back squats were performed during familiarization sessions. Thereafter, the participants were grouped based on their relative strength (i.e., 1RM/body mass) into two experimental groups, i.e., stronger individuals (CCT-ST; relative strength of 1.75 or more) and weaker individuals (CCT-WK; relative strength less than 1.55). A schematic representation of the study design is in Figure 1. Participants were asked to refrain from any strenuous activity for 24 hrs and were asked to eat a habitual meal and refrain from consuming caffeine for three hrs before testing. A two (within-subject; pre-post) by two (between-subject; CCT-ST, CCT-WK) experimental design with the baseline scores as a covariate was used to compare the effects of training intervention on 30 m linear sprint, SLJ, CMJ, and peak torque of both legs during unilateral isokinetic tests (i.e., leg extension and flexion). Pre-post measurements were performed at similar times during the day for all participants to minimize circadian effects, with 30 m linear sprint, SLJ, and CMJ conducted on day one and isokinetic testing conducted on day two. The sequence of testing order was the same for all the participants. Upon arrival for testing, participants underwent a 10-min general warm-up procedure.

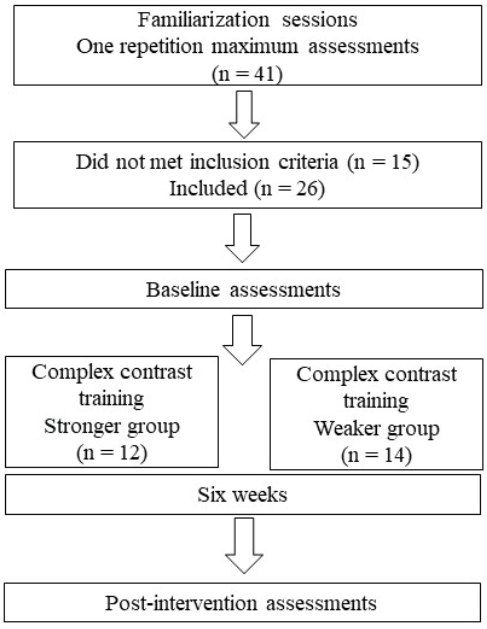

Figure 1. Schematic representation of the study

Training intervention

Before the start of the training intervention, 1RM assessments were conducted according to methods outlined by Faude et al. (2013) to define the intensity of each participant for bench press, barbell lunges, Romanian deadlift, and squat. Before each assessment a 10-min general warm-up was conducted, including, jogging, dynamic stretching, and body weight exercise (e.g., freehand squat, walking lunges, push-ups). A short specific warm-up consisting of five to ten repetitions with a load of 40 – 60% as well as three to five repetitions with about 60 – 80% of the estimated 1RM was performed. Thereafter, the load was

Table 2. Protocols for complex contrast training intervention.

	High-load resistance activity		Low-load high-velocity activity	
	Exercise	Sets × reps	Exercise	Sets × reps
Week 1-2	Squat	3 × 15	Squat jump	3 × 6
65 % 1RM	Romanian deadlift	3 × 15	Kettlebell swing	3 × 10
	Barbell lunge	3 × 15	Barbell high knees	3 × 15 sec
	Bench press	3 × 15	Plyo-push up	3 × 6
Week 3-4	Squat	3 × 10	Squat jump	3 × 8
75% 1RM	Romanian deadlift	3 × 10	Kettlebell swing	3 × 10
	Barbell lunge	3 × 10	Barbell high knees	3 × 20 sec
	Bench press	3 × 10	Plyo-push up	3 × 8
Week 5-6	Squat	3 × 6	Squat jump	3 × 10
85% 1RM	Romanian deadlift	3 × 6	Kettlebell swing	3 × 10
	Barbell lunge	3 × 6	Barbell high knees	3 × 25 sec
	Bench press	3 × 6	Plyo-push up	3 × 10

gradually increased in steps of 10 kg or less to achieve the 1RM within a maximum of five sets. The rest between 1RM attempts was four mins.

The training intervention was conducted for a period of six-week duration. The participants in both CCT-ST and CCT-WK had similar activity levels during the intervention period. The exercises used in the contrast pairs for CCT were squat with CMJ, lunges with barbell high knees, Romanian deadlift with kettlebell swings, and bench press with plyometric push-ups (Kumar et al., 2023). Biomechanically similar exercises were selected for pairing as per recommendations from Cormier et al. (2022). More details on the training protocol used across the six-week intervention are presented in Table 2.

Assessments

30-m Linear sprint test

The protocol was adapted from the methods outlined in a previous study (Singh, Kushwah, Singh, Thapa, et al., 2022) and conducted on an outdoor synthetic track. Participants were instructed to stand behind a start line with a self-selected leg forward and start only after the command of the assessor. Two independent assistants who were not part of this study were recruited as timekeepers (between timekeepers interclass correlation coefficients [ICC] were 0.99) and assigned to record the timing of each trial using a hand stopwatch (Casio S053 HF-70W-1DF, Casio Computer Co., Ltd., Tokyo, Japan). The times recorded by the two timekeepers were averaged for analysis. Three trials were conducted with a one-min recovery between trials, and the fastest trial was selected for further analysis. The ICC for test-retest was 0.86 (95% confidence interval [CI]: 0.61 – 0.95).

Standing long jump

The protocol was adapted from methods outlined in a previous study (Singh, Kushwah, Singh, Ramirez-Campillo, et al., 2022) and conducted on a synthetic outdoor track. Participants stood behind a marked start line with feet slightly apart and were instructed to swing their arms and perform a countermovement to a self-selected depth before taking off and landing with both legs. Verbal encouragement was provided to jump as far as possible. The measurement was recorded from the start line to the nearest point of contact on the landing (i.e., the back of the nearest heel). Three jumps were performed with one-min rest between jumps, and the longest jump was selected for analysis. The ICC for test-retest was 0.93 (95% CI: 0.81 – 0.98).

Countermovement jump with arm swing

An inertial moment sensor (BTS G-walk, Italy) was used to measure the vertical jump height during CMJ. A pilot study reported the sensor to be valid and reliable (concurrent to MyJump 2 [ICC = 0.96, r = 0.973, mean difference = 0.2 ± 1.3, and t-test p = 0.550]) for measuring the CMJ performance. The sensor was placed on the lower back using a belt with the center of the device at the fifth lumbar vertebrae. Participants stood with feet slightly apart and were instructed to swing their arms and perform a countermovement to a self-selected depth before taking off and landing with both legs. Knee flexion was not permitted during the flight phase of the jump. Three trials were performed with one-min rest between jumps, and the best trial was selected for analysis. The ICC for test-retest was 0.96 (95% CI: 0.89 – 0.99).

Isokinetic tests

The tests were conducted on a HUMAC NORM isokinetic dynamometer (Computer Sports Medicine Inc., Stoughton, USA). A general 10-min warm-up was completed before the test which included jogging and dynamic stretching of the lower limbs. Thereafter participants sat on the machine's chair, with the axis of rotation of the dynamometer arm aligned with the axis of rotation of the knee. The 'Knee Extension/Flexion' test was selected to be performed with isokinetic 'CONC/CONC' mode. The right side was always selected first across all testing sessions. The test protocol included a set of six repetitions at 60°/seconds speed with one-min of rest between sets. Verbal instructions were provided to push and pull as hard and fast as possible throughout the full range of motion. Furthermore, the screen was positioned so participants could see real-time feedback on their effort. Two sets were performed and the highest peak torque (PT) value obtained was selected for analysis. The ICC for test-retest was 0.99 (95% CI: 0.98 – 1.00) for right knee extension, 0.97 (95% CI: 0.94 – 0.99) for right knee flexion, 0.93 (95% CI: 0.84 – 0.99) for left knee extension, and 0.98 (95% CI: 0.97 – 0.99) for left knee flexion.

Statistical analysis

The analyses were conducted using IBM SPSS version 20.0.0 (IBM, New York, USA). The normality of data was verified using the Shapiro-Wilk test. Data are presented as means and standard deviations. A two (pre-post intervention) by two (CCT-ST, CCT-WK) mixed ANOVA with the baseline scores as a covariate was used to analyze the exercise-specific effects. Percentage change scores were also calculated for each variable in each group using the equation in Microsoft Excel ([meanpost – meanpre] / meanpre) × 100. Effects sizes (ES) in the form of partial eta squared (ηp2) were used from ANOVA output. Hedge's g effect size derived from mean and standard deviations of pre- and post-measurements were calculated to assess within-group changes for each group. The magnitude of effects for ηp2 was interpreted as small (<0.06), moderate (≥0.06-0.13), and large (≥0.14) (Cohen, 1988), while Hedge's g was interpreted as trivial (<0.2), small (0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0), very large (>2.0-4.0) and extremely large (>4.0) (Hopkins et al., 2009). The ICC between trials and assessors was interpreted as poor (<0.5), moderate (0.5-0.75), good (0.75-0.9), and excellent (>0.9) reliability based on the lower bound of the 95% confidence interval (CI; ICC95%CI lower bound) (Koo & Li, 2016). Statistical significance was set at $p \leq 0.05$.

Results

No participants dropped out of the study, sustained any injuries, or missed any training sessions. The results for all dependent variables of the main analysis are presented in Table 3, with a graphical representation of pre-post percentage change in Figure 2. Individual response to CCT is represented in Figure 3, Figure 4 and Figure 5, respectively.

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Table 3. Statistical comparisons between complex contrast training (CCT) stronger versus weaker group.

	CCT-stronger (n =12)			CCT-weaker (n =14)			Time	Time × Group	ANCOVA
	Pre-test	Post-test	p-value [g] Magnitude	Pre-test	Post-test	p-value [g] Magnitude	p-value [ηp^2] Magnitude	p-value [ηp^2] Magnitude	p-value
	Mean ± SD			Mean ± SD					
30 m sprint (s)	4.61 ± 0.20	4.47 ± 0.18	<0.001 [0.71] Moderate	4.79 ± 0.18	4.64 ± 0.18	<0.001 [0.81] Moderate	<0.001 [0.83] Large	0.523 [0.02] Small	0.988
Standing long jump (m)	2.38 ±0.16	2.54±0.18	<0.001 [0.91] Moderate	2.37±0.15	2.51±0.15	<0.001 [0.91] Moderate	<0.001 [0.86] Large	0.330 [0.04] Small	0.340
Countermovement jump (cm)	38.82±5.29	45.18±7.10	<0.001 [0.98] Moderate	40.21±5.08	47.21±5.04	<0.001 [1.34] Large	<0.001 [0.87] Large	0.542 [0.02] Small	0.599
PT leg extension (right) (Nm)	166.0 ± 47.3	180.8±49.6	<0.001 [0.29] Small	166.4±37.7	180.5±36.7	<0.001 [0.37] Small	<0.001 [0.85] Large	0.805 [0.00] Small	0.809
PT leg extension (left) (Nm)	176.7±51.8	191.6±54.0	<0.001 [0.27] Small	159.1±30.5	171.6±29.6	<0.001 [0.40] Small	<0.001 [0.89] Large	0.223 [0.06] Moderate	0.294
PT leg flexion (right) (Nm)	112.4±21.6	122.3±24.9	<0.001 [0.41] Small	104.6±21.7	113.6±21.9	<0.001 [0.40] Small	<0.001 [0.85] Large	0.543 [0.02] Small	0.747
PT leg flexion (left) (Nm)	113.7±25.0	123.8±27.6	<0.001 [0.37] Small	99.4±20.4	107.6±20.6	<0.001 [0.39] Small	<0.001 [0.86] Large	0.450 [0.025] Small	0.450

Note: g – Hedges' g; Nm – Newton meters; PT – peak torque; ηp^2 – partial eta squared ; SD - standard deviation; ANCOVA - analysis of covariance

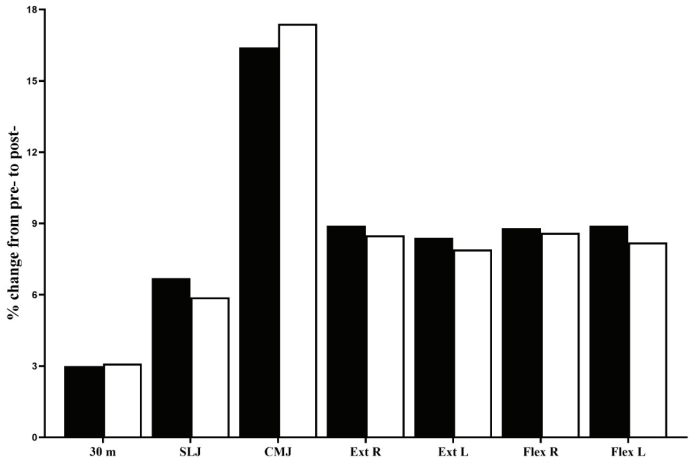

Figure 2. Relative (%) change in dependent variables between pre- and post-training intervention for the complex contrast training stronger group (CCT-ST; black bars) versus weaker group (CCT-WK; white bars). For all parameters, a significant effect of time was noted. No group-by-time interaction effects were noted. Hedge's g ranged from 0.27 to 0.98 for CCT-ST and from 0.37 to 1.34 for CCT-WK.

Note: 30 m (linear sprint time), CMJ (countermovement jump height), Ext (maximal knee extension isokinetic torque), Flex (maximal knee flexion isokinetic torque), L (left), R (right), SLJ (standing long jump distance).

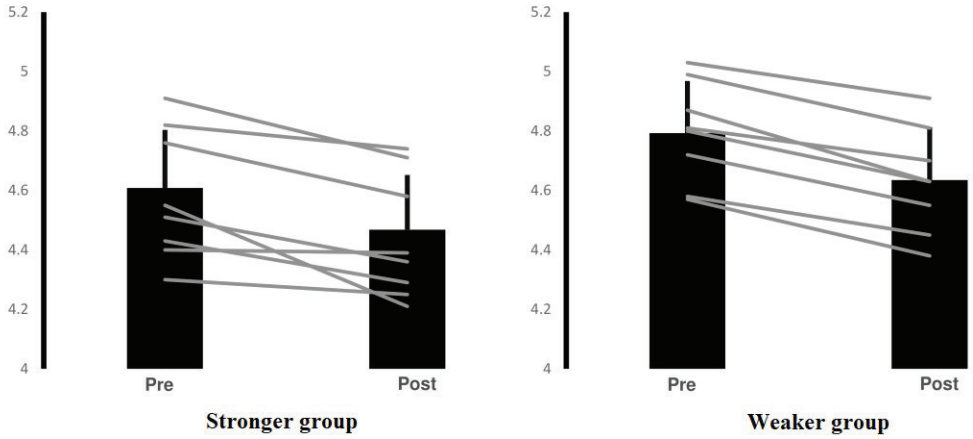

Figure 3. Mean (column) ± standard deviation (error bar) along with individual responses (grey lines) for 30-m linear sprint time prior to and following a six weeks CCT intervention between stronger and weaker groups

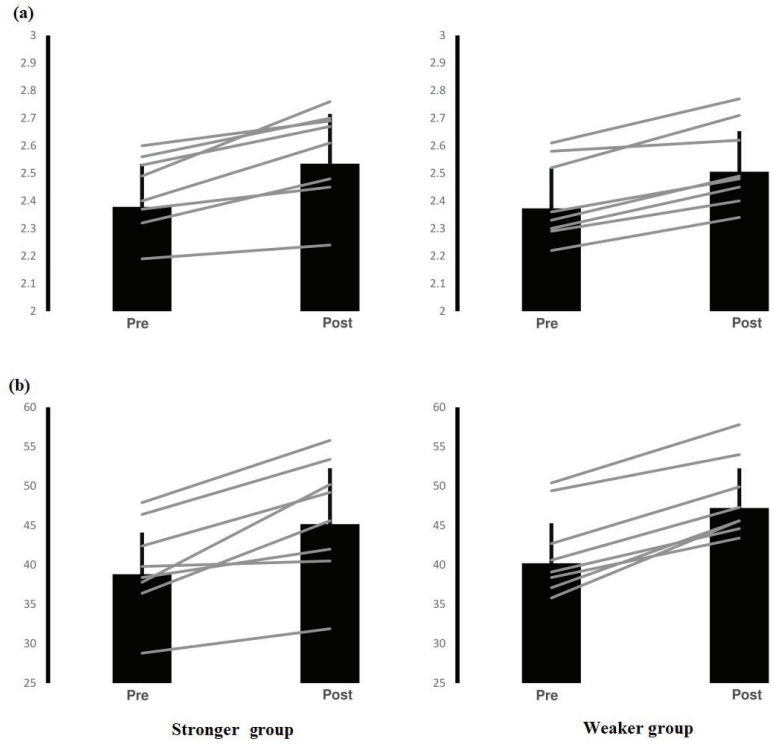

Figure 4. Mean (column) ± standard deviation (error bar) along with individual responses (grey lines) for (a) standing long jump distance and (b) countermovement jump height prior to and following a six weeks CCT intervention between stronger and weaker groups.

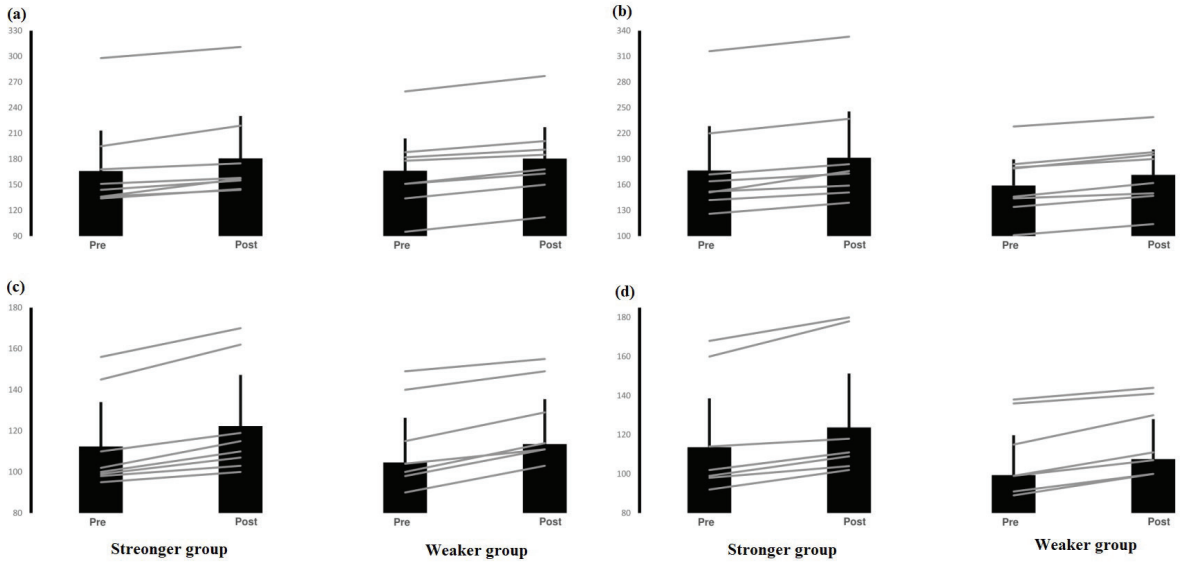

Figure 5. Mean (column) ± standard deviation (error bar) along with individual responses (grey lines) for (a) peak torque of right leg during extension, (b) peak torque of left leg during extension, (c) peak torque of right leg during flexion, and (d) peak torque of left leg during flexion prior to and following a six weeks CCT intervention between stronger and weaker groups.

There was a significant main effect of time with CCT intervention in all dependent variables (all $p < 0.001$; $\eta p2 = 0.83 – 0.89$ [all large]). However, no significant time × group interaction effects was observed for the dependent variables ($p = 0.223 – 0.805$; $\eta p2 = 0.00 – 0.06$ [small to moderate]). Furthermore, post-hoc tests using Bonferroni adjusted paired t-test revealed significant improvements in all dependent variables in CCT-ST (all $p < 0.001$, $g = 0.27 – 0.98$ [small to moderate], $\%\Delta = 3.0 – 16.4$) and CCT-WK (all $p < 0.001$, $g = 0.37 – 1.34$ [small to large], $\%\Delta = 3.1 – 17.4$). In addition, post-hoc tests with baseline scores as covariates showed no differences between CCT-ST and CCT-WK ($p = 0.294 – 0.988$).

Discussion

The study reported improvement in both stronger and weaker individuals after a six-weeks CCT intervention. The magnitude of improvement in CCT-ST was small for isokinetic leg strength and moderate for 30 m sprint time, SLJ distance, and CMJ height. While the magnitude of improvement in

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CCT-WK was small for isokinetic leg strength, moderate for 30 m sprint time and SLJ distance, and large for CMJ height. However, no significant differences were found in improvement with CCT between stronger or weaker individuals.

The improvement in both CCT intervention groups may be attributed to specific neuromuscular adaptations that may have led to an improved stretch-shortening cycle, increased motor unit recruitment, firing frequency, intra-and-inter-muscular coordination, and morphological changes that help with muscle's force-generating capacity (Cormier et al., 2022; Thapa et al., 2021; Thapa et al., 2022). Furthermore, incorporating high-load low-velocity and low-load high-velocity exercises during CCT may induce specific neuromuscular adaptations that optimize the force-velocity relationship (Cormier et al., 2022; Thapa et al., 2021; Thapa et al., 2022). Although the heavy resistance and plyometric exercises involves both the force and velocity components, it is possible to majorly target only one component (i.e., force or velocity) of the force-velocity spectrum (Cormier et al., 2022). This implicates that the heavy resistance exercises (greater force component) and plyometric exercises (greater velocity component) are placed at the opposite end of the force-velocity curve. However, including both resistance as well as plyometric exercise within a single training session as in the CCT format, may allow improvements across the spectrum (Cormier et al., 2022). In addition, optimization of the force-velocity relationship also helps recruit fast-twitch muscle fibers that underpin athletic performance (e.g., sprints, jumps) (Jiménez-Reyes et al., 2022; Macaluso et al., 2012).

Of note, previous studies have also reported hormonal adaptations such as increased testosterone level concentration in male soccer athletes following a six-week CCT intervention (Ali et al., 2019). Similarly, another six-week CCT study reported an increase in leg volume in junior male soccer players (Hammami et al., 2017). These hormonal and structural adaptations might be responsible for the strength-power development reflected through increased peak torque during the isokinetic assessments in our current study. In addition to the aforementioned rationale, another possible mechanism that may have contributed to the positive improvements in both CCT groups is the post-activation potentiation of performance (Blazevich & Babault, 2019). This phenomenon is suggested to work on the potentiating effects that higher-load activity may generate on the immediate performance of a lower-load activity (Blazevich & Babault, 2019). Indeed, Cormier et al. (2020) have reported that using high-load resistance exercises and low-load plyometric exercises in the CCT format is superior to performing the combination of the exercises in other formats (e.g., heavy resistance exercises completed first followed by plyometric exercises sets) in improving sprints, jumps, change of direction, and maximal strength.

Furthermore, our study reported that the initial relative strength level did not influence the improvement gains after six weeks of CCT. Previous studies have reported similar findings with ballistic power training (Cormie et al., 2010) and traditional resistance training protocol (Mangine et al., 2018). Cormie et al. (2010) compared the magnitude of performance improvement between strong and weak individuals after 10 weeks of a ballistic power training program. Both experimental groups reported significant improvements in jump and sprint performance after 10 weeks of training with no significant differences between strong and weak individuals. Similarly, Mangine et al. (2018) reported no differences in 1RM back squat, muscle size of rectus femoris, and vastus lateralis between strong and weak athletes after eight weeks of resistance training. One possible moderating factor that may have elucidated such findings is the principle of diminishing returns which suggests initial improvements are easily invoked and further improvements are harder to achieve. According to the aforementioned principle, the training program for individuals with greater strength levels needs to contain variability compared to weaker individuals to observe further enhancement (Newton & Kraemer, 1994). However, in our study both stronger and weaker individuals underwent similar training programs (i.e., frequency, intensity, time, type) during the six weeks. Although the training program was designed to target specificity to common athletic movements, the training may have lacked variability for the stronger individuals to observe greater improvement. Indeed, although non-significant (between groups), one finding reported in our study was higher magnitude improvement observed in CMJ performance for CCT-WK compared to CCT-ST (Hedge's g 1.34 versus 0.98). This difference in the magnitude of improvement for CMJ, favoring the weaker individuals may be in line with the principle of diminishing returns as priorly mentioned, where the weaker individuals had a greater window of oppurtunity for improvement (Sale, 1987). In line with this, the CCT has also been reported to increase the maximal squat strength among male soccer athletes (Thapa et al., 2022), that has shown to be strongly correlated with the vertical jump performance (Wisløff et al., 2004). Therefore, a speculative argument could be that the CCT-WK also improved the maximal strength to a greater extent compared to the CCT-ST, considering the greater window of oppurtunity and principle of diminishing returns (Newton & Kraemer, 1994; Sale, 1987) and thus a greater magnitude improvement in the CMJ.

There are limitations of this study that should be acknowledged. Firstly, our study included only active male participants, therefore the findings should not be extrapolated to females or athletes. Secondly, the training intervention was limited to a six-week duration. An investigation of longer duration may provide further information as to how stronger and weaker individuals adapt to CCT. Thirdly, this study included a small sample size. Although we conducted a sample size estimation before conducting the study, larger sample size may be required to support current findings. Fourthly, the absence of biochemical or physiological data collection. Such data would provide a better interpretation of the results.

Conclusion

Our findings suggest that there is no influence of initial strength level on improvement in physical fitness attributes after six weeks of CCT intervention. Therefore, CCT can be an effective training strategy to improve physical fitness among active individuals irrespective of their relative strength. However, the magnitude of improvements in stronger individuals was small for isokinetic leg strength and moderate for 30 m sprints, SLJ, and CMJ. Whereas the magnitude of improvements in weaker individuals was small for isokinetic leg strength, moderate for 30 m sprint and SLJ, and large for CMJ. Furthermore, future longitudinal studies (i.e., more than six-weeks duration) involving higher number of participants should examine if similar findings are observed in females as

well as athletes participating in different sports. In addition, future studies may also examine how variability in the frequency, intensity, time, and type of exercises may affect the outcomes between stronger versus weaker individuals.

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Conflict of Interest

All authors declare no conflicts of interest regarding the content of this study.

Availability of data and material

All data generated or analyzed during this study will be/are included in the published article as Table(s) and Figure(s). Any other data requirement can be directed to the corresponding author upon reasonable request.

Author's contributions

RKT and GK conceived the idea and designed the study. GK was involved in data collection procedures. RKT performed the formal analysis and interpretation of the data. RKT and GK wrote or revise the draft of the manuscript. Both authors read and approved the final version of the manuscript.

References

Ali, K., Verma, S., Ahmad, I., Singla, D., Saleem, M., & Hussain, M. E. (2019). Comparison of complex versus contrast training on steroid hormones and sports performance in male soccer players. *Journal of Chiropractic Medicine*, *18*(2), 131-138. https://doi.org/10.1016/j.jcm.2018.12.001

Blazevich, A. J., & Babault, N. (2019). Post-activation potentiation versus post-activation performance enhancement in humans: historical perspective, underlying mechanisms, and current issues. *Frontiers in Physiology*, *10*, 1359. https://doi.org/10.3389/fphys.2019.01359

Carter, J., & Greenwood, M. (2014). Complex training reexamined: Review and recommendations to improve strength and power. *Strength & Conditioning Journal*, *36*(2), 11-19.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (Second ed.). Lawrence Erlbaum Associates.

Cormie, P., McGuigan, M. R., & Newton, R. U. (2010). Influence of strength on magnitude and mechanisms of adaptation to power training. *Medicine & Science in Sports & Exercise*, *42*(8), 1566-1581. https://doi.org/10.1249/MSS.0b013e3181cf818d

Cormier, P., Freitas, T. T., Loturco, I., Turner, A., Virgile, A., Haff, G. G., Blazevich, A. J., Agar-Newman, D., Henneberry, M., Baker, D. G., McGuigan, M., Alcaraz, P. E., & Bishop, C. (2022). Within session exercise sequencing during programming for complex training: historical perspectives, terminology, and training considerations. *Sports Medicine*. https://doi.org/10.1007/s40279-022-01715-x

Cormier, P., Freitas, T. T., Rubio-Arias, J., & Alcaraz, P. E. (2020). Complex and contrast training: does strength and power training sequence affect performance-based adaptations in team sports? a systematic review and meta-analysis. *Journal of Strength & Conditioning Research*, *34*(5), 1461-1479. https://doi.org/10.1519/jsc.0000000000003493

Faude, O., Roth, R., Di Giovine, D., Zahner, L., & Donath, L. (2013). Combined strength and power training in high-level amateur football during the competitive season: a randomised-controlled trial. *Journal of Sports Science*, *31*(13), 1460-1467. https://doi.org/10.1080/02640414.2013.796065

Hammami, M., Negra, Y., Shephard, R. J., & Chelly, M. S. (2017). The effect of standard strength vs. contrast strength training on the development of sprint, agility, repeated change of direction, and jump in junior male soccer players. *Journal of Strength & Conditioning Research*, *31*(4), 901-912. https://doi.org/10.1519/jsc.0000000000001815

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, *41*(1), 3-13. https://doi.org/10.1249/MSS.0b013e31818cb278

Jiménez-Reyes, P., Garcia-Ramos, A., Párraga-Montilla, J. A., Morcillo-Losa, J. A., Cuadrado-Peñafiel, V., Castaño-Zambudio, A., Samozino, P., & Morin, J. B. (2022). Seasonal changes in the sprint acceleration force-velocity profile of elite male soccer players. *Journal of Strength & Conditioning Research*, *36*(1), 70-74. https://doi.org/10.1519/jsc.0000000000003513

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine*, *15*(2), 155-163. https://doi.org/10.1016/j.jcm.2016.02.012

Kumar, G., Pandey, V., Thapa, R. K., Weldon, A., Granacher, U., & Ramirez-Campillo, R. (2023). Effects of exercise frequency with complex contrast training on measures of physical fitness in active adult males. *Sports*, *11*(1), 11. https://www.mdpi.com/2075-4663/11/1/11

Macaluso, F., Isaacs, A. W., & Myburgh, K. H. (2012). Preferential type II muscle fiber damage from plyometric exercise. *Journal of Athletic Training*, *47*(4), 414-420. https://doi.org/10.4085/1062-6050-47.4.13

Mangine, G. T., Gonzalez, A. M., Townsend, J. R., Wells, A. J., Beyer, K. S., Miramonti, A. A., Ratamess, N. A., Stout, J. R., & Hoffman, J. R. (2018). Influence of Baseline Muscle Strength and Size Measures on Training Adaptations in Resistance-trained Men. *International Journal of Exercise Science*, *11*(4), 198-213.

Newton, R. U., & Kraemer, W. J. (1994). Developing Explosive Muscular Power: Implications for a Mixed Methods Training Strategy. *Strength & Conditioning Journal*, *16*(5), 20-31.

Ramirez-Campillo, R., Perez-Castilla, A., Thapa, R. K., Afonso, J., Clemente, F. M., Colado, J. C., de Villarreal, E. S., & Chaabene, H. (2022). Effects of Plyometric Jump Training on Measures of Physical Fitness and Sport-Specific Performance of Water Sports Athletes: A Systematic Review with Meta-analysis. *Sports Medicine Open*, *8*(1), 108. https://doi.org/10.1186/s40798-022-00502-2

Sáez de Villarreal, E., Requena, B., Izquierdo, M., & Gonzalez-Badillo, J. J. (2013). Enhancing sprint and strength performance: combined versus maximal power, traditional heavy-resistance and plyometric training. *Journal of Science & Medicine in Sport*, *16*(2), 146-150. https://doi.org/10.1016/j.jsams.2012.05.007

Sale, D. G. (1987). Influence of exercise and training on motor unit activation. *Exercise & Sport Sciences Reviews*, *15*, 95-151.

Sale, D. G. (2002). Postactivation potentiation: role in human performance. *Exercise & Sport Sciences Reviews*, *30*(3), 138-143. https://doi.org/10.1097/00003677-200207000-00008

Seitz, L. B., de Villarreal, E. S., & Haff, G. G. (2014). The temporal profile of postactivation potentiation is related to strength level. *Journal of Strength & Conditioning Research*, *28*(3), 706-

 DOI 10.26773/mjssm.230306

715. https://doi.org/10.1519/JSC.0b013e3182a73ea3

Seitz, L. B., & Haff, G. G. (2016). Factors Modulating Post-Activation Potentiation of Jump, Sprint, Throw, and Upper-Body Ballistic Performances: A Systematic Review with Meta-Analysis. *Sports Medicine*, *46*(2), 231-240. https://doi.org/10.1007/s40279-015-0415-7

Singh, G., Kushwah, G., Singh, T., Ramirez-Campillo, R., & Thapa, R. K. (2022). Effects of six weeks outdoor versus treadmill running on physical fitness and body composition in recreationally active young males: a pilot study. *PeerJ*, *10:e13791*. https://doi.org/10.7717/peerj.13791

Singh, G., Kushwah, G. S., Singh, T., Thapa, R. K., Granacher, U., & Ramirez-Campillo, R. (2022). Effects of sand-based plyometric-jump training in combination with endurance running on outdoor or treadmill surface on physical fitness in young adult males. *Journal of Sports Science and Medicine*, *21*(2), 277-286.

Spineti, J., Figueiredo, T., Bastos, D. E. O. V., Assis, M., Fernandes, D. E. O. L., Miranda, H., Machado, D. E. R. R. V. M., & Simão, R. (2016). Comparison between traditional strength training and complex contrast training on repeated sprint ability and muscle architecture in elite soccer players. *Journal of Sports Medicine & Physical Fitness*, *56*(11), 1269-1278.

Suchomel, T. J., Sato, K., DeWeese, B. H., Ebben, W. P., & Stone, M. H. (2016). Potentiation Following Ballistic and Nonballistic Complexes: The Effect of Strength Level. *Journal of Strength & Conditioning Research*, *30*(7), 1825-1833. https://doi.org/10.1519/jsc.0000000000001288

Thapa, R. K., Kumar, A., Kumar, G., & Narvariya, P. (2020). A combination of ballistic exercises with slow and fast stretch-shortening cycle induces post-activation performance enhancement. *Trends in Sport Sciences*, *27*(4), 203-211. https://doi.org/10.23829/TSS.2020.27.4-3

Thapa, R. K., Kumar, A., & Sharma, D. (2020). Effect of drop height on different parameters of drop jump among soccer players. *Trends in Sport Sciences*, *27*(1), 13-18. https://doi.org/10.23829/TSS.2020.27.1-2

Thapa, R. K., Lum, D., Moran, J., & Ramirez-Campillo, R. (2021). Effects of complex training on sprint, jump, and change of direction ability of soccer players: A systematic review and meta-analysis. *Frontiers in Psychology*, *11*, 627869. https://doi.org/10.3389/fpsyg.2020.627869

Thapa, R. K., Narvariya, P., Weldon, A., Talukdar, K., & Ramirez-Campillo, R. (2022). Can complex contrast training interventions improve aerobic endurance, maximal strength, and repeated sprint ability in soccer players? A systematic review and meta-analysis. *Montenegrin Journal of Sports Science and Medicine*, *11*(2), 45-55. https://doi.org/10.26773/mjssm.220906

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, *38*(3), 285-288. https://doi.org/10.1136/bjsm.2002.002071

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REVIEW ARTICLE

Teaching models in physical education: current and future perspectives

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Abstract

The study of teaching models used during the discipline of physical education has been the object of analysis over the last few years. Even so, due to the increasing reduction in the levels of participation in sport, there is a need to reflect on the most effective pedagogy and teaching models to reverse this trend. For these reasons, this review has as main objective to synthesize the teaching methodologies present in the literature. The search strategy comprised search words that combined one of two primary keywords ("physical education", "teaching-learning process", and "teachers), with a second keyword ("model", "pedagogy", "competency") and a third keyword ("sports", "games"). After applying the inclusion and exclusion criteria, 28 articles were counted for analysis. The results indicate that there is a need to strengthen the relationship between pedagogical theory and practice through innovation, which can emerge from the experimentation of new models, strategies, and teaching contents so that the discipline of physical education, in order to contribute unequivocally to the training of children and young people, resulting in lifelong involvement in physical activity.

Keywords: *Teachers, Teaching Models, Physical Education, Children*

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Introduction

Over the last five years, the professional training of Health and Physical Education (HPE) teachers has undergone changes (Ferry & Romar, 2020; Green et al., 2018; Winslade & Deborah, 2020). For example, in Australia, there appears to be a greater emphasis placed on personal, community and social health, while lacking adequate training of pre-service teachers to delivery physical education (PE) curriculum effectively (Varea, 2018). However, according to past investigations (Kirk, 2013; Siedentop et al., 2011) the breadth of pre-service teacher training into PE has not be questioned, but the training of teaching models predominantly focused traditional approaches to teaching team sports has been a topic of contention. Examination of professional training of HPE teachers regarding effective pedagogy and teaching models is necessary considering that the global physical activity levels and participation in sport are decreasing amongst young people and needs to be reversed (Guthold et al., 2020; Vukelja et al., 2022).

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It is known, that through HPE, pedagogical approaches to teaching students the skills, tactics and movement strategies to participate competently continue to favor a traditionalist approach. Indeed, it seems necessary to resort to contemporary teaching models that adapt to the school context and increase students' motivation to get involved in the proposed activities (Donnelly et al., 2017; Metzler, 2017). Previous studies show that most HPE teachers continue to regularly use analytical models in the teaching-learning process (Kirk, 2013; Wang & Ha, 2009), although current scientific studies suggest the use of other approaches (Ferraz et al., 2021; Metzler, 2017).

The teaching of PE is a continuous process, which intrinsically depends on new theories evolving that support effective pedagogy to the teaching-learning process (Parra-González et al., 2021; Steinberg et al., 2020; Zach, 2020). Recently, and following the avant-garde theories that emphasize the reorganization of the process of motor development and performance in a school context, contemporary teaching models have been promoting innovative processes in the form of student development (Anderson, 2018; Gimazutdinov, 2020). Teaching models are characterized as long term development plans for teaching that convey a central idea and that must follow a unified theoretical structure (Casey & MacPhail, 2018). These models must use a technical language and use the most valid assessment method for learning, thus being a means of facilitating the teacher's decision making within a work structure (Dyson et al., 2004; Wallhead & Ntoumanis, 2004). Thus, and considering the needs of current generations, it seems important to carry out a review of the current state of knowledge about teaching models in HPE and their implications in the teaching-learning process in school context.

There is a wide range of teaching models, which vary in their approach between more teacher-centered models and those that allow more space for student discovery and initiative, so it is essential to find a balance between the needs of direction and support and the need to exercise autonomy, in order to create favorable conditions to encourage the practice of sports throughout life (Bayraktar, 2011). The literature reports the Sports Education Model (SEM); Direct Instruction Model (DIM); Teaching Games for Understanding (TGfU); Non-linear Pedagogy (NLP); Progressive Approach to Game Model (PAGM); Developmental Model of Game Tasks (GMDT); Competency Model in Invasion Games (CMIG) as models that can be used in the teaching process. However, it is important to note that there is no model that is suitable for all learning involvements and therefore there are fundamental issues that must be taken into account by the teacher, in order to use the teaching models that best suit the needs of students (Rink, 2001). Furthermore, disproportionate comparisons were made over time between teaching models, without considering their implementation processes, which led to decontextualized generalizations of teaching processes (Metzler, 2017).

The heterogeneity of learning groups presents a major challenge for PE teachers (Decristan et al., 2019; Parsons et al., 2018; van de Pol et al., 2010). Evidence indicates that it is critical for teachers to adapt their teaching to the diverse needs of their students (Goodyear & Dudley, 2015; Wibowo, 2020). Heterogeneity is a reality in all groups of students, regardless of the teaching model, since each individual has their individual characteristics and ideas (Rovegno & Dolly, 2006; Wibowo et al., 2014). Thus, to enhance their students' development, teachers must have a broad knowledge of the different existing teaching models (Darnis-Paraboschi et al., 2005; Metzler, 2017) and this seems to be one of the biggest challenges of teachers today where contexts are highly volatile due to uncertainty. For these reasons, exploring theoretical considerations, current issues and future perspectives can shed light on the current scientific landscape on this research topic. Thus, the objective of this review was to synthesize the published literature on teaching methodologies in HPE.

Materials and Methods

Search Strategy

The present review was conducted using the PRISMA guidelines (Moher et al., 2009). A search was performed in the Web of Science, Scopus and PubMed databases between January and June 2022 using a boolean opoerator. The detailed form used for the inclusion of articles is illustrated in Figure

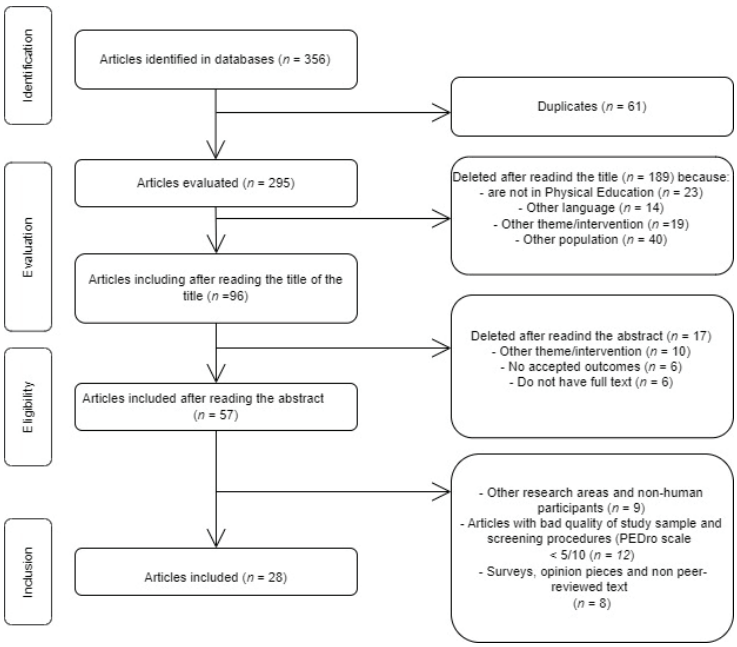

Figure 1. PRISMA flowchart of included studies

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1. Overall, 295 studies were identified after removing the duplicates, and after this screening, 96 articles were included in this review. The search strategy comprised search words that combined one of two primary keywords ("physical education", "teaching-learning process", and "teachers), with a second keyword ("model", "pedagogy", "competency") and a third keyword ("sports", "games").

The articles were screened based on the evaluation of the title and abstract. All articles that did not focus on the investigation were excluded. In total, 57 articles were considered relevant for this review. All articles have been read in detail and assessed for relevance and quality by two senior researchers with experience and relevant publications in the field. Discrepancies between the authors in the study selection were solved with support a third reviewer. The authors did not prioritize authors or journals. All articles that did not meet the criteria were excluded. A total of 61 duplicate records were removed, and 29 articles were removed based on the full text content, different outcomes, unavailable of full text, PEDro Scale was used to inclusion and exclusion criteria. After this procedure, 28 articles remained for analysis (Figure 1).

Selection Criteria

Papers were considered for inclusion in this review if they met the following criteria: (1) original articles about professional training of HPE; (2) studies current scientific overviews in the teaching-learning process; (3) studies which addresses at least one of the following issues in the HPE such as SEM; DIM , TGFU; NLP; PAGM; GMDT and CMIG; (5) studies of human physical, reporting the Sports Sciences as scope; (6) original article published in a peer-review journal; (7) full text available in English; (8) article reported sample and screening procedures (e.g. data collection, study design, instruments, and the outcomes).

The exclusion criteria were: (1) others research areas and non-human participants; (2) articles with bad quality in the description of study sample and screening procedures (e.g., data collection, study design, instruments, and the measures) according to PEDro scale; and (3) surveys, opinion pieces, non-peer-reviewed text.

Quality Assessment

The methodological quality of the studies was assessed using, the PEDro. This scale developed to be used for randomized studies with variable control, non-randomized studies and observational studies (de Morton, 2009). Also, the narrative review was conducted using the based on the methodological quality by the Consolidated Standards of Reporting Trial (CONSORT) (Nunan et al., 2022).

A survey and narrative interpretation were subsequently carried out to scrutinize the theoretical considerations and future perspectives about multivariate training programs in PE classes. The studies present methodological quality with an arithmetic mean of 6.71 out of 10 on the PEDro scale (Table 1).

Table 1. Methodological quality of the studies included in the review, according the PEDro scale

Author(s)	PEDro scale score	Author(s)	PEDro scale score
(Siedentop et al., 2011)	5/10	(Webb et al., 2006)	7/10
(Wallhead & O'sullivan, 2005)	5/10	(Webb & Pearson, 2008)	8/10
(Harvey et al., 2020)	6/10	(Pill, 2011)	5/10
(Ratten & Jones, 2018)	7/10	(Díaz-Cueto et al., 2010)	6/10
(Casey & Kirk, 2020)	6/10	(Chow & Atencio, 2014)	7/10
(Casey & MacPhail, 2018)	7/10	(Rudd et al., 2020)	6/10
(Ratten & Jones, 2018)	5/10	(Renshaw et al., 2009)	7/10
(Rocamora et al., 2019)	7/10	(Moy et al., 2016)	6/10
(Brophy, 1979)	6/10	(Lee et al., 2017)	5/10
(Stolz & Pill, 2014)	7/10	(Mesquita et al., 2009)	5/10
(Pereira et al., 2014)	5/10	(Mesquita & Graça, 2011)	6/10
(Lardika & Tulyakul, 2020)	5/10	(Rink et al., 2016)	7/10
(Bunker & Thorpe, 1982)	5/10	(Farias et al., 2018)	5/10
(López et al., 2016)	6/10		

Study Information Extraction

The principal information that was considered relevant to the present review, was based on previous review articles (Silva et al., 2022; Teixeira et al., 2021). The data extraction was organized in a narrative manner in agreement in the subsequent alignment: (1) SEM; (2) DIM; (3)TGFU; (4) NPL; (5) PAGM; (6) DMGT; (7) CMID.

Results

Over the years, several teaching models have been evidenced in the literature as capable of being applied in the teaching-learning process of the discipline of PE (i.e., SEM, DIM, TGFU, Non-linear Pedagogy; PAGM; and CMIG (Quina, 2009)).

Sports Education Model

SEM was designed to provide authentic sport experiences in PE , and to develop skills, literacy and sports enthusiasts (Siedentop et al., 2011). Furthermore the literature shows that this is probably one of the world's most widely implemented and researched instructional approaches (Bessa et al., 2019; Ginanjar et al., 2019; Perlman & Karp, 2010; Siedentop et al., 2004; Wallhead & O'sullivan, 2005).

SEM emphasizes the socializing role of sport, through an active role of the practitioner in the organization of tasks that belong to the game and in the game itself (Siedentop et al., 2011). The same author adds that this model has as its principal objective to reduce barriers in the involvement of

sport, appealing to inclusion (i.e., sport for all and with all). In addition, it also promotes contextualized learning at a sports level, and students' competence , leading them to be enthusiastic and cultured from the point of view of learning (Harvey et al., 2020). In fact, in SEM, the enthusiastic student and the competent student are considered. The enthusiastic student actively participates in sport, through the sporting experiences he takes from that moment and develops the ability to make rational decisions about sports problems (Casey & Kirk, 2020; Harvey et al., 2020). The competent student has visible abilities to participate in the game satisfactorily, feels good in the various stages of learning the game, whether with the ball or without the ball, and works in groups to achieve common goals (Bessa et al., 2019). In a complementary way, other investigations (Casey & Kirk, 2020; Eldar & Ayvazo, 2009) reinforce that the SEM establishes the formation of the educated, competent, educated and enthusiastic sports student as a fundamental purpose. According to the same author, this model will provide students with an authentic and complete sporting experience, instituting the organization of the activity in sports seasons and the affiliation of students in teams. For this reason, and for the same author, this model values inclusion and equity in the participation of all students in the activity, mutual assistance in teamwork, autonomy and the performance of the various roles associated with the sports context (Wallhead & O'sullivan, 2005). SEM will foster the recreation of an authentic sports context (i.e., that students are part of a team), intrinsically value competition as a central element of the sporting experience, carefully take care of the formation of teams, distinguish the notions of training and competing, compete and strive to win, competition based on sports ethics, using forms of play suited to the abilities of students, developing autonomy, leadership, and shared responsibility.

In SEM, the teacher's role goes through several stages of intervention and assumes the role of supervisor of activities, which are student led and the teacher only intervenes in aspects that require explicit teaching and correction of teaching-learning activities (Casey & MacPhail, 2018; Ratten & Jones, 2018). However, for SEM to operate as an effective approach , it is necessary for the teacher to plan and have a good level of organization and developmental appropriate objectives relating to students' teamwork (Wallhead & O'sullivan, 2005). The role of questioning on the part of the teacher is crucial to develop students' critical inquiry skills that underpin understanding developed during his learning, that is, autonomy, problem-solving, decision-making by the students is one of the main objectives of SEM, essentially in the most advanced stages of its development (Casey & Kirk, 2020; Ginanjar et al., 2019; Harvey et al., 2020; Siedentop et al., 2011).

Direct Instruction Model

As with other instructional models, DIM was designed by teachers to facilitate learning and to promote the acquisition of basic skills and knowledge, which can be taught gradually (Rocamora et al., 2019). According to Brophy (Brophy, 1979), the concept of Direct Instruction is associated with an investigation carried out with regard to the process-product, which aims to recognize the relationships between the process of pedagogical interaction in the form of teacher behaviors and the learning benefits that it has in students. The DIM was emphasized for centralizing practically all decisions about the teaching-learning process on the teacher, mainly in prescribing the pattern of student involvement in learning tasks (Stolz & Pill, 2014). In this domain, the teacher performs administrative control, delimiting the rules and routines of student management, to obtain maximum effectiveness in their teaching and learning activities (Lardika & Tulyakul, 2020; Pereira et al., 2014). The activities are organized in fractions of time, and in this way it is essential to use the class time effectively, performing a high motor practice time. It is crucial that students obtain a high sense of responsibility and commitment to the learning tasks, thus contributing to the indication of criteria for success in achieving them (Donnelly et al., 2017; Metzler, 2017).

Teaching Games for Understanding

TGfU, which has its roots in a reform movement in the teaching of games that began in the late 60s and 70s of the last century, at the English University of Loughborough (Butler, 2006). Bunker and Thorpe (Bunker & Thorpe, 1982) founded this teaching model with the aim of transposing the attention traditionally dedicated to the development of basic game skills, to the teaching of isolated techniques, to the development of game ability through the tactical understanding of the game. Another investigation stats that the objective of the TGfU model is to allow students to learn the tactical aspects of the modalities through the practice of modified versions of the game, (e.g., conditioned, reduced and simplified games, thus adapted to the students' learning needs) (Chow et al., 2015). In the TGfU model, game analysis refers to students' understanding of the rules and nature of the game (López et al., 2016). In turn, tactical perception seeks to challenge students to solve problems posed by the game and, naturally, to increase knowledge in order to understand the game, to be able to play it or to allow it to observe (Stolz & Pill, 2014; Webb et al., 2006). The decision-making process follows the tactical perception, encouraging the student to know and identify ways to deal with the problem and consequently ways to solve it (Webb & Pearson, 2008). It is important to highlight that the model does not reject the need to teach the technique, it only contests that its development takes place after the understanding of current game situations by reinforcing intentional behavior, recognizing the situated nature of skills and their strategic use (Díaz-Cueto et al., 2010; Pill, 2011).

Non-linear Pedagogy

Non-linear pedagogy was developed and built on an ecological dynamics approach. At the base of this pedagogical framework is exploratory learning, with an emphasis on encouraging individualized movement solutions for individuals (Chow & Atencio, 2014). Based on these data, a perspective was advocated, that children should be given the freedom to explore a learning environment meticulously to leverage constraint-led synergies to generate functional movement solutions (Rudd et al., 2020). Consequently, non-linear pedagogy involves a child-centered approach to PE, where teachers direct learning based on modifying task constraints to improve linkage with task-determining skills (Renshaw et al., 2009).

In this sense, the teacher stands out for his preponderant role when selecting the tasks and constraints imposed. In fact, and according to the non-linear pedagogy model, one of the essential competences of the teacher lies in the identification and manipulation of essential constraints, which facilitate the emergence of functional actions and decision-making by students in different sports modalities or practices [45].

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Several authors have proposed that non-linear pedagogy could support children's basic psychological needs for autonomy, relationship, and competence from a self-determination theory perspective, and therefore could lead to higher levels of motivation for engaging in PA, the which can positively affect AF levels. in children compared to traditional teaching approaches (Lee et al., 2017; Moy et al., 2016).

Progressive Approach to Game Model

The PAGM refers to an approach to the game based on the progressive development of the ability to play, subjecting the teaching of technical skills to the teaching of tactics, that is, technical skills are built from the context of the game and its understanding, in this way students are confronted with problems that challenge their ability to understand and act in the game (Mesquita et al., 2009; Metzler, 2017). It follows the idea of learning motor skills in a gradual progression and a progressive increase in the introduction of the complexity and contextualization of the game, in a process of continuous approximation to real game situations (Mesquita & Graça, 2011). This model is important to encourage players to understand the game and make their learning process a constant search for solutions (i.e., cognitive dimension), thus offering everyone opportunities for practice and equitable participation (i.e., social dimension), certifying the acquisition of tactical, technical and physical skills in playing the game (i.e., motor dimension) (Mesquita et al., 2009). It is a model of didactic approach strongly associated with learning the game of volleyball, matching the complexity of the game to concrete proposals for activities adapted to the students' level. This model arises from ideas transmitted by other teaching models of collective sports games, such as the TGfU (Bunker & Thorpe, 1982), the DMGT (Rink et al., 2016), as well as the aforementioned Sports Education Model (Siedentop et al., 2011). The influence of the TGfU model lies in the fact that the approach to the game is centered on the tactical dimension and on problem solving, using modified forms of the game, according to the student's level (Tan et al., 2012; Webb et al., 2006).

Development Model of Game Tasks

The GMDT (Rink et al., 2016) is based on the assumption that not only the mastery of the teaching subject is sufficient to structure the teaching-learning process, nor is the contribution of didactic techniques sufficient to effectively carry out this task. It is from the intersection of the teaching subject with the didactic principles that the effective structuring of the instruction process results, offering at this level a coherent and scientifically supported proposal (Mesquita & Graça, 2011). The GMDT envisages the teaching of sports games according to a progression of tasks of increasing complexity, without obeying a rigid hierarchy, nor passing through all levels, with the manipulation of tasks dictated by the particularities of learning (Mesquita, 1998; Mesquita & Graça, 2011). This model is based on three fundamental concepts that guide the curricular structure (i.e., progression, refinement and application), which are particularly relevant in the context of sports games, due to the fact that in this type of modality there are multiple choices in the search for solutions. In the progression, there is an establishment of relationships between content, objectives and the level of performance, given that the mastery of skills is essential in the initial phase of exercise to be recreated in more demanding situations. In the concept of refinement, there is a definition of critical components to be observed, orientation in the focus of observations/ corrections to be made to the student and the specification of a certain task, that is, the teacher's instruction and the use of keywords, which are fundamental in the transmission of the feedback to be given to the student. Finally, the concept of application emerges in competition and in carefully selected self-assessment tasks, serving as a self-regulatory and as a contextualize of learning.

Competency Model in Invasion Games

CMIG, allows a choice of simplified forms of play, adapted to the abilities of the students, confrontation with real problems of the game, introduction of game skills in accordance with relevance to the form of play adopted, subordinating them to their tactical use in the game (i.e., decision making), the construction of an authentic sports context, fair-play and promotion of supporting and coordinating roles (Mesquita et al., 2012). In this model, the concept of learning to play follows, in a simpler than formal context, with active instruction from the teacher. This model was conceived to enable students to learn not only to participate in modified forms of collective invasive sports games successfully, but also to play other organizational roles in sports, distinguishing themselves into two complementary skill groups: student competence as a player in modified invasion games and competence as an autonomous exercise guidance function (Farias et al., 2018; Mesquita et al., 2012). Thus, the entire instructional process in the competency model in invasion games focuses on articulating of three categories of learning tasks (i.e., the basic forms of play, partial forms of play and game-based tasks) (Graça & Mesquita, 2002). These three categories are centered on game problems that players have to solve as a group or individually. In this way, the basic forms of play are modified versions of the formal game, adjusted to the level of play of the students and that allow them to update and exercise their motor, cognitive and social skills (Farias et al., 2018; Mesquita et al., 2012; Mesquita et al., 2009). Partial forms of play aim to create a favorable context, without decontextualizing their connection to the real situation of the game. The importance of one of the partial structures of the game allows students to focus on the problems of executing one of the parts of the basic form of the game. Finally, game-based tasks point to the means necessary to achieve solutions to game problems. These tasks thus limit the possibilities of schooling the solutions, or make the choices obvious, in order to give importance to the execution mechanisms in a very simplified context, but referring to the particular game situation (Mesquita & Graça, 2011). The assessment of students in this model always takes place in a real context and involves essential aspects of acting in the basic forms of play and the performance of supporting and coordinating roles (Anderson, 2018; Díaz-Cueto et al., 2010; Mesquita & Graça, 2011; Wallhead & O'sullivan, 2005). Through the use of checklists appropriate to the level of the basic form of play practiced, students and teachers will be able to observe and evaluate the different components of game performance (Mesquita & Graça, 2011).

The results of this work are not free of limitations and must be interpreted with consistency due to the variety of effects analyzed and methods used in the articles considered. In addition, few longitudinal studies were observed. Finally, it would have been interesting to consider the most appropriate

typology of teaching model in terms of contextual variables (e.g., cultural issues, geographic location), which can condition learning environments, and therefore a generalization should not be made.

Conclusions

This literature review is evidenced by the attempt to synthesize the main characteristics of different teaching models in PE. It is important that in education, we can no longer accept that physical activity in PE alone will drive sufficient learning and development of students. Furthermore, at a time when deep and rapid transformations can occur in society (e.g., COVID -19 pandemic), teachers must be able to adapt to meet the needs of students. Therefore, there is a need to strengthen the relationship between pedagogical theory and practice through innovation, which can emerge from the crossing teaching models, experimentation of new teaching models, strategies, and contents so that the PE discipline continues to contribute unequivocally to the formation of children and youth, resulting in lifelong engagement in physical activity. The teaching model chosen or the resulting interaction model by each teacher needs be based on the specific characteristics, stage of development and needs of individuals, as this is most likely to increase learning and achievement of PE curriculum outcomes. Yet teachers may use different strategies and characteristics of different models to meet the same type of needs based on the student's strengths and the learning environment. Future studies should focus on the use of quantitative methods to explain in detail the reasons for teachers' decision-making in relation to the teaching model adopted, verifying whether there are significant variations based on the historical and sociological points of view. This information seems to be even more important if we consider the results of a previous study that reported that PE teachers usually use teaching models different from those they think they use when they are asked about the topic (SueSee & Edwards, 2015).

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References

Anderson, D. I. (2018). Motor development: Far more than just the development of motor skills. *Kinesiology Review*, *7*(2), 99–114. https://doi.org/10.1123/kr.2018-0011

Bayraktar, G. (2011). The effect of cooperative learning on students' approach to general gymnastics course and academic achievements. *Educational Research and Reviews*, *6*(1), 62–71.

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 and Medicine*, *18*(4), 812–829.

Brophy, J. E. (1979). Teacher behavior and its effects. *Journal of Educational Psychology*, *71*(6), 733–750. https://doi.org/10.1037/0022-0663.71.6.733

Bunker, D., & Thorpe, R. (1982). A model for the teaching of games in secondary schools. *Bulletin of Physical Education*, *18*(1), 5–8.

Butler, J. I. (2006). Curriculum constructions of ability: Enhancing learning through Teaching Games for Understanding (TGfU) as a curriculum model. *Sport, Education and Society*, *11*(3), 243–258. https://doi.org/10.1080/13573320600813408

Casey, A., & Kirk, D. (2020). Models-based Practice in Physical Education. In *Models-based Practice in Physical Education*. Routledge. https://doi.org/10.4324/9780429319259

Casey, A., & MacPhail, A. (2018). Adopting a models-based approach to teaching physical education. *Physical Education and Sport Pedagogy*, *23*(3), 294–310. https://doi.org/10.1080/17408989.2018.1429588

Chow, J. Y., & Atencio, M. (2014). Complex and nonlinear pedagogy and the implications for physical education. *Sport, Education and Society*, *19*(8), 1034–1054. https://doi.org/10.1080/13573322.2012.728528

Chow, J. Y., Davids, K., Button, C., & Renshaw, I. (2015). Nonlinear pedagogy in skill acquisition: An introduction. In *Nonlinear Pedagogy in Skill Acquisition: An Introduction*. Routledge. https://doi.org/10.4324/9781315813042

Darnis-Paraboschi, F., Lafont, L., & Menaut, A. (2005). A social-constructivist approach in physical education: Influence of dyadic interactions on tactical choices in an instructional team sport setting. *European Journal of Psychology of Education*, *20*(2), 171–184. https://doi.org/10.1007/BF03173506

de Morton, N. A. (2009). The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Australian Journal of Physiotherapy*, *55*(2), 129–133. https://doi.org/10.1016/S0004-9514(09)70043-1

Decristan, J., Klieme, E., & Hardy, I. (2019). Adaptive teaching in research on learning and instruction Adaptiver Unterricht in der Lehr-Lernforschung Zusammenfassung. *Journal for Educational Research Online Journal Für Bildungsforschung Online*, *11*(2), 169–191.

Díaz-Cueto, M., Hernández-Álvarez, J. L., & Castejón, F. J. (2010). Teaching games for understanding to in-service physical education teachers: Rewards and barriers regarding the changing model of teaching sport. *Journal of Teaching in Physical Education*, *29*(4), 378–398. https://doi.org/10.1123/jtpe.29.4.378

Donnelly, F. C., Mueller, S. S., & Gallahue, D. L. (2017). Developmental Physical Education for All Children. In *Developmental Physical Education for All Children*. Human Kinetics. https://doi.org/10.5040/9781718210400

Dyson, B., Griffin, L. L., & Hastie, P. (2004). Sport education, tactical games, and cooperative learning: Theoretical and pedagogical considerations. *Quest*, *56*(2), 226–240. https://doi.org/10.1080/00336297.2004.10491823

Eldar, E., & Ayvazo, S. (2009). Educating through the physical-rationale. *Education and Treatment of Children*, *32*(3), 471–486. https://doi.org/10.1353/etc.0.0061

Farias, C., Valério, C., & Mesquita, I. (2018). Sport education as a curriculum approach to student learning of invasion games: Effects on game performance and game involvement. *Journal of Sports Science and Medicine*, *17*(1), 56–65.

Ferraz, Ricardo, Silva, M., A. Marinho, D., P. Neiva, H., & Branquinho, L. (2021). Student Motivation Associated With the Practice of Individual and Team Sports in Physical Education Classes. *Journal of Advances in Sports and Physical Education*, *4*(4), 51–58. https://doi.org/10.36348/jaspe.2021.v04i04.002

Ferry, M., & Romar, J. E. (2020). Physical education preservice teachers' physical activity habits and perceptions of the profession and subject: Development during teacher

 DOI 10.26773/mjssm.230307

education. *Journal of Physical Education and Sport*, *20*(4), 3108–3119. https://doi.org/10.7752/jpes.2020.s6422

Gimazutdinov, R. G. (2020). Theoretical Basis of Physical Education of Children of Preschool Age. *Academic Research in Educational Sciences Volume*, *1*(4), 2181–1385. www.ares.uz

Ginanjar, A., Suherman, A., Juliantine, T., & Hidayat, Y. (2019). Competitions in Physical Education Using Sports Education Model. *3rd International Conference on Sport Science, Health, and Physical Education (ICSSHPE 2018)*, 282–284. https://doi.org/10.2991/icsshpe-18.2019.80

Goodyear, V., & Dudley, D. (2015). "I'm a Facilitator of Learning!" Understanding What Teachers and Students Do Within Student-Centered Physical Education Models. *Quest*, *67*(3), 274–289. https://doi.org/10.1080/00336297.2015.1051236

Graça, A. S., & Mesquita, I. R. (2002). A investigação sobre o ensino dos jogos desportivos: ensinar e aprender as habilidades básicas do jogo. *Revista Portuguesa de Ciências Do Desporto*, *2002*(5), 67–79. https://doi.org/10.5628/rpcd.02.05.67

Green, K., Cale, L., & Harris, J. (2018). Re-imagination and re-design in physical education. *Redesigning Physical Education: An Equity Agenda in Which Every Child Matters*, 156.

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 and Adolescent Health*, *4*(1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2

Harvey, S., Pill, S., Hastie, P., & Wallhead, T. (2020). Physical education teachers' perceptions of the successes, constraints, and possibilities associated with implementing the sport education model. *Physical Education and Sport Pedagogy*, *25*(5), 555–566. https://doi.org/10.1080/17408989.2020.1752650

Kirk, D. (2013). Educational Value and Models-Based Practice in Physical Education. *Educational Philosophy and Theory*, *45*(9), 973–986. https://doi.org/10.1080/00131857.2013.785352

Lardika, R. A., & Tulyakul, S. (2020). The Effect of Direct Instruction Model in Physical Education Towards Students' Adversity Quotient (AQ). *Journal Sport Area*, *5*(1), 1–12. https://doi.org/10.25299/sportarea.2020.vol5(1).4460

Lee, M. C. Y., Chow, J. Y., Button, C., & Tan, C. W. K. (2017). Nonlinear Pedagogy and its role in encouraging twenty-first century competencies through physical education: a Singapore experience. *Asia Pacific Journal of Education*, *37*(4), 483–499. https://doi.org/10.1080/02188791.2017.1386089

López, I., Práxedes, A., & del Villar, F. (2016). Effect of an Intervention Teaching Program, Based on Tgfu Model, on the Cognitive and Execution Variables, in the Physical Education Context. / Efecto De La Aplicación De Un Modelo De Enseñanza Tgfu Sobre Las Variables Cognitivas Y De Ejecución, En La Edu. *Motricidad: European Journal of Human Movement*, *37*(37), 88–108. http://leedsbeckett.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=120882011&site=ehost-live&scope=site

Mesquita, I. (1998). *A instrução e a estruturação das tarefas no treino de Voleibol: Vol. I*. Universidade do Porto. Reitoria.

Mesquita, I., Farias, C., & Hastie, P. (2012). The impact of a hybrid Sport Education-Invasion Games Competence Model soccer unit on students' decision making, skill execution and overall game performance. *European Physical Education Review*, *18*(2), 205–219. https://doi.org/10.1177/1356336X12440027

Mesquita, I., Farias, C., Oliveira, G., & Pereira, F. (2009). A intervenção pedagógica sobre o conteúdo do treinador de futebol. *Revista Brasileira de Educação Física e Esporte*, *23*(01), 25–38. https://doi.org/10.1590/S1807-55092009000100003

Mesquita, I., & Graça, A. (2011). Modelos instrucionais no ensino do Desporto. *Pedagogia Do Desporto*, 39–68.

Mesquita, I., Pereira, F., & Graça, A. (2009). Modelos de ensino dos jogos desportivos: investigação e ilações para a prática. *Motriz*, *15*(4), 944–954.

Metzler, M. (2017). Instructional Models in Physical Education. In *Instructional Models in Physical Education*. Taylor & Francis. https://doi.org/10.4324/9781315213521

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Journal of Clinical Epidemiology*, *62*(10), 1006–1012. https://doi.org/10.1016/j.jclinepi.2009.06.005

Moy, B., Renshaw, I., & Davids, K. (2016). The impact of nonlinear pedagogy on physical education teacher education students' intrinsic motivation. *Physical Education and Sport Pedagogy*, *21*(5), 517–538. https://doi.org/10.1080/17408989.2015.1072506

Nunan, D., Watts, I., Kaji, F. A., Hansjee, S., & Heneghan, C. (2022). Adherence in leading medical journals to the CONSORT 2010 statement for reporting of binary outcomes in randomised controlled trials: cross-sectional analysis. *BMJ Evidence-Based Medicine*, *27*(2), 120–124. https://doi.org/10.1136/bmjebm-2020-111489

Parra-González, M. E., López-Belmonte, J., Segura-Robles, A., & Moreno-Guerrero, A. J. (2021). Gamification and flipped learning and their influence on aspects related to the teaching-learning process. *Heliyon*, *7*(2), e06254. https://doi.org/10.1016/j.heliyon.2021.e06254

Parsons, S. A., Vaughn, M., Scales, R. Q., Gallagher, M. A., Parsons, A. W., Davis, S. G., Pierczynski, M., & Allen, M. (2018). Teachers' instructional adaptations: A research synthesis. *Review of Educational Research*, *88*(2), 205–242.

Pereira, J., Hastie, P., Araújo, R., Farias, C., Rolim, R., & Mesquita, I. (2014). A comparative study of students' track and field technical performance in sport education and in a direct instruction approach. *Journal of Sports Science and Medicine*, *14*(1), 118–127.

Perlman, D., & Karp, G. G. (2010). A self-determined perspective of the Sport Education Model. *Physical Education and Sport Pedagogy*, *15*(4), 401–418. https://doi.org/10.1080/17408980903535800

Pill, S. (2011). Teacher engagement with teaching games for understanding - game sense in physical education. *Journal of Physical Education and Sport*, *11*(2), 5–13.

Quina, J. do N. (2009). A organização do processo de ensino em Educação Física. In *Série Estudos Escola Superior de Educação* (pp. 41–44). Instituto Politécnico de Bragança, Escola Superior de Educação.

Ratten, V., & Jones, P. (2018). Future research directions for

sport education: toward an entrepreneurial learning approach. *Education and Training*, *60*(5), 490–499. https://doi.org/10.1108/ET-02-2018-0028

Renshaw, I., Davids, K., Shuttleworth, R., & Chow, J. Y. (2009). Insights from ecological psychology and dynamical systems. Theory can underpin a philosophy of coaching. *International Journal of Sport Psychology*, *40*(4), 580–602.

Rink, J. E. (2001). Investigating the assumptions of pedagogy. *Journal of Teaching in Physical Education*, *20*(2), 112–128. https://doi.org/10.1123/jtpe.20.2.112

Rink, J. E., French, K. E., Werner, P. H., Lynn, S., & Mays, A. (2016). The Influence of Content Development on the Effectiveness of Instruction. *Journal of Teaching in Physical Education*, *11*(2), 139–149. https://doi.org/10.1123/jtpe.11.2.139

Rocamora, I., González-Víllora, S., Fernández-Río, J., & Arias-Palencia, N. M. (2019). Physical activity levels, game performance and friendship goals using two different pedagogical models: Sport Education and Direct Instruction. *Physical Education and Sport Pedagogy*, *24*(1), 87–102. https://doi.org/10.1080/17408989.2018.1561839

Rovegno, I., & Dolly, J. P. (2006). *Constructivist perspectives on learning. In, D. Kirk, D. MacDonald & M. O'Sullivan (Eds) The Handbook of Physical Education (pp. 242-261)*. London, SAGE publications.

Rudd, J. R., Crotti, M., Fitton-Davies, K., O'Callaghan, L., Bardid, F., Utesch, T., Roberts, S., Boddy, L. M., Cronin, C. J., Knowles, Z., Foulkes, J., Watson, P. M., Pesce, C., Button, C., Lubans, D. R., Buszard, T., Walsh, B., & Foweather, L. (2020). Skill Acquisition Methods Fostering Physical Literacy in Early-Physical Education (SAMPLE-PE): Rationale and Study Protocol for a Cluster Randomized Controlled Trial in 5–6-Year-Old Children From Deprived Areas of North West England. *Frontiers in Psychology*, *11*, 1228. https://doi.org/10.3389/fpsyg.2020.01228

Siedentop, D., Hastie, P., & Van der Mars, H. (2011). Complete guide to Sport Education. Champaign: Human Kinetics. In *IL Human Kinetics* (Vol. 148). Human Kinetics.

Silva, A., Ferraz, R., Forte, P., Teixeira, J. E., Branquinho, L., & Marinho, D. A. (2022). Multivariate Training Programs during Physical Education Classes in School Context: Theoretical Considerations and Future Perspectives. *Sports*, *10*(6), 89. https://doi.org/10.3390/sports10060089

Steinberg, C., Zühlke, M., Bindel, T., & Jenett, F. (2020). Aesthetic education revised: a contribution to mobile learning in physical education. *German Journal of Exercise and Sport Research*, *50*(1), 92–101. https://doi.org/10.1007/s12662-019-00627-9

Stolz, S., & Pill, S. (2014). Teaching games and sport for understanding: Exploring and reconsidering its relevance in physical education. *European Physical Education Review*, *20*(1), 36–71. https://doi.org/10.1177/1356336X13496001

SueSee, B., & Edwards, K. (2015). Self-Identified and Observed Teaching Styles: A Case Study of Senior Physical Education Teachers in Queensland Schools. *Myths in Education, Learning and Teaching: Policies, Practices and Principles*, 73–93. https://doi.org/10.1057/9781137476982_5

Tan, C. W. K., Chow, J. Y., & Davids, K. (2012). "How does TGfU work?": Examining the relationship between learning design in TGfU and a nonlinear pedagogy. *Physical Education and Sport Pedagogy*, *17*(4), 331–348. https://doi.org/10.1080/17408989.2011.582486

Teixeira, J. E., Forte, P., Ferraz, R., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M., & Monteiro, A. M. (2021). Monitoring accumulated training and match load in football: A systematic review. *International Journal of Environmental Research and Public Health*, *18*(8), 1–47. https://doi.org/10.3390/ijerph18083906

van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher-student interaction: A decade of research. *Educational Psychology Review*, *22*(3), 271–296. https://doi.org/10.1007/s10648-010-9127-6

Varea, V. (2018). Mixed messages: pre-service Health and Physical Education teachers' understandings of health and the body and the expectations of the Australian curriculum. *Sport, Education and Society*, *23*(3), 244–256. https://doi.org/10.1080/13573322.2016.1179182

Vukelja, M., Milanovic, D., & Salaj, S. (2022). Physical Activity and Sedentary Behaviour in Croatian Preschool Children: A Population-Based Study. *Montenegrin Journal of Sports Science and Medicine*, *11*(1), 37–42. https://doi.org/10.26773/mjssm.220304

Wallhead, T. L., & Ntoumanis, N. (2004). Effects of a Sport Education Intervention on Students' Motivational Responses in Physical Education. *Journal of Teaching in Physical Education*, *23*(1), 4–18. https://doi.org/10.1123/jtpe.23.1.4

Wallhead, T., & O'sullivan, M. (2005). Sport Education: physical education for the new millennium? *Physical Education & Sport Pedagogy*, *10*(2), 181–210. https://doi.org/10.1080/17408980500105098

Wang, C. L.-J., & Ha, A. S.-C. (2009). The Teacher Development in Physical Education: A Review of the Literature. *Asian Social Science*, *4*(12). https://doi.org/10.5539/ass.v4n12p3

Webb, P. I., & Pearson, P. J. (2008). An Integrated Approach to Teaching Games for Understanding (TGfU). *1st Asia Pacific Sport in Education Conference*, *January*, 1–11.

Webb, P. I., Pearson, P. J., & Forrest, G. (2006). Teaching Games for Understanding (TGf U) in primary and secondary physical education. *ICHPER-SD International Conference for Health, Physical Education, Recreation, Sport and Dance, 1st Oceanic Congress, Wellington, New Zealand, October*, 1–4.

Wibowo, J. (2020). Measuring contingency during autonomous learning phases in physical education: Piloting of an observation instrument. *German Journal of Exercise and Sport Research*, *50*(4), 501–510. https://doi.org/10.1007/s12662-020-00673-8

Wibowo, J., Bähr, I., & Gröben, B. (2014). Scaffolding as an instruction model for the cooperative learning model in physical education. *Australian Council for Health, Physical Education, and Recreation Magazine*, *21*(2), 15–18.

Winslade, M., & Deborah, C. (2020). Exploring the impact of curriculum change on physical education teacher's professional identity and pre-service training: An Australian case study. In *Physical Education in Universities Researches–Best Practices–Situation* (pp. 411–420). Slovak Scientific Society for Physical Education and Sport and FIEP.

Zach, S. (2020). Co-teaching – an approach for enhancing teaching-learning collaboration in physical education teacher education (Pete). *Journal of Physical Education and Sport*, *20*(3), 1402–1407. https://doi.org/10.7752/jpes.2020.03193

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REVIEW ARTICLE

Physical activity, sport participation, and cigarette smoking in university students after COVID-19 pandemic; Cross sectional analysis of the associations in south-eastern Europe

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Abstract

Cigarette smoking (CS) and low physical activity levels (PAL) are known to be risk factors for cardiovascular diseases. However, few studies have examined the associations between these factors in population of university students, and, to the best of our knowledge, no study examined this issue in period after the COVID-19 pandemic, despite the detrimental social and health consequences of the pandemic. The aim of this cross-sectional study was to examine associations between sport-participation, PAL and CS among university-level students in the first year after the COVID-19 pandemic. Participants were 761 students (411 females) from three universities in Bosnia and Herzegovina and Croatia, who were tested using semi-structured anonymous questionnaires at the beginning of the 2022/2023 academic year. Questions included queries on sociodemographic characteristics, CS, PAL, and sport-participation. Differences between genders were established by Chi-square test and gender-stratified logistic regressions were calculated to evaluate the associations between sport-participation and PAL, with binomized CS (smoking vs. non-smoking). One third of participants were daily smokers. Logistic regression showed no correlation between PAL and smoking prevalence for total sample (OR = 0.88, 95%CI: 0.75-1.05), males (OR = 0.95, 95%CI: 0.41-1.45), or females (OR = 0.90, 95%CI: 0.54-1.52). In addition, sport participation was not significantly associated with smoking. Results did not prove that sport and physical exercising are a way of reducing the likelihood of smoking; this finding could be a characteristic of the studied sample of participants, but could also be related to the period that was observed (the first year after the COVID-19 pandemic). Further studies examining the associations between PAL/sport participation and other types of substance misuse are warranted.

Keywords: *substance misuse, physical exercising, students, sport participation*

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Introduction

Physical activity is defined as any movement of the human body produced by skeletal muscles that requires energy expenditure (Caspersen, Powell, & Christenson, 1985); it comes in different forms and intensities, such as sports and structured exercise, fundamental movement skills, active play, leisure activities (walking, biking, dancing), active transport and household activities. Consistent and appropriate physical activity has numerous benefits. It develops a healthy cardiovascular and musculoskeletal system, neuromuscular coordination, movement control, and metabolic health, and assists in maintaining a healthy body weight (Hallal, Victora, Azevedo, & Wells, 2006; Whooten, Kerem, & Stanley, 2019).

Another important benefit of being physically active is that physical activity generally leads to adopting other healthy behaviors (i.e., healthy diet and avoiding tobacco, alcohol, and drugs) and social development and integration (Daskalopoulou et al., 2017). Collectively, an appropriate level of physical activity during adolescence and early adulthood contributes to the development and maintenance of a healthy adult lifestyle (Telama, 2009). Unfortunately, there is a lot of concern about the incidence of physical inactivity in the period of adolescence and early adulthood and >80% of adolescents worldwide do not meet the recommended guidelines of 60 minutes of moderate-to-vigorous physical activity a day; in early adulthood (age 18–21), the situation is even worse (Guthold, Stevens, Riley, & Bull, 2020).

Despite a decrease in prevalence globally, smoking remains the most common type of substance misuse in the world (Vink & Boomsma, 2011). Specifically, statistics and national data on substance use and abuse in the territory of south-eastern Europe and former Yugoslavia show that the prevalence of smoking is high (Modric, Zenic, & Sekulic, 2011; Sekulic, Ostojic, Ostojic, Hajdarevic, & Ostojic, 2012). Identifying protective and risk factors related to smoking will allow public health authorities to define specific and targeted preventive campaigns to emphasise and encourage these protective factors and to control risk factors (Kaleta, Korytkowski, & Makowiec-Dabrowska, 2013; Sekulic et al., 2012).

One potential protective factor against smoking is physical activity and sport participation (Grogan et al., 2022). However, physical activity (physical exercising) has not been consistently validated as a buffering factor against cigarette smoking. While some studies have indicated that sports and physical activity are protective, other studies have shown an increased likelihood of smoking among individuals who practice sports (Guo, Reeder, McGee, & Darling, 2011; Rodriguez Garcia, Lopez Villalba, Lopez Minarro, & Garcia Canto, 2013; Sekulic et al., 2012).

The rapid spread of a novel coronavirus led to the declaration of the COVID-19 pandemic on March 11th, 2020 (Cucinotta & Vanelli, 2020). The main strategy for controlling the COVID-19 pandemic was the implementation of social distancing measures, which included the closures of schools, universities, cafe bars, restaurants, sports–recreational facilities and clubs, and other places of social gathering (Bedford et al., 2020). Such restrictions led to decreased opportunities for movement and studies regularly reported a decrease in physical activity levels (PAL) as a result of imposed social distancing measures and lockdown during the COVID-19 pandemic (Caputo & Reichert, 2020; Castañeda-Babarro, Arbillaga-Etxarri, Gutiérrez-Santamaría, & Coca, 2020; Giustino et al., 2020). Such a decline in PAL represents a major health concern, as even a small reduction of PAL can result in serious health consequences (Narici et al., 2020).

In the meantime, studies showed an increase in the cigarette smoking during the pandemic period. For example, a Californian study confirmed higher use of cigarettes during lockdown, which was explained by increased stress, changes in workplace, and increased opportunities for smoking or vaping (Gonzalez, Epperson, Halpern-Felsher, Halliday, & Song, 2021). Supportively, another US study noted an increase in smoking during the COVID-19 pandemic at the sample of adults from vulnerable populations, indicating unemployment and anxiety as factors which could contribute to greater risk of tobacco use (Wiley et al., 2023). Finally, a very comprehensive UK study discussed increased smoking as a coping mechanism to deal with anxiety, boredom, stress, and anger during the COVID-19 lockdown (Grogan et al., 2022).

It is globally accepted that low physical activity levels and cigarette smoking present serious health-threatening behaviors. In the period of the COVID-19 pandemic, physical activity decreased, whereas cigarette smoking increased. It is theorized that physical activity could be protective against cigarette smoking, but, to the best of our knowledge, no study has examined this issue, considering previously specified changes in patterns of physical activity and cigarette smoking in the period after the COVID-19 pandemic. As a result, the aim of this study was to examine correlations between physical activity levels, and CS among university-level students in the period after the COVID-19 pandemic. Initially, we hypothesized that lower physical activity would be associated with higher tendency toward cigarette smoking.

Methods

Participants

Participants in this study were university students aged from 18 to 21 years (n = 761, 411 females) from three universities in south-eastern Europe: one University from southern Croatia (n = 156; 81 females; aged 20.11±3.1 years), one university from northern Croatia (n = 373, 229 females; aged 20.98±2.2 years), and one university from Bosnia and Herzegovina (n = 232, 101 females; aged 21.32±2.9 years). The sample size was calculated on the basis of the basis of (i) the number of students at each University for the 2020 school year, (ii) a previously reported prevalence of appropriate PAL in Croatian, and Bosnian and Herzegovinian older adolescents (e.g. 30%), (iii) a confidence level of 95%, and (iv) a margin of error of 5%. The required sample size was 784. The sampling was performed by the multi-stage cluster sampling method. First, in each studied university, faculties (note that faculties are constitutional units of the universities in the studied region) were grouped into two clusters, according to size (i.e., small and large faculties). Next, one-half of faculties in each cluster was selected randomly. Finally, in each of the selected faculties, one group was tested in each academic year. Collaborating partners in each studied university visited faculties, explained the aims of the study to faculty authorities, and organized the dissemination of the consent forms. Only students who provided written consent

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were included in the study. All participants were informed about the study aims, risks, and benefits, that participation was voluntary and that no personal information would be known outside of the project personal. The study was approved by Ethical Board of the Faculty of Kinesiology, University of Split, Croatia.

Variables

Variables observed were gender (male, female, intersex) and age of participants, academic year (school year), physical activity level (PAL), sport participation, and cigarette smoking.

Cigarette smoking was evidenced on a five-point scale including "never smoked", "quit", "from time to time, but not daily", "daily smoking". For statistical purposes participants were additionaly grouped as "non-smokers" (first three responses) and "daily smokers" (last response). Sport participation was assessed on a three-point scale that consisted of the answers "never participated in sport", "quit", "currently participating". These scales have previously been used in studies in the region and have been confirmed as being reliable and valid (Maric, Bianco, Kvesic, Sekulic, & Zenic, 2021; Sekulic et al., 2017; Zenic et al., 2017).

The assessment of PAL was carried out by the short version of the International Physical Activity Questionnaire (IPAQ) (Fogelholm et al., 2006; Hagstromer, Oja, & Sjostrom, 2006). The IPAQ was developed to measure health-related physical activity. The short version of the IPAQ has been tested extensively and is now used in many international studies. In brief, IPAQ assesses physical activity undertaken across leisure time, domestic and gardening (yard) activities, work-related and transport-related activity; it also asks about three specific types of activity undertaken (walking, moderate-intensity activities and vigorous-intensity activities) and about sitting, in terms of its frequency and duration. Although the IPAQ calculates the energy expenditure in METs, for the purpose of this study, participants were grouped into three groups, (i) inactive, (ii) minimally active, and (iii) health-enhancing physical activity (HEPA) active, as previously suggested (Fogelholm et al., 2006).

Testing was done using a digital platform. All participants scanned the printed QR code with their smartphones, which directed them to Google form containing the questionnaire. Testing was done during school hours in the presence of one of the investigators (authors of the study).

Statistics

All variables were checked for normality by the Kolmogorov–Smirnov test. Consequently, means and standard deviations were calculated for normally distributed variables, while frequencies and percentages were calculated for remaining variables.

To evaluate differences between universities in the categorization of PAL and cigarette smoking, a Chi-square test was performed. Analysis of variance was used to establish the differences in normally distributed variables. To evaluate correlations between (i) PAL and binomized cigarette smoking, and (ii) sport participation and binomized cigarette smoking, logistic regressions were calculated, and odds ratio and 95% confidence intervals (CI) were reported. Analysis of differences and correlations was done on the total sample, and then separately for males and females (owing to small number of responses, the calculations were not done separately for intersex).

Statistica 13.5 (Tibco Inc., Palo Alto, California, USA) was used for all calculations, and the p-level of 95% was applied.

Results

There was no difference in the age of the participants between the three studied universities (F-test = 1.01, $p > 0.05$).

Descriptive statistics for smoking prevalence are presented in Table 1 (total sample), Table 2 (males), and Table 3 (females). In brief, almost one third of studied university students were daily smokers. The prevalence of daily smoking wqw similar across genders (32%–38% in males, and 30%–39% in females). Chi-square did not reveal significant differences between universities in smoking prevalence for total sample (chi-

Table 1. Smoking prevalence in studied university students (total sample) with Chi square differences among studied universities (F – frequencies; % - percentages)

	Croatia South		Bosnia and Herzegovina		Croatia North	
	F	%	F	%	F	%
Never smoked	48	31	78	34	96	26
Quit	16	10	21	9	23	6
From time to time, but not daily	50	32	77	33	142	38
Daily smoking	42	27	56	24	111	30

Chi square: 9.36; p = 0.15

Table 2. Smoking prevalence in studied university students (males only) with Chi square differences among studied universities (F – frequencies; % - percentages)

	Croatia South		Bosnia and Herzegovina		Croatia North	
	F	%	F	%	F	%
Never smoked	18	25	37	28	30	21
Quit	5	7	8	6	5	4
From time to time, but not daily	25	32	46	38	51	35
Daily smoking	27	36	37	28	58	40

Chi square: 5.83; p = 0.44

Table 3. Smoking prevalence in studied university students (females only) with Chi square differences among studied universities (F – frequencies; % - percentages)

	Croatia South		Bosnia and Herzegovina		Croatia North	
	F	%	F	%	F	%
Never smoked	30	37	40	39	68	30
Quit	11	13	13	13	18	8
From time to time, but not daily	25	32	29	30	90	39
Daily smoking	15	18	19	18	53	23

Chi square: 8.94; p = 0.17

square = 9.36, p = 0.16), males (chi-square = 5.83, p = 0.44), or females (chi square = 8.94, p = 0.17).

Distribution of the PAL results across the universities are presented in Table 4 (total sample), Table 5 (males), and Table 6 (females). About 50% of participants reached recommended PAL, with no significant differences between universities

Table 4. Physical activity of the studied participants (total sample) with Chi square differences among studied universities (F – frequencies; % - percentages)

	Croatia South		Bosnia and Herzegovina		Croatia North	
	F	%	F	%	F	%
Inactive	31	20	41	18	77	21
Minimally active	48	31	70	30	116	31
Health enhancing physical activity	77	49	121	52	180	48

Chi square: 8.94; p = 0.17

Table 5. Physical activity of the studied participants (males only) with Chi square differences among studied universities (F – frequencies; % - percentages)

	Croatia South		Bosnia and Herzegovina		Croatia North	
	F	%	F	%	F	%
Inactive	19	15	20	15	26	18
Minimally active	26	28	33	25	36	25
Health enhancing physical activity	29	57	78	60	82	57

Chi square: 0.46; p = 0.97

Table 6. Physical activity of the studied participants (females only) with Chi square differences among studied universities (F – frequencies; % - percentages)

	Croatia South		Bosnia and Herzegovina		Croatia North	
	F	%	F	%	F	%
Inactive	12	26	26	26	55	24
Minimally active	22	35	33	32	82	36
Health enhancing physical activity	48	39	42	42	92	40

Chi square: 9.23; p = 0.06

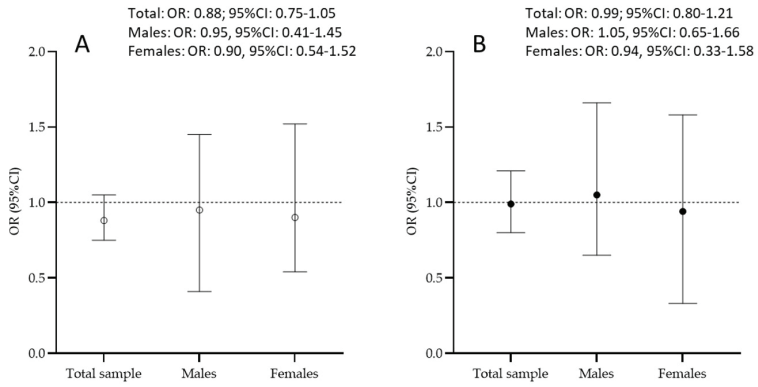

Figure 1. Logistic regression results; correlations between (A) physical activity levels, and (B) sport participation, and cigarette smoking (smoking vs. non-smoking) in university students for total sample and gender stratified (OR – Odds Ratio, 95%CI – 95% Confidence Interval)

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(chi-square = 1.13, p = 0.88). However, males are evidently more physically active than females, with 57%–60% of males - reaching recommended PAL; whereas only 39%–42% of females had sufficient PAL. Differences between universities were not established (none of the chi-square calculations reached statistical significance).

Figure 1 presents results of the logistic regressions calculated between PAL and sport participation as correlates of cigarette smoking.

Logistic regression showed no correlation between PAL and smoking prevalence for total sample (OR = 0.88, 95%CI: 0.75-1.05), males (OR = 0.95, 95%CI: 0.41-1.45), or females (OR = 0.90, 95%CI: 0.54-1.52) (Figure 1A). Also, no significant associations were found between sport participation and cigarette smoking (Total sample: OR = 0.99, 95%CI: 0.80-1.21; Males: OR = 1.05, 0.65-1.66; Females: OR = 0.88, 95%CI: 0.33-1.58) (Figure 1B).

Discussion

This study aimed to evaluate the association of PAL and sport participation with cigarette smoking in university students. Results showed that neither PAL nor sport participation are associated with prevalence of smoking in the studied university students. Therefore, our initial study hypothesis was not confirmed. Before discussing this issue, we will briefly look at the PAL results for university students.

For the last couple of years, interest about physical activity and PAL in the countries of southeastern Europe has increased, but studies have mostly investigated children and adolescents (Gilic, Ostojic, Corluka, Volaric, & Sekulic, 2020; Sekulic, Rodek, & Sattler, 2020; Stefan, Kasovic, & Zvonar, 2020). This trend was particularly evident during the period of COVID-19, when authors published series of studies examining the changes in PAL which occurred as a result of lockdown among adolescents, and the factors that were correlated with these changes (Geets Kesic et al., 2021; Gilic et al., 2020; Gilic, Zenic, Separovic, Jurcev Savicevic, & Sekulic, 2021; Sekulic et al., 2021). However, this issue has rarely been examined in a population of university students, and therefore our results are hardly comparable to those other reports in the region before the COVID-19 pandemic.

The closest comparison that could therefore be done is with the results of high school students, their PAL being established by same measurement tool that we used in this study. Croatian study evaluated the PAL of high school students, and showed 59% of high-school students to be sufficiently active, which is more than we established herein (note that 50% of our participants reached sufficient PAL) (Ajman, Novak, & Mišigoj-Duraković, 2019). Furthermore, 54% of high school girls reached appropriate PAL, whereas, in our study only, 39% females were at that level; the difference is similar for boys/males (65% vs. 57% in high-school and university students, respectively) (Ajman et al., 2019). Although samples of participants observed are not absolutely identical, some explanations could be offered for the evident differences.

First, one of the important determinants of PAL in adolescence is (mandatory) physical education (PE) classes in high school. Although the PE curriculum in the territory is often criticized for being insufficient in frequency, it still provides an important source of physical activity in the elementary and high-school education period (until the age of 18 years) (Škegro & Čustonja, 2014). Meanwhile, PE is only sporadically included in university curricula in Croatia and Bosnia and Herzegovina, the countries we studied in this investigation (Bagarić, Špehar, & Zvonarek, 2005; Caput-Jogunica, Neljak, & Ćurković, 2013). Unfortunately, the number of universities that provide opportunity for their students to be physically active is also decreasing, although some examples of good practice emerge (Onofre et al., 2012). Taking this into account, the higher PAL in high-school students than in university students is easily explainable.

The second explanation is related to the period when this investigation was done: the first year after the COVID-19 pandemic (note that during 2022, when study was undertaken, the pandemic was not officially over, but generally there were no strict lockdowns in the studied countries). In brief, studies in the region regularly confirmed a decrease in PAL as a result of the COVID-19 pandemic and the imposed measures of social distancing (Geets Kesic et al., 2021; Gilic et al., 2021; Sekulic et al., 2021). It is well known that physical activity is a habitual behavior and that good habits should be developed (Saris, 1986). Therefore, it is logical to expect that those individuals who decreased their PAL during the period of COVID-19 pandemic did not adopt behaviors of increased physical activity, in the first year after the pandemic, and consequently did not reach pre-pandemic PAL.

For more than 50 years a clear link between cigarette smoking and lung cancer has been known, but smoking still remains the most prevalent type of substance misuse in the world (Hecht, 2002; World Health Organization, 2018). The territory of south-eastern Europe is particularly endangered in this regard, and studies regularly show alarmingly high numbers for smoking in the region (Mayer et al., 2015; Milosevic Georgiev, Kotur-Stevuljevic, & Krajnovic, 2019; Samardzic, Marvinac, & Prlic, 2009). The high prevalence of smoking in the territory is mostly explained by (i) culture and traditional background, (ii) lack of a clear ban of smoking in public places in most of the territory, and (iii) relatively cheap tobacco products (Idrizovic, Zenic, Tahirajl, Rausavljevic, & Sekulic, 2015). Therefore, the high levels of smoking prevalence in our sample are not surprising and are in line with previous reports (Idrizovic et al., 2015; Sekulic et al., 2017; Zenic et al., 2017). For the purpose of this study, the lack of association between sport and physical activity and smoking behaviors in university students is more important.

Sport and physical-activity in general are associated with pro-social behavior (De Martelaer & Struyven, 2012; Florić & Ninković, 2013). Moreover, cigarette smoking directly alters physical capacities, which are important factors in active participation in sport and physical exercise (Mundal et al., 1997). Logically, it would be expected that those individuals who practice sport and are physically active will be less oriented toward cigarette smoking. However, findings on that matter are not straightforward. In some cases, authors have confirmed lower prevalence of smoking in those who practice sports (and consequently were more physically active), whereas other studies have shown higher smoking rates in athletic samples (Guo et al., 2011; Rodriguez Garcia et al., 2013; Sekulic et al., 2012). Therefore, even our results of a non-significant association between PAL and sport-participation and smoking in university students are not as surprising as it may appear at first glance.

The first explanation for the lack of a correlation is related to the social character of sport and physical exercise, especially

in the period of early adulthood (i.e., university students). It cannot be ignored that sport participation and general activities that increase PAL (i.e., fitness centers) are "social activities". Therefore, social gatherings are common, especially after participation (i.e., after sport games or exercising in fitness centers). These gatherings often happen in bars and restaurants, where different kinds of substances are consumed. As previously stated, cigarette smoking is not strictly prohibited in public places in the region (Maric et al., 2021). Therefore, physical activity increases the overall possibility of smoking, irrespective of the fact that sport itself should present a certain barrier against smoking as an unhealthy behavior. What additionally aggravates the possibility of smoking is the fact that the sport participants in the studied age group are rarely "competitive athletes", since, in the previous period of life (i.e., 17–18 years of age), a significant drop-out from competitive sports occurs. As a result, it is not likely that university students who participate in sports will be concerned about the eventual negative consequences of smoking on their physical capacities and the deterioration in their sport-performance.

A second explanation is again related to the period when our participants were tested. As mentioned earlier, the COVID-19 pandemic introduced numerous negative changes to everyday life and habits, globally. One of such negative change was an increase in substance misuse, including increased figures of smoking cigarettes (Gonzalez et al., 2021; Wiley et al., 2023). This is indirectly confirmed even in our study: the numbers of daily smokers in our study are somewhat higher than previously reported numbers for similar age groups in the region (Zenic et al., 2017). Similar to previously discussed changes in PAL as a result of the pandemic, (negative) changes in smoking habits are hard to reverse immediately after the pandemic stopped. Moreover, as we know that smoking is an addiction, it is unreasonable to expect that people who smoked during the pandemic period will quickly get rid of the habit.

Limitations and strengths

The main limitation of the investigation comes from the fact that it is cross-sectional study. Therefore, although associations can be evaluated, causality remains unclear. Therefore, in future studies a prospective approach is needed. In addition, this study examined one specific sample of participants, university students, and therefore the generalizability of the findings is limited solely to similar samples. However, the sample was selected intentionally simply because of the fact that university students are an understudied population with regard to PAL and substance misuse.

This is one of the first studies examining the PAL and smoking behaviors in the period after the COVID-19 pandemic, and is probably the first one to investigate the associations between PAL/sport participation and smoking in university students in south-eastern Europe. Furthermore, the fact that we observed participants from two countries is another important strength of the investigation.

Conclusion

Our results suggest that the COVID-19 pandemic and its imposed measures of social distancing resulted in similar changes in PAL and smoking in Croatia and Bosnia and Herzegovina, at least as far as university students are concerned. This was not surprising, considering the similarity of (i) cultural and traditional frameworks in the studied countries (which almost certainly resulted even in a similar prevalence of smoking), (ii) public health policies (no strict prohibition of smoking in public places), and (iii) status of physical education at the universities, the role of sport and the acceptance of recreational physical exercising in the studied countries.

Despite our initial considerations, PAL/sport participation was not associated with cigarette smoking in university students in the post-pandemic year. The most likely reasons for the lack of correlation could be found in (i) the social nature of sport participation in this age group and (ii) negative changes in PAL and smoking which occurred during the pandemic years. However, it must be mentioned that figures (and associations) could change, and therefore future studies are warranted.

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References

Ajman, H., Novak, D., & Mišigoj-Duraković, M. (2019). Social capital and physical activity among Croatian high school students: a school type-based cross-sectional study. *Medica Jadertina, 49*(2), 75-83.

Bagarić, I., Špehar, N., & Zvonarek, N. (2005). *Physical education and sports at Zagreb and other Croatian universities.* Paper presented at the 4th International Scientific Conference on Kinesiology: Science and profession-challenge for the future: proceedings book.

Bedford, J., Enria, D., Giesecke, J., Heymann, D. L., Ihekweazu, C., Kobinger, G., . . . Wieler, L. H. (2020). COVID-19: towards controlling of a pandemic. *Lancet, 395*(10229), 1015-1018. doi:10.1016/s0140-6736(20)30673-5

Caput-Jogunica, R., Neljak, B., & Ćurković, S. (2013). The role and challenges of physical education at the Croatian Universities.

Caputo, E. L., & Reichert, F. F. (2020). Studies of Physical Activity and COVID-19 During the Pandemic: A Scoping Review. *J Phys Act Health*, 1-10. doi:10.1123/jpah.2020-0406

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 Rep, 100*(2), 126-131.

Castañeda-Babarro, A., Arbillaga-Etxarri, A., Gutiérrez-Santamaría, B., & Coca, A. (2020). Physical Activity Change during COVID-19 Confinement. *International Journal of Environmental Research and Public Health, 17*(18), 6878. doi:10.3390/ijerph17186878

Cucinotta, D., & Vanelli, M. (2020). WHO Declares COVID-19 a Pandemic. *Acta Biomed, 91*(1), 157-160. doi:10.23750/abm.v91i1.9397

Daskalopoulou, C., Stubbs, B., Kralj, C., Koukounari, A., Prince, M., & Prina, A. M. (2017). Physical activity and healthy ageing: A systematic review and meta-analysis of longitudinal cohort studies. *Ageing Res Rev, 38*, 6-17. doi:10.1016/j.arr.2017.06.003

De Martelaer, K., & STRUYVEN, J. D. B. K. (2012). Youth sport ethics: teaching pro-social behaviour. In *Ethics in Youth Sport* (pp. 69-87): Routledge.

Florić, O. K., & Ninković, S. (2013). The contribution of sport

 DOI 10.26773/mjssm.230308

to prosocial behavior in youth. *Stanisław Juszczyk*, 175.

Fogelholm, M., Malmberg, J., Suni, J., Santtila, M., Kyrolainen, H., Mantysaari, M., & Oja, P. (2006). International Physical Activity Questionnaire: Validity against fitness. *Med Sci Sports Exerc, 38*(4), 753-760. doi:10.1249/01.mss.0000194075.16960.20

Geets Kesic, M., Gilic, B., Cerkez Zovko, I., Drid, P., Korovljev, D., & Sekulic, D. (2021). Differential impact of COVID-19 lockdown on physical activity in younger and older adolescents - prospective study. *Med Pr, 72*(6), 633-643. doi:10.13075/mp.5893.01180

Gilic, B., Ostojic, L., Corluka, M., Volaric, T., & Sekulic, D. (2020). Contextualizing Parental/Familial Influence on Physical Activity in Adolescents before and during COVID-19 Pandemic: A Prospective Analysis. *Children (Basel), 7*(9). doi:10.3390/children7090125

Gilic, B., Zenic, N., Separovic, V., Jurcev Savicevic, A., & Sekulic, D. (2021). Evidencing the influence of pre-pandemic sports participation and substance misuse on physical activity during the COVID-19 lockdown: a prospective analysis among older adolescents. *Int J Occup Med Environ Health, 34*(2), 151-163. doi:10.13075/ijomeh.1896.01733

Giustino, V., Parroco, A. M., Gennaro, A., Musumeci, G., Palma, A., & Battaglia, G. (2020). Physical Activity Levels and Related Energy Expenditure during COVID-19 Quarantine among the Sicilian Active Population: A Cross-Sectional Online Survey Study. *Sustainability, 12*(11), 4356.

Gonzalez, M., Epperson, A. E., Halpern-Felsher, B., Halliday, D. M., & Song, A. V. (2021). Smokers Are More Likely to Smoke More after the COVID-19 California Lockdown Order. *Int J Environ Res Public Health, 18*(5). doi:10.3390/ijerph18052582

Grogan, S., Walker, L., McChesney, G., Gee, I., Gough, B., & Cordero, M. I. (2022). How has COVID-19 lockdown impacted smoking? A thematic analysis of written accounts from UK smokers. *Psychology & Health, 37*(1), 17-33.

Guo, H., Reeder, A. I., McGee, R., & Darling, H. (2011). Adolescents' leisure activities, parental monitoring and cigarette smoking--a cross-sectional study. *Subst Abuse Treat Prev Policy, 6*, 12. doi:10.1186/1747-597X-6-12

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. *Lancet Child Adolesc Health, 4*(1), 23-35. doi:10.1016/s2352-4642(19)30323-2

Hagstromer, M., Oja, P., & Sjostrom, M. (2006). The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutr, 9*(6), 755-762. doi:10.1079/phn2005898

Hallal, P. C., Victora, C. G., Azevedo, M. R., & Wells, J. C. (2006). Adolescent physical activity and health: a systematic review. *Sports Med, 36*(12), 1019-1030. doi:10.2165/00007256-200636120-00003

Hecht, S. S. (2002). Cigarette smoking and lung cancer: chemical mechanisms and approaches to prevention. *The lancet oncology, 3*(8), 461-469.

Idrizovic, K., Zenic, N., Tahirajl, E., Rausavljevic, N., & Sekulic, D. (2015). Cigarette Smoking among 17-18 Year Old Adolescents - Prevalence and Association with Sociodemographic, Familial, Sport, and Scholastic. Factors. *Med Pr, 66*(2), 153-163. doi:10.13075/mp.5893.00104

Kaleta, D., Korytkowski, P., & Makowiec-Dabrowska, T. (2013). Cigarette Smoking among Economically Active Population. *Medycyna Pracy, 64*(3), 359-371. Retrieved from <Go to ISI>://WOS:000326993500008

Maric, D., Bianco, A., Kvesic, I., Sekulic, D., & Zenic, N. (2021). Analysis of the Relationship between Tobacco Smoking and Physical Activity in Adolescence: A Gender Specific Study. *Medicina (Kaunas), 57*(3). doi:10.3390/medicina57030214

Mayer, D., Simetin, I. P., Rodin, U., Benjak, T., Puntaric, E., & Puntaric, I. (2015). The impacts of media messaging and age and sex variance on adolescent smoking habits in Croatia. *J Addict Med, 9*(2), 147-154. doi:10.1097/ADM.0000000000000070

Milosevic Georgiev, A., Kotur-Stevuljevic, J., & Krajnovic, D. (2019). Socio-demographic Factors Associated with Smoking Habits Among University Students in Belgrade, Serbia. *Zdr Varst, 58*(1), 11-20. doi:10.2478/sjph-2019-0002

Modric, T., Zenic, N., & Sekulic, D. (2011). Substance use and misuse among 17- to 18-year-old Croatian adolescents: correlation with scholastic variables and sport factors. *Subst Use Misuse, 46*(10), 1328-1334. doi:10.3109/10826084.2011.579677

Mundal, R., Kjeldsen, S. E., Sandvik, L., Erikssen, G., Thaulow, E., & Erikssen, J. (1997). Predictors of 7-year changes in exercise blood pressure: effects of smoking, physical fitness and pulmonary function. *Journal of hypertension, 15*(3), 245-249.

Narici, M., De Vito, G., Franchi, M., Paoli, A., Moro, T., Marcolin, G., . . . Maganaris, C. (2020). Impact of sedentarism due to the COVID-19 home confinement on neuromuscular, cardiovascular and metabolic health: Physiological and pathophysiological implications and recommendations for physical and nutritional countermeasures. *European Journal of Sport Science*, 1-22. doi:10.1080/17461391.2020.1761076

Onofre, M., Marques, A., Moreira, R., Holzweg, M., Repond, R.-M., & Scheuer, C. (2012). Physical education and sport in Europe: From individual reality to collective desirability (Part 2). *International Journal of Physical Education, 49*(3), 17-31.

Organization, W. H. (2018). *WHO global report on trends in prevalence of tobacco smoking 2000-2025*: World Health Organization.

Rodriguez Garcia, P. L., Lopez Villalba, F. J., Lopez Minarro, P. A., & Garcia Canto, E. (2013). [Relationship between tobacco consumption and physical exercise in adolescents. Differences between genders]. *Adicciones, 25*(1), 29-36. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23487277

Samardzic, S., Marvinac, G. V., & Prlic, A. (2009). Regional pattern of smoking in Croatia. *Coll Antropol, 33 Suppl 1*, 43-46. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19563146

Saris, W. H. (1986). Habitual physical activity in children: methodology and findings in health and disease. *Medicine & Science in Sports & Exercise*.

Sekulic, D., Ostojic, D., Decelis, A., Castro-Pinero, J., Jezdimirovic, T., Drid, P., . . . Gilic, B. (2021). The Impact of Scholastic Factors on Physical Activity Levels during the COVID-19 Lockdown: A Prospective Study on

Adolescents from Bosnia and Herzegovina. *Children (Basel), 8*(10). doi:10.3390/children8100877

Sekulic, D., Ostojic, M., Ostojic, Z., Hajdarevic, B., & Ostojic, L. (2012). Substance abuse prevalence and its relation to scholastic achievement and sport factors: An analysis among adolescents of the Herzegovina-Neretva Canton in Bosnia and Herzegovina. *BMC public health, 12*(1), 274. doi:10.1186/1471-2458-12-274

Sekulic, D., Rodek, J., & Sattler, T. (2020). Factors associated with physical activity levels in late adolescence: a prospective study. *Med Pr, 71*(6), 637-647. doi:10.13075/mp.5893.01012

Sekulic, D., Sisic, N., Terzic, A., Jasarevic, I., Ostojic, L., Pojskic, H., & Zenic, N. (2017). Sport and scholastic factors in relation to smoking and smoking initiation in older adolescents: a prospective cohort study in Bosnia and Herzegovina. *BMJ Open, 7*(3), e014066. doi:10.1136/bmjopen-2016-014066

Stefan, L., Kasovic, M., & Zvonar, M. (2020). Association between the levels of physical activity and plantar pressure in 6-14-year-old children. *PeerJ, 8*, e8551. doi:10.7717/peerj.8551

Škegro, D., & Čustonja, Z. (2014). The beginnings of education and training for delivering physical education classes in Croatia–140 years of tradition. *Kinesiology, 46*(Supplement 1.), 127-133.

Telama, R. (2009). Tracking of physical activity from childhood to adulthood: a review. *Obes Facts, 2*(3), 187-195. doi:10.1159/000222244

Vink, J. M., & Boomsma, D. I. (2011). Interplay between heritability of smoking and environmental conditions? A comparison of two birth cohorts. *BMC Public Health, 11*, 316. doi:1471-2458-11-316 [pii] 10.1186/1471-2458-11-316

Whooten, R., Kerem, L., & Stanley, T. (2019). Physical activity in adolescents and children and relationship to metabolic health. *Curr Opin Endocrinol Diabetes Obes, 26*(1), 25-31. doi:10.1097/med.0000000000000455

Wiley, R. C., Oliver, A. C., Snow, M. B., Bunn, J. Y., Barrows, A. J., Tidey, J. W., . . . Heil, S. H. (2023). The impact of the Covid-19 pandemic on smoking among vulnerable populations. *Nicotine and Tobacco Research, 25*(2), 282-290.

Zenic, N., Ban, D., Jurisic, S., Cubela, M., Rodek, J., Ostojic, L., . . . Sekulic, D. (2017). Prospective Analysis of the Influence of Sport and Educational Factors on the Prevalence and Initiation of Smoking in Older Adolescents from Croatia. *Int J Environ Res Public Health, 14*(4). doi:10.3390/ijerph14040446

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ORIGINAL SCIENTIFIC PAPER

Absolute and relative maximum strength measures show differences in their correlations with sprint and jump performances in trained youth soccer players

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Abstract

Speed strength performances are heavily dependent on maximum strength. However, various strength testing methods determined inconsistent relationships between absolute and relative strength and sprint and jump performances. The aim of the study was to calculate the one tailed correlation coefficients between both the One-Repetition Maximum (1RM) and 1RM in relation to body mass (1RM/BM) in parallel squats and different jump (squat jump and countermovement jump) and sprint performances (5-, 10-, 20-, and 30-m) in youth soccer players (n= 63, 17.9±2.1 years old). Relative strength showed significantly larger correlations with jump performances (r= 0.52 to 0.58) than absolute strength (r= 0.16 to 0.26, z= -1.81 to -1.90, p= 0.029 to 0.035). However, the r values between relative strength measures and sprint performances (r= -0.32 to -0.42) were of non-statistical difference to the correlations of absolute strength measurements with sprint performances (r= -0.19 to -0.3, z= 0.349 to 1.17, p= 0.121 to 0.363). The results of this study support findings in previous literature of enhanced speed strength performances by higher levels of maximal strength in youth soccer players, with faster and more powerful athletes being able to generate larger forces against their own body weight. The data suggests that strength expressed relative to body mass might be considered as a superior predictor of speed strength performance in general.

Keywords: *Squat, 1RM, linear sprint, jump, speed-strength, soccer*

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Introduction

Team sports, such as competitive soccer, require a complex mix of technical, tactical, and conditional qualities (Stolen et al., 2005). Repeated changes between jogging, sprinting, jumping and rapidly performed directional changes add up to approx. 1300 diverse speed strength actions per player per game (Bangsbo et al., 2006; Stolen et al., 2005). These speed strength actions, according to detailed analyses, contribute substantially to the overall game performance. (Bangsbo et al., 2006; Reilly, 2006). Thus, to be successful, it is mandatory for soccer players to develop reasonably high levels of sprint and jump ability in addition to other technical, tactical, and conditional qualities (Reilly et al., 2000; Stolen et al., 2005).

The execution of sprints and jumps requires the generation of largest possible ground reaction forces by the neuromuscular system within short ground contact times (Hunter et al., 2005; Morin et al., 2012). Peak values of vertical ground reaction forces of up to 2 times body weight during push-off (Weyand et al., 2000) and 4 to 6 times body weight during landings are reported (Dempsey et al., 2014). Similarly, ground reaction forces during sprint starts and acceleration phase are reported with 2 to 5 (Bass et al., 2007; Lafortune et al., 2000) and 2 to 3 (Allmann, 1985; Joch, 1992; Schmidtbleicher, 2000) times the athlete's body weight, respectively. Therefore, these speed strength performances are heavily dependent on maximum strength (Schmidtbleicher, 1992) and consequently on relative strength as the athlete's body mass must be accelerated (Hunter et al., 2005). Numerous studies utilizing various strength testing methods have investigated these relationships. Consequently, small to large correlations between speed strength measurements and both absolute and relative strength have been determined utilizing dynamic free-weight squats in different sports (r= |0.26| to |0.60|) (Hori et al., 2008; Loturco et al., 2021).

These observed correlations between speed strength measurements and both absolute and relative strength are also true for studies analyzing soccer (r= |0.10| to |0.94|) (Boraczynski et al., 2020; Chelly et al., 2010; Comfort et al., 2014; Keiner et al., 2021; Keiner et al., 2014; McBride et al., 2009; Nuzzo et al., 2008; Rodriguez-Rosell et al., 2017; Wisloff et al., 2004; Wisloff et al., 1998). In detail, small to large correlations have been reported for absolute strength measures with various sprint performances (LS 5m to LS 40m) (r= |0.23| to |0.94|) (Boraczynski et al., 2020; Chelly et al., 2010; Comfort et al., 2014; Keiner et al., 2021; Keiner et al., 2014; Wisloff et al., 2004). Moreover, moderate to very large correlations have been reported for absolute strength measures with squat jump (SJ) and countermovement jump (CMJ) height, respectively (r= |0.39| to |0.78|) (Boraczynski et al., 2020; Comfort et al., 2014; Keiner et al., 2021; Rodriguez-Rosell et al., 2017; Wisloff et al., 2004; Wisloff et al., 1998)

Of the above-mentioned studies analyzing soccer players only a small number considered the potential effect of body mass on speed strength performances by correlating strength measures relative to the athlete's body mass. However, expressed relatives of body mass, squats strength showed mostly moderate to large correlations with sprint performances (r= |0.44| to |0.67|), squat jump, and countermovement jump height (r= |0.35| to |0.69|), respectively (Boraczynski et al., 2020; Comfort et al., 2014; Keiner et al., 2014; McBride et al., 2009). Correspondingly, there is no consent on magnitude of correlation between various jump performances and maximum strength. Moreover, due to the lack of studies comparing both absolute and relative strength measures in relation to speed strength performance, sampling errors, and the diversity of strength testing methods and protocols, which is impeding the comparison of results between studies, it is still not apparent whether absolute or relative strength measures show greater correlations with speed strength performances.

However, Boraczynski et al. (2020) reported small to moderate correlations between absolute squat strength, short sprint (LS 5m) (r= |0.28|), and countermovement jump performance (r= |0.39|), but strong correlations between relative strength short sprint performance (r= |0.51|), and countermovement jump height (r= |0.60|). 30-m sprint performance showed similar correlations for both absolute (r= |0.57|) and relative (r= |0.57|) strength measures, respectively. Similarly, Loturco et al. (2021) found large correlations (r= |0.54| to |0.60|) between squat and countermovement jump height, 30-m sprint performance and maximum strength expressed relative to body mass, but non-significant correlations in absolute terms (r= |0.26| to |0.34|). In contrast, Comfort et al. (2014) reported comparable large to very large correlations for both absolute (r= |0.59| to |0.76|) and relative (r= |0.51| to |0.67|) strength measurements with speed strength performances.

Therefore, the aim of the study was to analyze whether absolute and relative maximum strength measurements of the 1RM parallel squat correlate differently with different jump (squat jump and countermovement jump) and sprint performances (5-, 10-, 20- and 30-m), respectively. It was hypothesized that, while both absolute and relative strength correlate moderately to highly with athletes' sprint and jump performances, correlations of relative strength performances to be higher (Loturco et al., 2021).

Methods

Experimental approach to the problem

The objective of the study was to analyze potential correlations between maximal strength measures (1RM parallel back squat) with jump performance (squat jump and countermovement jump) and linear sprint performance (5-, 10-, 20-, and 30-m times), respectively, in trained youth soccer players (n=63, weekly training frequency 3-4 times over the last 2-3 years). To account for the possible effects of body composition and absolute body mass on jump performance and sprint performances, strength measures were included in the correlation analysis both as absolute (kg) and relative values (kg/kg of BM). Study protocol is presented in Figure 1.

Participants

In this investigation, 63 male youth soccer players (height = 182.9±5.9 cm, body mass [BM] = 72.2±8.0 kg, age = 17.9±2.1 years old) participated during in-season training throughout the Covid-19 pandemic. None of the athletes reported any injuries at the time of testing. The subjects were recruited from three teams (U21 [under 21 years], U19, U17) of a youth elite training center associated with a professional club in the third division in Germany. The U17 and U19 youth soccer teams played in the highest (Junior National League) and the second highest (Bavarian League) league, respectively. The U21

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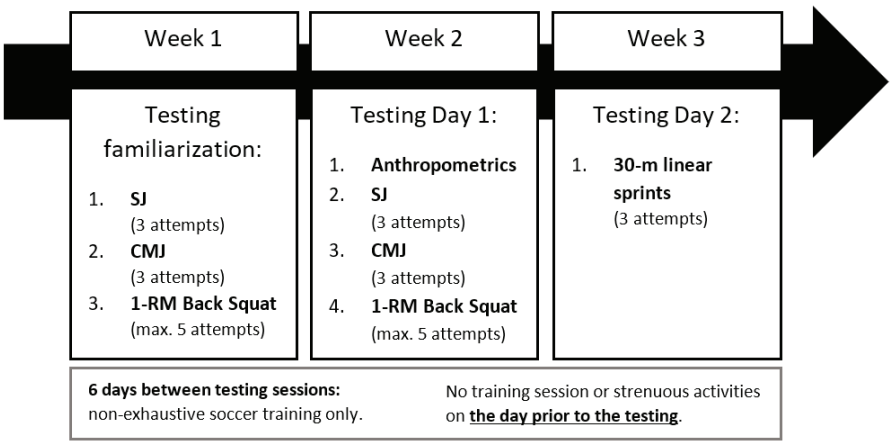

Figure 1. Study protocol. SJ – squat jump, CMJ – countermovement jump.

amateur team played in the 5th highest German league (Senior Bavarian League). The soccer players who were investigated had played soccer since early childhood. Their training during the period of testing consisted of 5 training sessions per week with competitions on weekends. The training sessions consisted of team and position specific soccer training, as well as athletic training including resistance training and plyometric exercises (i.e., jumping and sprinting). Based on their surpassing age-related training experience they were characterized as trained adolescents (3-4 times per week for 2-3 years).

All participants and participants' parents, for those participants under the age of 18, read and signed written informed consent to participate approved by the local University's institutional Ethics committee (DHGS-EK-2021-002). All procedures complied with the principles outlined in the Declaration of Helsinki.

Procedures

Adequate familiarization with the tests was given through familiarization sessions and a pre-test one week prior to data acquisition. The actual test protocol was divided into 2 testing days with maximum strength and speed strength measures taken on one test day 1 week apart from linear sprint measurements. On the day prior to the respective test days, no trainings sessions were conducted, and participants were instructed to avoid strenuous activities. After completing a standardized warm-up, the subjects completed all tests in the order described below.

Maximal Strength Test

A 1-RM back squat measurement was taken to assess the maximum lower body strength in the participants after a standardized additional warm-up. The warm-up protocol consisted of multiple repetitions with submaximal loads (3 sets of squats with 6-8 repetitions). During all attempts, participants were required to squat to a standardized depth where the top of the thigh was parallel to the ground. Squat depth was visually assessed and verbally reinforced by the investigators while the subjects were squatting. The participants were familiar with back squats as they received a technical training twice a week for two weeks prior to testing. Attempts failed when the soccer players were not able to stabilize the bar with their backs, lost the bar, or were unable to hit required depth. Rest periods of at least 5 minutes were given between the trials. 1RMs were achieved within a maximum of 5 attempts. Considering the importance of body weight for speed strength performances 1-RMs were reported as both absolute (kg) and relative strength (kg/kg of BM). A high intraclass correlation coefficient (ICC) of 0.91-0.99, as measure of test-retest reliability, has been reported in previous research (Keiner et al., 2021; McMaster et al., 2014).

Jump Performance Tests

Squat jumps and countermovement jumps were tested using a portable contact mat [ALGE, Lustenau, Austria]. To ensure adequate familiarization the participants were granted 3 test trials for each jump type. After that, the participants completed 5 trails of each jump, with a 1-minute rest between jumps. All jumps were performed with hands fixed on the hips throughout the whole measurement. The best result was used for statistical analysis. A successful squat jump was initiated from squat position (approx. 90° knee angle) after a 2-second hold without momentum. The countermovement jump utilizes the momentum of a preceding squat movement (to approx. 90° knee angle) to initiate the immediate jump. Correct movement execution was visually assessed and verbally reinforced by the investigators while the subjects were jumping. ICCs of 0.87-0.98 and 0.94 have been reported for squat jumps and countermovement jumps, respectively (Keiner et al., 2021; Keiner et al., 2015).

Sprint Performances Test

A 30-m sprint measurement was taken to assess acceleration and linear sprint ability in the soccer players. Time measurements were initiated by the participants crossing the initial light barrier and sprint times were taken at 5, 10-, 20- and 30-m using four additional double-light barriers (wk7 time watch, Ditzingen, Germany). To avoid an early triggering of the system by hand movement or a tilted upper body position the participants started 0,75 meters ahead of the initial light barrier. Each participant completed three trials, with a 3-min rest between sprints. The best result after 30 meters was used for statistical analysis. ICCs of 0.91-0.97 has been reported in previous research (Keiner et al., 2021; Sander et al., 2013)

Statistical Analysis

Descriptive statistics were calculated for all data and reported as mean ± standard deviations. Shapiro-Wilk test was performed to analyze the data for normal distribution. The best performances in each test were used for the

statistical analysis. Relationships between the performance variables were calculated for the normally distributed data using one-tailed bivariate Pearson correlations. If the data were not normally distributed, relationships between the test variables were calculated using one-tailed Spearman correlation coefficients. Correlations were interpreted according to the following thresholds: ≤0.1 = trivial, >0.1-0.3 = small, >0.3-0.5 = moderate, > 0.5-0.7 = large, >0.7-0.9 = very large, and >0.9-1.0 = nearly perfect/perfect (Hopkins et al., 2009). To statistically compare correlations of absolute and relative strength values with sprint and jump performances, Fisher's Z was calculated using the Pearson's correlation coefficients and sample size and tested for statistical significance (Z = (z1 – z2) / sqrt((1 / (n1 – 3) + (1 / (n2 – 3))). To assess the relative reliability of performances ICCs and 95% CI were calculated from familiarization and testing sessions for squats and jumps and from in between trials for sprints. Portney (2020) suggests values above 0.75 as being indicative for good reliability. The significance level was set at $p < 0.05$. The All calculations were performed using the statistical software package SPSS 27.0.1.0 (IBM, Ehningen, Germany).

Results

Eighteen participants did not participate in all tests due to organizational reasons or injury not related to the intervention. These athletes were not included in the correlations. Except athletes' age all data displayed a normal distribution. Performance variables, ICCs, and the 95% confidence intervals (95% CIs) are presented in Table 1. The test-retest reliabilities of strength sprint and jump performances were greater than 0.75, indicating high reliability.

Table 1. Descriptive Statistics and Reliability of Maximum Strength and Sprint and Jump Performances

	Mean±SD	ICC (95% CI)
1 RM	94.3±13.2	0.94 (0.89-0.97)
1 RM/BM	1.3±0.1	
SJ	37.3±4.2	0.87 (0.75-0.93)
CMJ	40.0±4.6	0.94 (0.91-0.96)
LS 5m	1.01±0.04	0.80 (0.68-0.87)
LS 10m	1.73±0.05	0.87 (0.81-0.92)
LS 20m	2.97±0.08	0.94 (0.91-0.96)
LS 30m	4.14±0.12	0.97 (0.95-0.98)

1 RM= One Repetition Maximum back squat (in kg); 1 RM/BM= One Repetition Maximum back squat divided by body mass (in kg*kg-1); SJ= squat jump (in cm); CMJ= countermovement jump (in cm); LS= linear sprint (in s);

Statistically significant differences between the correlations of absolute and relative strength measurements were obtained (Table 2). More precisely, the r values between relative strength measures and jump performances (r= 0.52 to 0.58) were significantly larger than those between absolute strength measurements and jump performances (r= 0.16 to 0.26, z= -1.816 to -1.902, p= 0.029 to 0.035). However, in contrast, the r values between relative strength measures and sprint performances (r= -0.32 to -0.42) were of non-statistical difference to the correlations of absolute strength measurements with sprint performances (r= -0.19 to -0.3, z= 0.349 to 1.17, p= 0.121 to 0.363).

Table 2. Pearson's Correlations (r-Values) and Differences (Z) Between Absolute and Relative Strength With Sprint and Jump Performances

	SJ	CMJ	LS 5m	LS 10m	LS 20m	LS 30m
1RM	0.16	0.26*	-0.19	-0.25*	-0.28*	-0.3*
1RM/BW	0.52*	0.58*	-0.42*	-0.32*	-0.36*	-0.37*
Z	-1.90*	-1.81*	1.17	0.34	0.40	0.36

1 RM = One Repetition Maximum back squat; 1 RM/BM = One Repetition Maximum back squat divided by body mass; SJ = squat jump; CMJ = countermovement jump; LS = linear sprint; *= significant ($p<0.05$)

Discussion

The study was designed to analyze whether absolute and relative maximum strength measurements of the 1RM parallel squat correlate differently with different jump and sprint performances among a population of trained male youth soccer players. The data showed significant moderate to large correlations for relative strength and sprint and jump performances (r= |0.32| to |0.58|). However, only non-existent to weak correlations (r= |0.16| to |0.30|) were found between absolute strength and sprint and jump performances, respectively. In line with our hypothesis, relative strength measurements demonstrated significantly stronger correlations with jump performances than absolute strength (p= 0.029 to 0.035). However, other than expected the differences between the correlations of absolute and relative strength with sprint performances were of no statistical significance (p= 0.121 to 0.363). Still, it has been well established that the ability to generate largest possible ground reaction forces within a short ground contact time to accelerate one's body mass is a critical contributor to speed-strength performance (Hunter et al., 2005; Morin et al., 2012; Weyand et al., 2010; Weyand et al., 2000). Therefore, considering Newton's second law (force = mass * acceleration), athletes who are able to exert greater amounts of force against their own body mass should be able accelerate faster. With absolute values these relationships between force, mass, and acceleration are not considered,

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which could explain the scattering of results in previous literature.

What also must be considered is, that with increased complexity of the performance task (jump vs. short sprint performance vs. long sprint performance) smaller correlations with strength measurements are generally observed. Therefore, the data might not be sensible enough to illustrate the influence of body weight on more complex speed strength performances like sprinting, as other influences like technical fluency affect performance to a certain extent.

However, recently, Loturco et al. (2021) found large correlations (r= |0.54| to |0.60|) between squat and countermovement jump height, 30-m sprint performance and maximum strength expressed relative to body mass, but non-significant correlations in absolute terms (r= |0.26| to |0.34|). These results are of particular significance as all r values of relative strength measures with jump and sprint performances were, considering Fisher's Z, significantly larger than those of absolute strength measures (p= 0.02 to 0.03). These results, in conjunction with the findings of the current study, suggest that superior speed strength performances are a product of the athlete's ability to exert greater amounts of force against their own body weight. Consequently, it seems reasonable to consider strength expressed relatively to body mass to be a superior indicator for speed strength performance, especially for short sprint and jump performances. Moreover, this conclusion is in accordance with previous literature showing largest possible ground reaction forces of 2 to 5 times body weight during jumps and sprint starts to be mandatory for superior speed strength performance (Bass et al., 2007; Hunter et al., 2005; Lafortune et al., 2000; Weyand et al., 2000).

The study has limitations. Initially, 63 athletes were part of this study but due to organizational reasons or injury, not related to the intervention, 18 missed some of the measurements. This should have had small effect on the results considering the total sample size. On the contrary, with 45 participants the study provides a substantial sample size considering the performance level of the participants. It is also noteworthy that this study actually controlled for significant differences between the correlations of absolute and relative strength measures with jump and sprint performances. This has not been done in previous literature (Boraczynski et al., 2020; Comfort et al., 2014). Investigating the data of this study, it is conspicuous that the strength levels and jumping heights, especially in the squat jump, are considerably lower compared to similar studies with well-trained youth soccer players (Comfort et al., 2014). However, these studies also reported sprinting performances similar to those examined in this investigation. Technical disparities in measuring squats and squat jumps as maximum strength and speed strength tests could be a possible explanation for differences between the present study and previous studies. When determining a 1RM of the squat, a key limiting factor in many cases, especially in younger, less experienced athletes, seems to be trunk strength (Keiner et al., 2014). As such, only accepting trials with proper technique, with the athlete stabilizing the barbell load with his trunk without spinal flexion, the one-repetition maximum squat might not be an adequate assessment of pure maximum lower body strength. However, this might explain why this investigation reached lower strength values and showed weaker correlations compared to previous research. Still, even though all participants were already accustomed with the testing procedures as they had performed similar exercises during their regular athletic training, this study utilized an extensive familiarization protocol to ensure reliable performance measurements. In terms of evaluating the squat jump, similar difficulties could explain the lower correlations between the measurement and the observed values. Initiating a jump out of 90° knee flexion after a two second hold without momentum and pure concentric movement usually does not belong to the typical movement repertoire of a team sports athlete. Therefore, it is reasonable to assume lower technical efficiency, resulting in limited force production and jumping height, especially when emphasizing on correct form without the utilization of momentum. Further evidence is found in a lower ICC in the squat jump. Despite these limitations, the applied study protocol and the included sample allow a solid evaluation of the relationships between the analyzed variables.

Conclusion

The primary findings of this study were significant differences between the correlations of absolute and relative strength measurements with jump performances. The data supports findings in previous literature of enhanced acceleration and speed strength performances by higher levels of absolute and relative strength in various athletic populations, with faster and more powerful athletes being able to generate larger forces against their own body weight. However, taking into account the results by Loturco et al. (2021), strength expressed relative to body mass might be considered a superior indicator of speed strength performance in general. Therefore, assessing relative strength performances within soccer-specific performance diagnostic protocols might provide more relevant information than absolute strength values about the athlete's speed strength abilities.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Allmann, H. (1985). Maximalkraft und Sprintleistung – Maximalkrafttraining im Sprinttraining. In M. Bührle (Ed.), *Grundlagen des Maximal- und Schnellkrafttrainings* (pp. 282-300). VerlagHofmann.

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *J Sports Sci*, *24*(7), 665-674. https://doi.org/10.1080/02640410500482529

Bass, S. L., Daly, R. M., & Blimkie, C. J. R. (2007). Growing a Healthy Skeleton: Exercise—the Primary Driving Force. In *The Young Athlete* (pp. 112-126): Blackwell Publishing Ltd.

Boraczynski, M., Boraczynski, T., Podstawski, R., Wojcik, Z., & Gronek, P. (2020). Relationships Between Measures of Functional and Isometric Lower Body Strength, Aerobic Capacity, Anaerobic Power, Sprint and Countermovement Jump Performance in Professional Soccer Players. *J Hum Kinet*, *75*, 161-175. https://doi.org/10.2478/hukin-2020-0045

Chelly, M. S., Cherif, N., Amar, M. B., Hermassi, S., Fathloun, M., Bouhlel, E., Tabka, Z., & Shephard, R. J. (2010). Relationships of peak leg power, 1 maximal

repetition half back squat, and leg muscle volume to 5-m sprint performance of junior soccer players. *J Strength Cond Res*, *24*(1), 266-271. https://doi.org/10.1519/JSC.0b013e3181c3b298

Comfort, P., Stewart, A., Bloom, L., & Clarkson, B. (2014). Relationships between strength, sprint, and jump performance in well-trained youth soccer players. *J Strength Cond Res*, *28*(1), 173-177. https://doi.org/10.1519/JSC.0b013e318291b8c7

Dempsey, P. C., Handcock, P. J., & Rehrer, N. J. (2014). Body armour: the effect of load, exercise and distraction on landing forces. *J Sports Sci*, *32*(4), 301-306. https://doi.org/10.1080/02640414.2013.823226

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*, *41*(1), 3-13. https://doi.org/10.1249/MSS.0b013e31818cb278

Hori, N., Newton, R. U., Andrews, W. A., Kawamori, N., McGuigan, M. R., & Nosaka, K. (2008). Does performance of hang power clean differentiate performance of jumping, sprinting, and changing of direction? *J Strength Cond Res*, *22*(2), 412-418. https://doi.org/10.1519/JSC.0b013e318166052b

Hunter, J. P., Marshall, R. N., & McNair, P. J. (2005). Relationships between ground reaction force impulse and kinematics of sprint-running acceleration. *J Appl Biomech*, *21*(1), 31-43. https://doi.org/10.1123/jab.21.1.31

Joch, W. (1992). *Rahmentrainingsplan für das Aufbautraining Sprint* (Vol. 2). Meyer & Meyer Verlag.

Keiner, M., Kadlubowski, B., Hartmann, H., Stefer, T., & Wirth, K. (2021). The Influence of Maximum Strength Performance in Squats and Standing Calf Raises on Squat Jumps, Drop Jumps, and Linear as well as Change of Direction Sprint Performance in Youth Soccer Players. *Int J Sports Exerc Med 7:190*. https://doi.org/10.23937/2469-5718/1510190

Keiner, M., Sander, A., Wirth, K., & Hartmann, H. (2015). Differences in the performance tests of the fast and slow stretch and shortening cycle among professional, amateur and elite youth soccer players. *Journal of Human Sport and Exercise*, *10*, 563-570. https://doi.org/10.14198/jhse.2015.102.03

Keiner, M., Sander, A., Wirth, K., Hartmann, H., & Yaghobi, D. (2014). Correlations between maximal strength tests at different squat depths and sprint performance in adolescent soccer players. *American Journal of Sports Science*, *2*(6-1), 1-7. https://doi.org/10.11648/j.ajss.s.2014020601.11

Lafortune, M. A., Valiant, G. A., & McLean, B. (2000). Biomechanics of running. In J. A. Hawley (Ed.), *Running*. Blackwell Sciences.

Loturco, I., Pereira, L. A., Freitas, T. T., Bishop, C., Pareja-Blanco, F., & McGuigan, M. R. (2021). Maximum Strength, Relative Strength, and Strength Deficit: Relationships With Performance and Differences Between Elite Sprinters and Professional Rugby Union Players. *Int J Sports Physiol Perform*, 1-6. https://doi.org/10.1123/ijspp.2020-0342

McBride, J. M., Blow, D., Kirby, T. J., Haines, T. L., Dayne, A. M., & Triplett, N. T. (2009). Relationship between maximal squat strength and five, ten, and forty yard sprint times. *J Strength Cond Res*, *23*(6), 1633-1636. https://doi.org/10.1519/JSC.0b013e3181b2b8aa

McMaster, D. T., Gill, N., Cronin, J., & McGuigan, M. (2014). A brief review of strength and ballistic assessment methodologies in sport. *Sports Med*, *44*(5), 603-623. https://doi.org/10.1007/s40279-014-0145-2

Morin, J. B., Bourdin, M., Edouard, P., Peyrot, N., Samozino, P., & Lacour, J. R. (2012). Mechanical determinants of 100-m sprint running performance. *Eur J Appl Physiol*, *112*(11), 3921-3930. https://doi.org/10.1007/s00421-012-2379-8

Nuzzo, J. L., McBride, J. M., Cormie, P., & McCaulley, G. O. (2008). Relationship between countermovement jump performance and multijoint isometric and dynamic tests of strength. *J Strength Cond Res*, *22*(3), 699-707. https://doi.org/10.1519/JSC.0b013e31816d5eda

Portney, L. G. (2020). *Foundations of clinical research: applications to evidence-based practice* (4th ed.). Philadelphia: F.A. Davis Company.

Reilly, T. (2006). The Science of Training - Soccer: A Scientific Approach to Developing Strength, Speed and Endurance.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *J Sports Sci*, *18*(9), 669-683. https://doi.org/10.1080/02640410050120050

Rodriguez-Rosell, D., Mora-Custodio, R., Franco-Marquez, F., Yanez-Garcia, J. M., & Gonzalez-Badillo, J. J. (2017). Traditional vs. Sport-Specific Vertical Jump Tests: Reliability, Validity, and Relationship With the Legs Strength and Sprint Performance in Adult and Teen Soccer and Basketball Players. *J Strength Cond Res*, *31*(1), 196-206. https://doi.org/10.1519/JSC.0000000000001476

Sander, A., Keiner, M., Wirth, K., & Schmidtbleicher, D. (2013). Influence of a 2-year strength training programme on power performance in elite youth soccer players. *Eur J Sport Sci*, *13*(5), 445-451. https://doi.org/10.1080/17461391.2012.742572

Schmidtbleicher, D. (1992). Training for power events. In P. Komi (Ed.), *Strength and power in sport* (pp. 381-395). Blackwell Scientific Publications.

Schmidtbleicher, D. (2000). Biomechanische Belastungen verschiedener Sportarten - Möglichkeiten der präventiven Biomechanik. In L. Zichner, M. Engelhardt, & J. Freiwald (Eds.), *Sport bei Arthrose und nach endoprothetischem Einsatz* (Vol. 6, pp. 47-62). Novartis Pharma Verlag.

Stolen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of soccer: an update. *Sports Med*, *35*(6), 501-536. https://doi.org/10.2165/00007256-200535060-00004

Weyand, P. G., Sandell, R. F., Prime, D. N., & Bundle, M. W. (2010). The biological limits to running speed are imposed from the ground up. *J Appl Physiol (1985)*, *108*(4), 950-961. https://doi.org/10.1152/japplphysiol.00947.2009

Weyand, P. G., Sternlight, D. B., Bellizzi, M. J., & Wright, S. (2000). Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *J Appl Physiol (1985)*, *89*(5), 1991-1999. https://doi.org/10.1152/jappl.2000.89.5.1991

Wisloff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). 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

Wisloff, U., Helgerud, J., & Hoff, J. (1998). Strength and endurance of elite soccer players. *Med Sci Sports Exerc*, *30*(3), 462-467. https://doi.org/10.1097/00005768-199803000-00019

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REVIEW

The influence of inter-limb asymmetries in muscle strength and power on athletic performance: a review

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Abstract

The aim of this review was to examine the available literature on inter-limb strength and power asymmetries and their effect on sports performance. In total, 31 studies were included. The findings indicate a negative effect of strength asymmetries on change of direction, sprinting, cycling and kicking performance. They may also be detrimental to jumping performance, however, more research is needed to confirm this. The findings on power asymmetries are more inconsistent and indicate that asymmetries measured with various power tests may affect some performance measures. For example, jumping performance is affected by the power asymmetries measured with jumps, but not by those measured with change of direction tests. Furthermore, the correlation between asymmetry tests and performance outcomes can be affected by the type of sport, training period and the magnitude of the asymmetry. To better understand the effects of strength and power asymmetries on athletic performance, further research is needed, particularly on the effects on sport-specific performance tests.

Keywords: *imbalance, muscle performance, sport performance, neuromuscular assessment*

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Introduction

Body asymmetries are divided into local (joint-level strength) and global (jumping performance). Local asymmetries can be further divided into contralateral (often referred to as inter-limb asymmetries), comparing left and right side of the body, and ipsilateral, comparing opposite muscle groups on the same side of the body. In this review, we focus on contralateral asymmetries in strength and power and their effect on sports performance. These types of asymmetries have been reported to be present in various team sports (Bailey, Sato, Alexander, Chiang & Stone, 2013; Bell, Sanfilippo, Binkley & Heiderscheit, 2014; Bishop, Read, McCubbine & Turner, 2021a; Bishop et al., 2019; Bishop et al., 2022a; Bishop, Rubio, Gullon, Maloney & Balsalobre-Fernandez, 2022b; Coratellaa, Beatoc & Schenab, 2018; Dos'Santos, Thomas, Jones & Comfort, 2017; Fort-Vanmeerhaeghe et al., 2020; Hart, Nimphius, Spiteri & Newton, 2016; Hoffman, Ratamess, Klatt,

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Faigenbaum & Kang, 2007; Işın, Akdağ, Özdoğan & Bishop, 2022; Kozinc & Šarabon, 2020; Lockie, Schultz, Jeffriess & Callaghan, 2012; Lockie et al., 2014; Madruga-Parera et al., 2021b; Madruga-Parera et al., 2020b; Madruga-Parera et al., 2021a; Maloney, Richards, Nixon, Harvey & Fletcher, 2016; Pardos-Mainer et al., 2021; Philipp, Crawford, Garver, Davis & Hair, 2022; Schons et al., 2019), swimming (Phukan et al., 2021; Morouço, Marinho, Fernandes & Marques, 2015; Dos'Santos, Pereira, Papoti, Bento & Rodacki, 2013), cycling (Bini & Hume, 2015; Rannama, Port, Bazanov & Pedak, 2015), tennis (Madruga-Parera et al., 2020a) and sprint (Exell, Irwin, Gittoes & Kerwin, 2017). Although long-distance running is considered to be a fairly symmetrical sport, it has also been discussed with regard to contralateral asymmetries (Blagrove et al., 2021). Limb dominance, previous injuries, specific requirements of sports and the extent of exposure to a particular sport or activity may contribute to the further development of asymmetries (Newton et al., 2006). In addition to research proving the presence of asymmetries in adults (Bailey et al., 2013; Bell et al., 2014; Bini et al., 2015; Bishop et al., 2019; Bishop et al., 2021b; Bishop et al., 2022a; Coratella et al., 2018; Dos Santos et al., 2013; Dos Santos et al., 2017; Exell et al., 2017; Hart et al., 2016; Hoffman et al., 2007; Lockie et al., 2012; Lockie et al., 2014; Madruga-Parera et al., 2021a; Maloney et al., 2016; Philipp et al., 2022; Rannama et al., 2015; Schons et al., 2019), many recent studies also consider the younger population (Atkins et al., 2016; Bishop et al., 2021a; Bishop et al., 2022b; Blagrove et al., 2021; Fort-Vanmeerhaeghe et al., 2020; Işın et al., 2022; Kozinc et al., 2020; Madruga-Parera et al., 2021b; Madruga-Parera et al., 2020a; Madruga-Parera et al., 2020b; Morouço et al., 2015; Pardos-Mainer et al., 2021; Phukan et al., 2021). The magnitude of the asymmetry is also affected by the way it is calculated. Many approaches of quantifying these differences have been established including dominant vs. non-dominant, stronger vs. weaker, as well as injured vs. non-injured leg. The wide range of classifications has emerged to accommodate specific purposes of asymmetry evaluation. In any case, the asymmetries are almost exclusively reported as the percentage difference from one limb in respect to the other (Bishop, Read, Chavda & Turner, 2016; Bishop, Turner & Read, 2018).

In recent years, the magnitude of these asymmetries has been brought to the forefront. In rehabilitation, a threshold of < 10% is typically used to discharge a patient recovering from an injury. However, it should be noted that this is an arbitrary threshold (Bishop et al., 2018). Although it is thought that asymmetries > 15% are associated with increased injury risk, recent literature is showing that these asymmetry magnitudes are test-specific, which means that individual tests require specific "critical" thresholds (Bishop et al., 2021a; Bishop et al., 2019; Dos'Santos et al., 2017; Hart et al., 2016; Kozinc et al., 2020; Lockie et al., 2014; Maloney et al., 2016; Parkinson, Apps, Morris, Barnett & Lewis, 2021; Philipp et al., 2022; Read et al., 2021). The same goes for the direction of the asymmetry, which has been brought to attention only in the recent years. It is increasingly being shown that the more capable limb depends on the performance test used (Bishop et al., 2022b; Kozinc et al., 2020; Pardos-Mainer et al., 2021).

Although the effect of asymmetries in power on sports performance has already been discussed in several older studies, it has intensely been researched only in the recent years. The studies showed contradictory results. Some of them reported a negative effect of the asymmetries on performance (Bell et al., 2014; Bishop et al., 2021a; Bishop et al., 2019; Bishop et al., 2021b; Exell et al., 2017; Fort-Vanmeerhaeghe et al., 2020; Kozinc et al., 2020; Madruga-Parera et al., 2021b; Madruga-Parera et al., 2020a; Madruga-Parera et al., 2020b; Madruga-Parera et al., 2021a; Maloney et al., 2016; Philipp et al., 2022). They found that asymmetries measured with jumps, isoinertial tests, crossover and lateral shuffle steps, and change of direction (CoD) tests negatively affect jumping, CoD and sprinting performance as well as some sport-specific skills such as swimming sprint. In contrary, other studies did not find a relationship between asymmetry and performance (Bishop et al., 2022a; Bishop et al., 2022b; Dos'Santos et al., 2017; Hoffman et al., 2007; Isin et al., 2022; Lockie et al., 2014; Pardos-Mainer et al., 2021; Phukan et al., 2021).

Studies discussing the effect of strength asymmetries on sport performance showed contradictory results. Some confirm the asymmetries measured with isokinetic dynamometry, isometric squats and pulls and sport specific test negatively affect CoD, jump and sprint ability along with cycling sprint, kicking accuracy and swimming sprint (Bailey et al., 2013; Bini et al., 2015; Coratella et al., 2018; Dos'Santos et al., 2013; Kozinc et al., 2020; Hart et al., 2016; Lockie et al., 2012; Rannama et al., 2015). Others could not find a correlation between asymmetries and performance, suggesting their independence (Blagrove et al., 2021; Morouço et al., 2015; Schons et al., 2019). To a lesser extent, the effect of different magnitudes of asymmetries is observed in the studies. While Lockie et al., (2014) and Hoffman et al., (2007) state that there is no difference in performance between individuals with smaller and larger asymmetries, Bell et al., (2014) demonstrated that asymmetries between limbs > 10% negatively affect jump height. Philipp et al., (2022) also suggest the threshold of 10 – 15% to reflect the magnitude where a negative effect of asymmetries occurs, however, it is again important to note that this threshold varies from one test to another.

As summarized throughout the introduction, the influence of inter-limb asymmetries in muscle strength and power on sports performance is still equivocal. The purpose of this review is to collect and summarize all available literature on this topic. This way, specific gaps in the literature will be recognized, while coaches and other professionals will be able to use this information to address the most critical asymmetries that may present in their athletes.

Methods

From January to May 2022, we searched for relevant studies and articles that were accessed through the PubMed and Google Scholar online scientific database. To avoid excessive quantities of unrelated articles, we combined the phrase »sports performance« with different phrases: »inter-limb asymmetry«, »strength asymmetry« and »power asymmetry«. The papers were considered eligible if they a) reported at least one inter-limb asymmetry variable based on strength or power assessment; b) reported at least one general (e.g., jump height, sprint time, CoD time) or sport-

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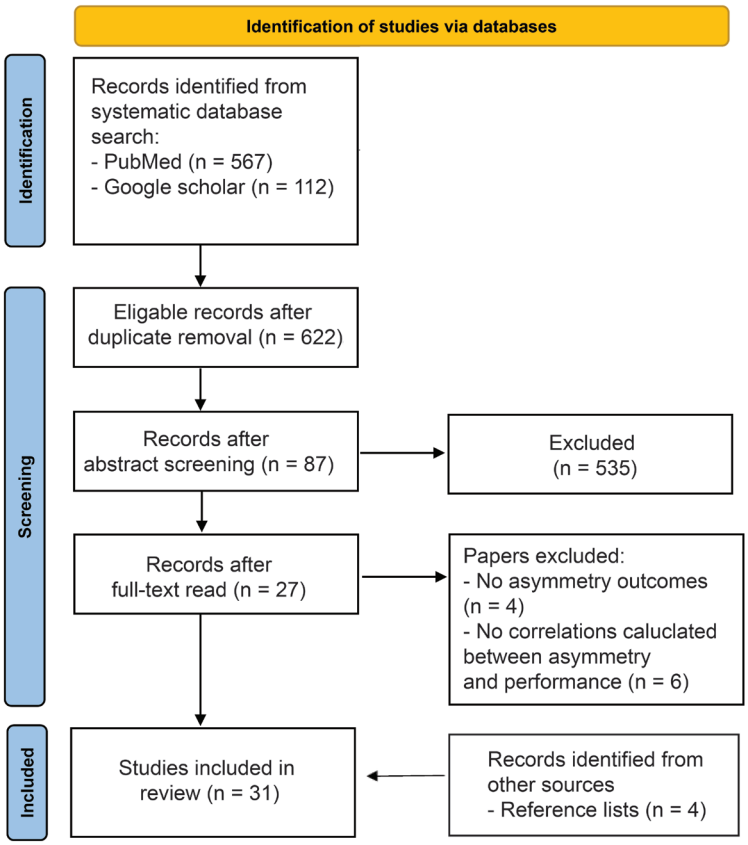

Figure 1. PRISMA flowchart of showing identified, included and excluded studies.

specific (e.g., kicking accuracy task) performance variable; and c) either reported correlation coefficients between the two types of variables or compared the mean performance between groups of participants, established based on the magnitude of the asymmetry. We made no restrictions regarding the population. The details on study search are shown in Figure 1. Upon database search, 27 papers were included in the review. Four additional studies were obtained from the reference lists of the included studies. When the research was not available in full-text, the authors were contacted. All 31 papers were made available eventually, therefore, all were included in the final review.

Results

Of all 31 studies included in the final analysis, 11 of them were conducted on soccer and football players, three on swimmers, two on cyclists, two on handball players, two on runners, two on volleyball players, one on tennis players and one on basketball players. Of all studies, five of them measured strength asymmetry with isokinetic dynamometry, three with isometric squats or pulls, and three with sport specific tests. Power asymmetries in 20 of the studies were calculated from jumps. Three of them measured asymmetry in power with isoinertial device and one with the Bulgarian split squat. Of the six studies researching asymmetries in CoD, two of them also calculated change of direction deficit. 12 studies observed the effect of asymmetries on jumping performance, 19 on CoD performance, 13 on sprint performance and seven on sport-specific tests such as maximal running or crawl,

Table 1. Studies investigating asymmetries in strength

Author & year	Population	Asymmetry measurement	Performance tests	Results
Bailey et al., 2013	36 students, actively participating in various team sports. Average age = 20	Isometric mid-thigh pull Equation: (stronger leg – weaker leg) / total × 100	SJ, CMJ with and without the bar	Asymmetry in peak force is negatively correlated with jump height (r = – 0.34 to – 0.52) and peak power (r = – 0.28 to – 0.43).
Blagrove et al., 2021	43 runners of which 31 were included in the asymmetry part of the study. They did not perform strength training. Age = 15-18	Bilateral quarter-squat Equation: (stronger leg – weaker leg)/ total x 100 Single leg isometric hip extension and abduction Equation: (stronger leg – weaker leg)/ stronger x 100	Sub-maximal and maximal running assessment	The correlations between asymmetries in strength and running assessment were negligible. Only the asymmetry in hip abductor strength and running assessment were weakly and negatively correlated (r = -0.47).

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Author & year	Population	Asymmetry measurement	Performance tests	Results
Coratella et al., 2018	21 elite soccer players, U21. Age = 18-21	Quadriceps and hamstring isokinetic dynamometry at 30 and 300°/s. Equation: (stronger leg – weaker leg)/ stronger x 100	SJ, CMJ, 10 m and 30 m sprint, 180° CoD test and T-test	Asymmetry in eccentric peak torque at different angular velocities for both quadriceps and hamstrings were weakly to moderately negatively correlated with 180° CoD test (r = 0.404 – 0.426) and T-test (r = 0.394 – 0.614) performance and weakly negatively correlated with SJ and CMJ performance (r = – 0.015 do – 0.218). Hamstring concentric peak torque asymmetry at 300°/s was moderately negatively correlated with sprint time (r = 0.343 – 0.466).
Hart et al., 2016	31 sub-elite Australian football players, training for at least five years and at least two of those at the current level. Average age = 22	Bilateral and unilateral isometric squat Equation: (kicking leg – standing leg) / 0,5 × (kicking leg + standing leg) × 100	10 drop punt kicks over twenty meters to a player target	They found that the kicking accuracy was moderately positively correlated with the relative bilateral and relative unilateral strength of both legs (r = 0.25 – 0.40). Asymmetry in strength on both standing and kicking leg was strongly negatively correlated with kicking accuracy (r = – 0.52).
Kozinc et al., 2020	25 male and 29 female volleyball players that have been training more than three times a week for the last three years. Average age = 17	SLCMJ, SLHJ, SLLJ, THOP maximal unilateral isometric knee extension, rapid isometric pulses Equation: (D leg – ND leg) / max (D, ND) × 100	SLCMJ, 90° and 180° CoD test	180° CoD test performance was weakly negatively correlated wtih asymmetry in RTD-SF (r = 0.30).
Lockie et al., 2012	16 males participating in various team sports. At the time they were performing at least 3 hours of resistance training a week. Average age = 23	Quadriceps and hamstring isokinetic dynamometry (concentric: 60, 180, 240°/s eccentric: 30°/s) Equation: (stronger leg – weaker leg) / stronger leg x 100	40 m sprint (0 – 10 m, 0 – 20 m, 0 – 40 m), T-test	Asymmetry in torque and work at 60°/s did not affect performance. Asymmetry in torque at 180°/s and 240°/s was negatively correlated with 0-10 m (r = – 0.554 to – 0.902), 0-20 m (r = – 0.579 to – 0.869) and 0-40 m (r = – 0.525 to – 0.772) sprint velocity. Asymmetry in work at 180°/s and 240°/s was also negatively correlated with 0-10 m (r = – 0.740), 0-20 m (r = – 0.521) and 0-40 m (r = – 0.548) sprint velocity. While asymmetry in torque at 30°/s negatively affected T-test performance (r = 0.669), asymmetry in word at 30°/s negatively affected the 0 – 20 m (r = 0.534) and 0 – 40 m (r = 0.597) sprint performance and T-test performance (r = 0.638)
Rannama et al., 2015	16 competitive male road cyclists with at least 6 years of focused cycling training and competitive experience and season's cycling total distance over 15000 km.	Isokinetic dynamometry of the ankle plantar and ankle dorsal flexors, knee and hip extensors and flexors (60, 180 in 240°/s). Equation: (left – right) / max (left, right) × 100	Cycling sprint on three cadences (100,120 and 140 rpm)	Knee extensors peak torque asymmetry negatively affected maximal power production during cycling sprint (r = -0.50).
Schons et al., 2019	11 professional volleyball players with at least two years of competitive experience and 4 hours of training daily.	Quadriceps and hamstring isokinetic dynamometry: 60, 180, 300°/s Equation: ((D leg – ND leg) / D leg) × 100	CMJ	Strength asymmetries were not significantly correlated with CMJ performance.

CMJ = counter-movement jump, CoD = change of direction, SJ = squat jump, SLCMJ = single leg counter-movement jump, SLHJ = single leg horizontal jump, SLLJ = single leg lateral jump, THOP = triple hop, D = dominant, ND = non-dominant

kicking accuracy and others. Of all studies, three of them divided asymmetries into groups of different magnitudes. Most of the studies were conducted on elite athletes, 22 of them included male population, three included female population and six included both. In 19 studies the athletes were adults aged 18 and above, while the other 13 studies included a younger population. More details regarding the population, assessments and results are given in Tables 1-3.

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Table 2. Asymmetries in sport-specific tests

Author & year	Population	Asymmetry measurement	Performance tests	Results
Bini et al., 2015	10 cyclists with competitive experience in cycling or triathlon. Average age = 32	Bilateral pedal forces measured using a pair of strain gauge instrumented pedals during a 4 km cycling test Equation: (D leg – ND leg) / 0,5 × (D leg + ND leg) × 100%	Time on a 4 km cycling test on a stationary cycloergometer	While asymmetries in resultant force and index of effectiveness did not affect performance, larger asymmetry in effective force was positively correlated with cycling performance on the 4 km test (r = 0.72).
Dos'Santos et al., 2013	16 swimmers. For the last two years they have been training three times per week and competing on a national level. Average age = 21	2-minute front crawl tethered-swimming. 6 strokes were collected – 3 for each side at the beginning, in the middle and at the end of the test Absolute asymmetry in force between the right and left hand	Participants best performance in the 200 m frontcrawl swimming.	They found that the fastest swimmers had the smallest asymmetries in average and peak force.
Morouço et al, 2015	18 swimmers with at least five years of competitive experience in sprint or middle-distance swimming. Average age = 15	30 seconds of maximal front crawl tethered-swimming test Equation: ((D arm – ND arm) / 0,5 × (D arm + ND arm)) × 100	Maximal 50 m front crawl bout with an underwater start	The asymmetry in the produced force between D and ND arm, but it did not affect crawl performance.

D = dominant, ND = non-dominant

Table 3. Asymmetries in power

Author & year	Population	Asymmetry measurement	Performance tests	Results
Bell et al., 2014	167 students, participating in various team sports. Average age = 20	CMJ Equation: (right leg – left leg) / 0,5 × (right leg + left leg) × 100%	CMJ	Participant were divided into four groups of different asymmetry magnitudes (0-5, 5-10. 10-15 and >15%). Asymmetries >10% lowered the jump height for approximately 9 cm.
Bishop et al., 2022b	30 basketball players with at least 4 years of competitive experience and 2 years of conditioning traning. Average age = 17	SLCMJ, SLDJ, 505 test No asymmetry calculation data is given	SLCMJ, SLDJ, 505 test	Negative correlation were found between asymmetry and jump height in SLDJ on the left (r = – 0.44), reactive strength index on the left (r = – 0. 46) and 505 test performance both on left and right (r = 0.45 – 0.48).
Bishop et al., 2021b	41 professional soccer and cricket players with at least 6 years of competitive experience and 2 years of conditioning training twice a week. Average age = 20	SLCMJ, SLDJ Equation: 100/(max value) x (min value) x (-1) + 100	10 m sprint, 505 test	505 test performance in cricket players was negatively affected by asymmetries in SLDJ height (r = 0.56 – 0.59) and reactive strength index (r = 0.63 – 0.74). There were no other correlations found.
Bishop et al., 2022a	18 professional soccer players with at least 6 years of competitive experience and 2 years of conditioning training. Average age = 19	SLCMJ, SLDJ, CoDD Equation: 100/(max value) x (min value) x (-1) + 100	10 m and 30 m sprint, 505 test	No correlations between jump height asymmetry and performance tests were found in pre and mid-season. At the end of the season negative correlations between asymmetry in SLDJ and 10 m sprint performance (r = 0.62) and 505 test performance on the right leg (r = 0.65) were found.
Bishop et al., 2021a	19 female soccer players, performing 30 minutes of conditioning training twice a week. Average age = 10	SLCMJ, SLHJ, THOP, XHOP Equation: 100/(max value) x (min value) x (-1) + 100	SLCMJ, SLH, THOP, XHOP, 5 m, 10 m and 20 m sprint	Larger asymmetry in SLCMJ negatively affected sprint (r = 0.49 – 0.59) and SLCMJ (r = – 0.47 to – 0.53) performance. Asymmetry in THOP reduced horizontal jump performance (r = – 0.47 do – 0.58).
Bishop et al., 2019	16 soccer players with at least 6 years of competitive experience and 1 year of conditioning and ballistic training twice a week. Average age = 20	SLCMJ, SLDJ, 505 test Equation: 100/(max value) x (min value) x (-1) + 100	10 m and 30 m sprint, 505 test	While asymmetry in SLCMJ did not affect performance, asymmetry in jump height and reactive strength index during SLDJ negatively affected 10 m (r = 0.52) and 30 m (r = 0.58) sprint performance and 505 test performance (r = 0.52 – 0.66).

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Author & year	Population	Asymmetry measurement	Performance tests	Results
Dos'Santos et al., 2017	22 male team-sport players with at least one year of experience with resistance training. Average age = 21	SLHJ, THOP Equation 1: (right leg – left leg/ right leg × 100) Equation 2: (D leg – ND leg/ D leg × 100)	Modified 505 test, 90° CoD test	Asymmetries in jumps were not correlated to CoD performance. This may be due to the fact that only few participants displayed asymmetries greater than 10-15%.
Exell et al., 2017	8 sprint-trained athletes with at least two years of competitive experience. Average age = 22	SJ Equation 1: (45° – arctan (Xleft/ Xright)) / 90° × 100% Equation 2: (45° – arctan (Xleft/ Xright) - 180°) / 90° × 100%	60 m sprint	Ankle work during sprint was positively correlated with asymmetry in peak vertical ground reaction force (r = 0.895) and asymmetry in peak power (r = 0.761).
Fort-Vanmeerhaeghe et al., 2020	81 female and male team-sport players. 90-120 minutes of training 8-10 times a week and a match at the weekends. Age = 14-18	SLCMJ, SLHJ Equation: (highest performing limb – lowest performing limb / highest performing limb) ×100	SLCMJ, SLH, 30 m sprint and V-test	Asymmetry in SLCMJ was weakly negatively correlated with its performance on the lower performing limb (r = – 0.26 do – 0.48) and sprint performance (r = 0.26). Moderate to large negative correlation were found between the asymmetry in SLHJ and its performance (r = – 0.56 do – 0.64).
Hoffman et al., 2007	62 American football players. Average age = 19	CMJ, SLCMJ No asymmetry calculation data is given	L-test	Asymmetries in power between D and ND leg did not affect L-test performance. Additionally, they were divided into quartiles, however no differences were found.
Isin et al., 2022	42 sub-elite soccer players divided into horizontal and vertical asymmetries. These two groups were further divided into three magnitudes < 5%, 5 – 10%, > 10%.	SLCMJ, SLHJ Equation: (max. value – min. value / max. value) ×100	505 test, 30 m sprint	Jump height, sprint and CoD performance did not differ between the groups of different magnitudes. Although no significant differences were found, groups with larger asymmetry reached higher velocity, however these differences were small. No significant correlation between asymmetries in both jumps and performance tests were found.
Kozinc et al., 2020	25 male and 29 female volleyball players that have been training more than three times a week for the last three years. Average age = 17	SLCMJ, SLHJ, SLLJ, THOP maximal unilateral isometric knee extension, rapid isometric pulses Equation: (D leg – ND leg) / max (D, ND) × 100	SLCMJ, 90° and 180° CoD test	180° CoD test performance was weakly negatively correlated wtih asymmetry in SLCMJ (r = 0.29). Asymmetry in SLLJ was negatively correlated with 90° CoD test performance (r = 0.3). A negative correlation was also found between SLCMJ asymmetry and its performance in female participants (r = – 0.42).
Lockie et al., 2014	30 recreative males participating in various team sports at least two times a week and maintaining their physical fitness level during the research. Average age = 22	SLVJ, SLLJ, SLHJ Equation: (better performing leg - lesser performing leg) / better performing leg) x 100	20 m sprint (0-5 m, 0-10 m, 0-20 m), 505 test, modified T-test	They found that higher and longer jumps, mainly horizontal and lateral jumps, indicated a better time in the performance tests used (r = – 0.729 to – 0.306), however the asymmetry in the jumps was not significantly correlated with the CoD performance tests. This may be due to the absence of larger asymmetries (>15%) in the participants.
Madruga-Parera et al., 2020a	22 elite tennis players with at least 8 years of tennis experience. 150 minutes of training six times a week (on court, fitness) Average age = 16	SLCMJ, SLHJ, SLLJ, 180° CoD test, isoinertial tests: crossover and lateral shuffle step Equation: (D leg – ND leg) / D leg × 100	SLCMJ, SLHJ, SLLJ, 180° CoD test, isoinertial tests: crossover and lateral shuffle step	180° CoD asymmetry was negatively correlated with SLCMJ performance on the D (r = – 0.50) and ND leg (r = – 0.53) and 180° CoD performance on the D (r = – 0.50) and ND leg (r = – 0.63).

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Author & year	Population	Asymmetry measurement	Performance tests	Results
Madruga-Parera et al., 2020b	42 handball players with at least 7 years of competitive experience and three handball training sessions per week. Average age = 16	SLCMJ, SLHJ, SLLJ Equation: 100/(max value) x (min value) x (-1) + 100	SLCMJ, SLHJ, SLLJ, 2x180° CoD test, V-test, repeated sprints (8x10 m), 20 m sprint	SLCMJ and SLHJ asymmetries were negatively correlated with their performances (r = – 0.32 to – 0.52). A negative correlation was also found between SLCMJ asymmetry and repeated sprints performance (r = 0.35 – 0.40). SLHJ asymmetry negatively affected V-test (r = 0.32) and 2x180° CoD test (r = 0.31) performance.
Madruga-Parera et al., 2021a	16 soccer players who performed eight hours of training a week. Average age = 25	Knee extension and flexion and crossover step with isoinertial resistance, 180° CoD test Equation: 100/(max value) x (min value) x (-1) + 100	Knee extension and flexion and crossover step with isoinertial resistance, 180° CoD test	Asymmetry during the concentric phase of knee extension negatively affected performance during the eccentric phase of the crossover step (r = -0.63). Asymmetry during the concentric phase of the crossover step impaired 180° CoD performance (r = 0.51-0.59).
Madruga-Parera et al., 2021b	26 handball players, actively participating in high level youth handball league with at least 5 years of competitive experience and 2 years of resistance training. They performed 120 minutes of training three times a week and played one match a week. Average age = 16	SLCMJ, SLHJ, SLLJ, 90° and 180° CoD test, CoDD, isoinertial tests: crossover and lateral shuffle step Equation: 100/(D leg) x (ND leg) x (-1) + 100	20 m sprint, 90° and 180° CoD test	Asymmetry in crossover step was negatively correlated with the performance of both CoD tests (r = 0.41 – 0.51) and 20 m sprint (r = 0.46). Asymmetry during the concentric phase of the lateral shuffle step negatively affected 90° CoD test performance on the ND leg (r = 0.44). They also found negative correlations between 180° CoD test performance on the ND leg and SLLJ asymmetry (r = 0.39),180° CoD asymmetry (r = 0.42) and 180° CoDD asymmetry (r = 0.46).
Maloney et al., 2016	18 recreative male, who were active for at least two hours a week. Average age = 22	SLDJ Equation 1: (45° – arctan (Xleft/Xright)) / 90° × 100% Equation 2: (45° – arctan (Xleft/Xright) - 180°) / 90° × 100%	U-test	Asymmetry in SLDJ was positively correlated with U-test time (r = 0.60)
Pardos-Mainer et al., 2021	54 female soccer players with at least four years of soccer experience. Age groups: U-18, U-16 and U-14	SLHJ, SLCMJ, 505 test Equation: 100/(max value) x (min value) x (-1) + 100	SLHJ, SLCMJ, 505 test, 40 m sprint (0 – 10 m, 0 – 20 m, 0 – 40 m)	There were no correlation found between asymmetries in both jumps and sprint or 505 test performance. Furthermore 505 test asymmetry did not affect sprint or jump performance.
Phillip et al., 2021	24 professional American football players. Average age = 19	SLCMJ, SLDJ, 3-RM Bulgarian split squat Equation: (max. value – min. value / max. value) ×100	L-test, 505 test, 40-yard dash, VJ, HJ	A negative correlation between L-test performance and asymmetry in mPP (rs = 0.467) and mAP (rs = 0.455) during Bulgarian split squat was found. These asymmetries affecting L-test performance ranged from 10-15%. Larger SLCMJ asymmetry negatively affected VJ performance (r = – 0.578).
Phukan et al., 2021	38 swimmers competing on a national level. They practiced multiple swimming styles and were engaged in multiple recreational sports activities (not more than 2 h/week) Average age = 12	SLCMJ, SLHJ Equation: ((D leg – ND leg) / D leg) × 100	front crawl (25 m and 50 m), front crawl kick with push (25 m and 50 m)	No correlation was found between jump asymmetries and sport-specific swimming performance.

CMJ = counter-movement jump, CoD = change of direction, CoDD = change of direction deficit, D = dominant, ND = non-dominant, SJ = squat jump, SLCMJ = single leg counter-movement jump, SLHJ = single leg horizontal jump, SLLJ = single leg lateral jump, SLDJ = single leg drop jump, SLVJ = single leg vertical jump, VJ = vertical jump, HJ = horizontal jump, THOP = triple hop for distance, XHOP = crossover hop for distance

Discussion

The aim of this review was to examine the available literature pertaining to inter-limb asymmetries in strength and power and critically evaluate their effect on sports performance. In general, the literature suggests a negative effect of asymmetries on sports performance, however, the findings depend on the test used to assess asymmetry and the performance outcome measure.

Asymmetries in strength

Bailey et al., (2013) researched the effect of strength asymmetries in isometric mid-thigh pull on squat jump (SJ) and counter-movement jump (CMJ) performance. Larger asymmetries were moderately and negatively correlated with the height (r = – 0.34 to – 0.52) and peak power (r = – 0.,28 to – 0.43) during vertical jumps. Coratella et al., (2018) also reported a negative correlation between strength asymmetry and jumping ability, however this correlation was negligible. When measuring strength with isokinetic dynamometry they found that larger quadriceps and hamstrings peak torque asymmetries at different angular velocities somewhat reduce SJ and CMJ ability (r = – 0.02 to – 0.22). On the contrary, Schons et al., (2019) found no correlation between quadriceps or hamstring strength asymmetry, also measured with isokinetic dynamometry, and CMJ ability. These results indicate that larger asymmetries could be detrimental to jumping performance, however the correlations were weak, therefore further research is needed.

Lockie et al., (2012) researched the effect of quadriceps and hamstrings strength asymmetries on sprint performance. Larger asymmetries in torque and work during the concentric phase of knee extension at the speed of 180°/s and 240°/s were significantly and negatively correlated with sprint time (r = – 0,521 do – 0,902), suggesting that faster individuals exhibited greater bilateral differences. It is important to note that these asymmetries scored below the 15% threshold, therefore, despite slightly larger asymmetries in the faster group compared to the slower group, individuals were able to reach high velocities. Sprint velocity was impaired by the asymmetry in torque and work during the eccentric phase of knee flexion at the speed of 30°/s (r = 0,534 – 0,638). The findings of Coratella et al., (2018) reported a negative effect of asymmetry in peak torque during the concentric phase of knee flexion at the speed of 300°/s (r = 0,343 – 0,466). Based on these results, it is important to ensure between-limb balance in hamstring strength. This is consistent with research showing the great significance of producing the horizontal force component, which is provided by hamstring performance.

Alongside the effect of asymmetries on sprint performance, Lockie et al., (2012) also researched their effect on CoD ability. Larger asymmetries in torque and work during the eccentric phase of knee flexion at the speed of 30°/s was associated with inferior the T-test performance (r = 0.67). This was confirmed by Coratella et al., (2018), who, in addition to the effect of torque asymmetries during knee flexion, also found a negative correlation between torque asymmetry during the eccentric phase of the knee extension and T-test performance (r = 0.39 – 0.61). The participants also performed a CoD test with a 180° turn and a similar correlation was obtained (r = 0.40 – 0.43). Furthermore, Kozinc et al., (2020) reported a somewhat weaker correlation between 180° CoD performance and asymmetry in rate of torque development scaling factor (r = 0.30), measured during rapid isometric pulses on an isometric dynamometer. Based on the findings, we can conclude that asymmetries in strength of the lower extremities negatively affect CoD performance and it is therefore advisable to reduce them.

Asymmetries in strength could also have a detrimental effect on sport specific skills. Hart et al., (2016) researched how asymmetry, measured with unilateral and bilateral isometric squats, affects football kicking accuracy at a 20-meter distance from the target. The results indicate that larger asymmetries reduced the accuracy of the kicks (r = -0,52). Furthermore, Rannama et al. (2015), who conducted the research on cyclists, also reported a negative impact of strength asymmetries. Asymmetries in the extensors and flexors of the ankle, knee and hip were measured on an isokinetic dynamometer. The findings showed that greater asymmetry in peak torque of the knee extensors was negatively correlated with maximal power production during cycling sprint (r = – 0.50). Blagrove et al. (2021) discussed the effect of strength asymmetries, measured with isometric quarter-squat and isometric hip extension and abduction, on the maximal and submaximal running performance in middle- and long-distance runners. With the exception of a weak negative correlation between asymmetry in hip abductor strength and running economy in women (r = – 0.47) that suggest a detrimental effect to running performance, no other relationship was found. This is most likely due to the fact that long-distance running is considered a fairly symmetrical sport.

Asymmetries in sport-specific tests

Strength asymmetries in a study written by Bini et al., (2015) were measured using a pair of strain gauge instrumented pedals during a 4-kilometer cycling test. The authors reported a strong positive correlation between the asymmetry in effective force and the performance during the 4-kilometer time trial (r = –0.72), which somewhat surprisingly suggests that cyclists presenting larger asymmetries may be more successful. Dos'Santos et al., (2013) reported that the fastest swimmers in the 200 m sprint crawl had smaller asymmetries in peak and mean force measured during a 2-minute maximal crawl. A similar study, researching the effect of asymmetry in force, produced during a 30-second maximal crawl, on the performance during a 50-meter sprint crawl, was conducted by Morouço et al., (2015). However no correlation was found. The conflicting findings suggest that the impact of asymmetries measured with sport-specific tests varies from sport to sport, and that additional research is needed.

Asymmetries in power

Bishop et al., (2021a) researched the effect of asymmetries in power, measured with different jumps, on sprint performance. They found a positive correlation between asymmetry in single leg counter-movement jump (SLCMJ) and sprint time (r = 0.49 – 0.59; direction of correlation implying slower sprinting). Fort-Vanmeerhaeghe et al., (2020) also reported a similar finding, however the correlation was slightly weaker (r = 0.26). In a study conducted by Isin et al., (2022), participants were divided based on asymmetries measured SLCMJ and the single leg horizontal jump (SLHJ) (5%, 5 – 10% and 10 – 15%). Although no statistically significant correlations were found, groups with greater asymmetry generally achieved

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higher sprint speed, but these differences were small. Furthermore, Madruga Parera et al., (2020b), Lockie et al., (2014) and Pardos-Mainer et al., (2021) also did not find a correlation between asymmetries, measured with the SLHJ and SLCMJ, and sprint performance. This independence was partly confirmed by Bishop et al., (2019), however only with asymmetry measured with SLCMJ. Additionally, they latter study measured the asymmetry with the single leg drop jump (SLDJ) and found that higher asymmetries in jump height and reactive strength index impaired sprint performance on the 10-m (r = 0.52) and 30-m (r = 0.58) sprint. Bishop et al. (2022a) compared the effect of SLCMJ and SLDJ asymmetries on sprint performance in soccer players in three different parts of the season. No correlations were evident during preseason and midseason. Only at the end of the season, a significant correlation was found between SLDJ asymmetry and 10-m sprint time (r = 0.62). Exell et al., (2017) researched the effect of asymmetry in power, measured with the SJ, on sprint performance in sprint-trained athletes. They reported that asymmetries in work in the ankle joint during sprint and asymmetry in maximal vertical ground reaction force were related (r = 0.895), however, sprint performance was not affected by the asymmetries. Alongside asymmetries in jumps, which were weakly and negatively correlated with sprint ability (r = 0.18 – 0.27), Madruga Perera et al., (2021b) also measured the asymmetry with isoinertial resistance device. The participants performed a crossover and a lateral shuffle step, during which maximal power was measured. The results indicate that asymmetries during the concentric phase of the crossover step are associated with impaired 20-meter sprint performance (r = 0.46). Overall, the results of the studies are contradictory, with some confirmed the negative effect of asymmetry measured with SLCMJ on sprint ability, others rejected it and simultaneously showed the detrimental effect of asymmetry measured with SLDJ. Although with both SLCMJ and SLDJ the asymmetry is measured in the vertical direction, the previous finding shows that its effect may vary from test to test. The correlation between asymmetry in power and sprint performance may also depend on the training period and the joint under consideration.

Besides the effect of asymmetry in power on sprint performance, Bishop et al., (2021a) also researched their effect on jumping performance. Their findings showed that SLCMJ performance was negatively affected by SLCMJ asymmetries (r = −0.47 to −0.53). Furthermore, the length of horizontal jumps was impaired by the asymmetry measured with single leg triple hop for distance (THOP) (r = −0.47 to −0.58). These results were confirmed by Madruga Parera et al., (2020b), who reported a moderate correlation between asymmetries in SLCMJ and SLLJ and the performances in the same tests (r = −0.32 to −0.52). The detrimental effect was also shown in a study conducted by Fort-Vanmeerhaeghe et al., (2020), reporting a negative correlation between SLHJ asymmetry and its performance (r = −0.56 to −0.64). The same authors also reported the detrimental effect of asymmetry in SLCMJ on impaired performance in the same jump (r = −0.26 to −0.48). Philipp et al., (2022) reported similar findings; specifically, they reported a somewhat stronger correlation in a study conducted on American football players (r = – 0.578). Kozinc et al. (2020) included both male and female volleyball players in their study, however, a negative correlation between asymmetry in SLCMJ and its performance was found only in female participants (r = −0.42). Furthermore Bell et al., (2014) divided the participants into four groups of different magnitudes: 0 – 5%, 5 – 10%, 10 – 15% in > 15% and found that asymmetries in SLCMJ larger than 10% impaired its performance by an average of 9 cm. In a research conducted on basketball players, Bishop et al., (2022b) also paid attention to the consistency of correlations between two testing sessions. The results of the second session confirm the results of the first, indicating a negative correlation between the asymmetry in SLDJ and its performance on the left leg (r = −0.44). Two of the studies researched the effect of asymmetries in CoD on jumping performance. Madruga-Parera et al., (2020a) conducted a study on tennis players and found that asymmetry in 180° CoD negatively affected SLCMJ performance on the dominant (r = −0.50) and non-dominant leg (r = −0.53). In contrary, Pardos-Mainer et al., (2021) did not find a correlation between asymmetry in 505 CoD test and jumping ability in female soccer players. Jumping ability therefore depends on the asymmetries in power measured with jumping, and perhaps on those measured with CoD tests. The impact of the latter is not yet fully clear and further research is needed.

Lockie et al., (2014) researched the effect of asymmetries in power, measured with single leg vertical jump (SLVJ), SLHJ and SLLJ, on the 505 test and T-test performance. The results showed no correlation between asymmetries and CoD tests. Fort-Vanmeerhaeghe et al., (2020) and Dos'Santos et al., (2017) also reported no correlations; they measured the asymmetries with SLCMJ, SLHJ and THOP, however none of the asymmetries affected the performance in 505 test, V-test or 90° CoD test. The same jump types were used by Pardos-Mainer et al., (2021), who also found no correlation between the asymmetries in 505 test performance in female soccer players. Isin et al., (2022) and Hoffman et al., (2007) additionally divided the population of soccer players into groups based on the asymmetry magnitudes. They both could not find an influence of the magnitude of asymmetry in CMJ, SLCMJ and SLHJ and performance in 505 test and L-test. In contrary, three of the studies have reported the negative effect of vertical, horizontal and lateral asymmetries on CoD performance. Kozinc et al., (2020) found a weak negative correlation between performance in 90° and 180° CoD tests and asymmetries measured with SLCMJ in female and male volleyball players (r = 0.29 – 0.30). The negative effect on 180° CoD test on the non-dominant leg (r = – 0.39) is confirmed by Madruga-Parera et al., (2021b), but only for the asymmetry measured with the SLLJ. No connection was found between asymmetries in SLCMJ and SLHJ and 90° or 180° CoD performance. This last finding is in contrast with the other study by Madrua-Parera et al., (2020b) that reported a negative effect of asymmetry in SLCMJ and performance in repeated sprints with CoD (r = 0.35 – 0.40) and asymmetry in SLHJ length and CoD performance (r = 0.31 in 0.32). Many of the studies also measured the asymmetry with the SLDJ. Bishop et al., (2022a) conducted a study on soccer players and monitored the effect of asymmetries through three different parts of the season. In the preseason and mid-season no correlation was found. Only at the end of the season a positive correlation was found between the asymmetry in SLDJ and 505 test time (r = 0.65). The effect of asymmetry in SLDJ on 505 test and U-test performance was also researched by Bishop et al., (2019) and Maloney et al.,

(2016). The former reported a negative correlation with 505 test performance (r = 0.52 – 0.66) in female football players, while others reported a negative effect of asymmetries on the U-test (r = 0.60) in recreational males. The negative effect of asymmetries measured with SLDJ is partly confirmed by Bishop et al., (2021b), who alongside soccer players also included a group of cricket players. The effect was only present in the latter group.

A few of the studies also measured the asymmetries with CoD tests. Madruga-Parera et al., (2020a) reported a moderate negative correlation between asymmetry in 180° CoD test and its performance on dominant (r = 0.50) and non-dominant (r = 0.63) leg. A similar correlation was found by Madruga-Parera et al., (2021b), however only on the non-dominant leg (r = 0.42). In their article, Nimphius, Callaghan, Spiteri in Lockie (2016) highlight the CoD deficit (CoDD). It is a subtraction of 10-m sprint time from 505 test time, which better isolates the actual CoD time. Asymmetries in CoDD are therefore more pronounced, as confirmed by Madruga-Parera et al., (2021b). They reported a moderate negative correlation between asymmetry in CoDD and 180° CoD performance (r = 0.46). Additionally, the authors measured the asymmetries with the lateral-shuffle step and crossover step performed on an isoinertial device. They found a negative correlation between asymmetry in the crossover step and performance in 90° CoD (r = 0.41 – 0.51) and 180° CoD (r = 0.48 – 0.51). The asymmetry during the concentric phase of the lateral-shuffle step also negatively affected the CoD performance (r = 0.44). The correlation between the asymmetry during the concentric phase of the crossover step and 180° CoD performance (r = 0.51 – 0.59) was also found by Madruga-Parera et al., (2021a). Philipp et al., (2022) measured the asymmetry in average and peak power with the Bulgarian split squat and reported its negative effect on L-test performance (r = 0.45 – 0.46). The magnitude of asymmetry that most affected L-test performance scored slightly above 10% for average power and around 15% for peak power. As seen, the authors of the studies tried to link CoD performance with many different tests. The results were the most consistent for asymmetries in SLDJ. For other jumps in all three directions, the results seem to be more contradictory. Despite the fact that asymmetry in power obtained from isoinertial tests, CoD tests, CoDD and Bulgarian split squat negatively affected the results of various CoD tests, studies that integrate these measurements are scarce, thus, additional literature is needed to confirm this effect.

Conclusion

In conclusion, inter-limb asymmetries in strength seem to negatively affect CoD and sprint performance, as well as certain sport-specific skills. Furthermore, a few correlations between these asymmetries and jumping performance were reported so far, indicating a negative effect of asymmetries. These correlations were mostly weak/moderate and not always consistent across studies, therefore further research is needed. The findings in the field of asymmetry in power are more contradictory, especially their effect on sprint and CoD performance. Jumping performance seems to only be affected by the power asymmetries measured with jumps, while the effect of power asymmetries measured with CoD tests is less well known. To better understand this complex relationship between strength and power asymmetries and sports performance further research is needed, especially on the effect on sport specific tests.

Conflict of interests

The authors declare that there is no conflict of interests arising from this paper.

References

Atkins, S. J., Bentley, I., Hurst, H. T., Sinclair, J. K., & Hesketh, C. (2016). The Presence of Bilateral Imbalance of the Lower Limbs in Elite Youth Soccer Players of Different Ages. *The Journal of Strength & Conditioning Research*, *30*(4), 1007–1013. https://doi.org/10.1519/JSC.0b013e3182987044

Bailey, C., Sato, K., Alexander, R., Chiang, C.-Y., & Stone, M. H. (2013). Isometric force production symmetry and jumping performance in collegiate athletes. *Journal of Trainology*, *2*(1), 1–5. https://doi.org/10.17338/trainology.2.1_1

Bell, D. R., Sanfilippo, J. L., Binkley, N., & Heiderscheit, B. C. (2014). Lean Mass Asymmetry Influences Force and Power Asymmetry During Jumping in Collegiate Athletes. *The Journal of Strength & Conditioning Research*, *28*(4), 884–891. https://doi.org/10.1519/JSC.0000000000000367

Bini, R. R., & Hume, P. A. (2015). Relationship between pedal force asymmetry and performance in cycling time trial. *The Journal of Sports Medicine and Physical Fitness*, *55*(9), 892–898. Retrieved from https://pubmed.ncbi.nlm.nih.gov/26470634/

Bishop, C., Perez-Higueras Rubio, M., Gullon, I. L., Maloney, S., & Balsalobre-Fernandez, C. (2022). Jump and Change of Direction Speed Asymmetry Using Smartphone Apps: Between-Session Consistency and Associations With Physical Performance. *The Journal of Strength & Conditioning Research*, *36*(4), 927–934. https://doi.org/10.1519/JSC.0000000000003567

Bishop, C., Read, P., Brazier, J., Jarvis, P., Chavda, S., Bromley, T., & Turner, A. (2021). Effects of Interlimb Asymmetries on Acceleration and Change of Direction Speed: A Between-Sport Comparison of Professional Soccer and Cricket Athletes. *The Journal of Strength & Conditioning Research*, *35*(8), 2095–2101. https://doi.org/10.1519/JSC.0000000000003135

Bishop, C., Read, P., Bromley, T., Brazier, J., Jarvis, P., Chavda, S., & Turner, A. (2022). The Association Between Interlimb Asymmetry and Athletic Performance Tasks: A Season-Long Study in Elite Academy Soccer Players. *The Journal of Strength & Conditioning Research*, *36*(3), 787–795. https://doi.org/10.1519/JSC.0000000000003526

Bishop, C., Read, P., Chavda, S., & Turner, A. (2016). Asymmetries of the Lower Limb: The Calculation Conundrum in Strength Training and Conditioning. *Strength & Conditioning Journal*, *38*(6), 27–32. https://doi.org/10.1519/SSC.0000000000000264

Bishop, C., Read, P., McCubbine, J., & Turner, A. (2021). Vertical and Horizontal Asymmetries Are Related to Slower Sprinting and Jump Performance in Elite Youth Female Soccer Players. *The Journal of Strength & Conditioning Research*, *35*(1), 56–63. https://doi.org/10.1519/JSC.0000000000002544

Bishop, C., Turner, A., Maloney, S., Lake, J., Loturco, I., Bromley, T., & Read, P. (2019). Drop Jump Asymmetry is Associated with Reduced Sprint and Change-of-Direction

 DOI 10.26773/mjssm.230310

Speed Performance in Adult Female Soccer Players. *Sports*, *7*(1), 29. https://doi.org/10.3390/sports7010029

Bishop, C., Turner, A., & Read, P. (2018). Effects of inter-limb asymmetries on physical and sports performance: A systematic review. *Journal of Sports Sciences*, *36*(10), 1135–1144. https://doi.org/10.1080/02640414.2017.1361894

Blagrove, R. C., Bishop, C., Howatson, G., & Hayes, P. R. (2021). Inter-limb strength asymmetry in adolescent distance runners: Test-retest reliability and relationships with performance and running economy. *Journal of Sports Sciences*, *39*(3), 312–321. https://doi.org/10.1080/02640414.2020.1820183

Coratella, G., Beato, M., & Schena, F. (2018). Correlation between quadriceps and hamstrings inter-limb strength asymmetry with change of direction and sprint in U21 elite soccer-players. *Human Movement Science*, *59*, 81–87. https://doi.org/10.1016/j.humov.2018.03.016

Dos'Santos, K. B. dos, Pereira, G., Papoti, M., Bento, P. C. B., & Rodacki, A. (2013). Propulsive Force Asymmetry during Tethered-Swimming. *International Journal of Sports Medicine*, *34*(07), 606–611. https://doi.org/10.1055/s-0032-1327575

Dos'Santos, T., Thomas, C., Jones, P. A., & Comfort, P. (2017). Asymmetries in single and triple hop are not detrimental to change of direction speed. *Journal of Trainology*, *6*(2), 35–41. https://doi.org/10.17338/trainology.6.2_35

Exell, T., Irwin, G., Gittoes, M., & Kerwin, D. (2017). Strength and performance asymmetry during maximal velocity sprint running. *Scandinavian Journal of Medicine & Science in Sports*, *27*(11), 1273–1282. https://doi.org/10.1111/sms.12759

Fort-Vanmeerhaeghe, A., Bishop, C., Buscà, B., Aguilera-Castells, J., Vicens-Bordas, J., & Gonzalo-Skok, O. (2020). Inter-limb asymmetries are associated with decrements in physical performance in youth elite team sports athletes. *PLOS ONE*, *15*(3), e0229440. https://doi.org/10.1371/journal.pone.0229440

Hart, N. H., Nimphius, S., Weber, J., Spiteri, T., Rantalainen, T., Dobbin, M., & 6 Newton, R. U. (2016). Musculoskeletal asymmetry in football athletes: A product of limb function over time. *Medicine in Science and Sports and Exercise 48*, 1379-1387. https://doi.org/10.1249/MSS.0000000000000897

Hoffman, J. R., Ratamess, N. A., Klatt, M., Faigenbaum, A. D., & Kang, J. (2007). Do Bilateral Power Deficits Influence Direction-Specific Movement Patterns? *Research in Sports Medicine*, *15*(2), 125–132. https://doi.org/10.1080/15438620701405313

Işın, A., Akdağ, E., Özdoğan, E. Ç., & Bishop, C. (2022). Associations between differing magnitudes of inter-limb asymmetry and linear and change of direction speed performance in male youth soccer players. *Biomedical Human Kinetics*, *14*(1), 67–74. https://doi.org/10.2478/bhk-2022-0009

Kozinc, Ž., & Šarabon, N. (2020). Inter-Limb Asymmetries in Volleyball Players: Differences between Testing Approaches and Association with Performance. *Journal of Sports Science & Medicine*, *19*(4), 745–752. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7675626/

Lockie, R. G., Callaghan, S. J., Berry, S. P., Cooke, E. R. A., Jordan, C. A., Luczo, T. M., & Jeffriess, M. D. (2014). Relationship Between Unilateral Jumping Ability and Asymmetry on Multidirectional Speed in Team-Sport Athletes. *The Journal of Strength & Conditioning Research*, *28*(12), 3557–3566. https://doi.org/10.1519/JSC.0000000000000588

Lockie, R. G., Schultz, A. B., Jeffriess, M. D., & Callaghan, S. J. (2012). The relationship between bilateral differences of knee flexor and extensor isokinetic strength and multi-directional speed. *Isokinetics and Exercise Science*, *20*(3), 211–219. https://doi.org/10.3233/IES-2012-0461

Madruga-Parera, M., Bishop, C., Beato, M., Fort-Vanmeerhaeghe, A., Gonzalo-Skok, O., & Romero-Rodríguez, D. (2021). Relationship Between Interlimb Asymmetries and Speed and Change of Direction Speed in Youth Handball Players. *The Journal of Strength & Conditioning Research*, *35*(12), 3482–3490. https://doi.org/10.1519/JSC.0000000000003328

Madruga-Parera, M., Bishop, C., Fort-Vanmeerhaeghe, A., Beltran-Valls, M. R., Skok, O. G., & Romero-Rodríguez, D. (2020). Interlimb Asymmetries in Youth Tennis Players: Relationships With Performance. *The Journal of Strength & Conditioning Research*, *34*(10), 2815–2823. https://doi.org/10.1519/JSC.0000000000003152

Madruga-Parera, M., Bishop, C., Read, P., Lake, J., Brazier, J., & Romero-Rodriguez, D. (2020). Jumping-based Asymmetries are Negatively Associated with Jump, Change of Direction, and Repeated Sprint Performance, but not Linear Speed, in Adolescent Handball Athletes. *Journal of Human Kinetics*, *71*(1), 47–58. https://doi.org/10.2478/hukin-2019-0095

Madruga-Parera, M., Dos'Santos, T., Bishop, C., Turner, A., Blanco, D., Beltran-Garrido, V., … Romero-Rodríguez, D. (2021). Assessing Inter-Limb Asymmetries in Soccer Players: Magnitude, Direction and Association with Performance. *Journal of Human Kinetics*, *79*(1), 41–53. https://doi.org/10.2478/hukin-2021-0081

Maloney, S. J. (2019). The Relationship Between Asymmetry and Athletic Performance: A Critical Review. *The Journal of Strength & Conditioning Research*, *33*(9), 2579–2593. https://doi.org/10.1519/JSC.0000000000002608

Maloney, S. J., Richards, J., Nixon, D. G. D., Harvey, L. J., & Fletcher, I. M. (2016). Do stiffness and asymmetries predict change of direction performance? *Journal of Sports Sciences*, *35*(6), 547–556. https://doi.org/10.1080/02640414.2016.1179775

Morouço, P. G., Marinho, D. A., Fernandes, R. J., & Marques, M. C. (2015). Quantification of upper limb kinetic asymmetries in front crawl swimming. *Human Movement Science*, *40*, 185–192. https://doi.org/10.1016/j.humov.2014.12.012

Newton, R. U., Gerber, A., Nimphius, S., Shim, J. K., Doan, B. K., Robertson, M., … Kraemer, W. J. (2006). Determination of functional strength imbalance of the lower extremities. *Journal of Strength and Conditioning Research*, *20*(4), 971–977. https://doi.org/10.1519/R-5050501x.1

Nimphius, S., Callaghan, S. J., Spiteri, T., & Lockie, R. G. (2016). Change of Direction Deficit: A More Isolated Measure of Change of Direction Performance Than Total 505 Time. *The Journal of Strength & Conditioning Research*, *30*(11), 3024–3032. https://doi.org/10.1519/JSC.0000000000001421

Pardos-Mainer, E., Bishop, C., Gonzalo-Skok, O., Nobari,

H., Pérez-Gómez, J., & Lozano, D. (2021). Associations between Inter-Limb Asymmetries in Jump and Change of Direction Speed Tests and Physical Performance in Adolescent Female Soccer Players. *International Journal of Environmental Research and Public Health*, *18*(7), 3474. https://doi.org/10.3390/ijerph18073474

Parkinson, A. O., Apps, C. L., Morris, J. G., Cleveland, T. B., & Lewis, M. G. C. (2021). The Calculation, Thresholds and Reporting of Inter-Limb Strength Asymmetry: A Systematic Review. *Journal of Sports Science and Medicine*, *20*(4), 594–617. https://doi.org/10.52082/jssm.2021.594

Philipp, N. M., Garver, M. J., Crawford, D. A., Davis, D. W. & Hair, J. N. (2022). Interlimb asymmetry in collegiate American football players: Effects on combine-related performance. Journal of Human Sport and Exercise, 17(3). https://doi.org/10.14198/jhse.2022.173.20

Philipp, N., Crawford, D., Garver, M., Davis, D. & Hair, J. (2020). Interlimb asymmetry thresholds that negatively affect change of direction performance in collegiate American football players. International journal of exercise science, 14(4), 606-612. https://doi.org/10.31236/osf.io/2u6nt

Phukan, M. I., Thapa, R. K., Kumar, G., Bishop, C., Chaabene, H., & Ramirez-Campillo, R. (2021). Inter-Limb Jump Asymmetries and Their Association with Sport-Specific Performance in Young Male and Female Swimmers. *International Journal of Environmental Research and Public Health*, *18*(14), 7324. https://doi.org/10.3390/ijerph18147324

Rannama, I., Port, K., Bazanov, B., & Pedak, K. (2015). Sprint cycling performance and asymmetry. *Journal of Human Sport and Exercise, 10,* 247-258. https://doi.org/10.14198/jhse.2015.10.Proc1.12

Read, P. J., McAuliffe, S., Bishop, C., Oliver, J. L., Graham-Smith, P., & Farooq, M. A. (2020). Asymmetry Thresholds for Common Screening Tests and Their Effects on Jump Performance in Professional Soccer Players. *Journal of Athletic Training*, *56*(1), 46–53. https://doi.org/10.4085/1062-6050-0013.20

Samozino, P., Peyrot, N., Edouard, P., Nagahara, R., Jimenez-Reyes, P., Vanwanseele, B., & Morin, J.-B. (2022). Optimal mechanical force-velocity profile for sprint acceleration performance. *Scandinavian Journal of Medicine & Science in Sports*, *32*(3), 559–575. https://doi.org/10.1111/sms.14097

Schons, P., Da Rosa, R. G., Fischer, G., Berriel, G. P., Fritsch, C. G., Nakamura, F. Y., … Peyré-Tartaruga, L. A. (2019). The relationship between strength asymmetries and jumping performance in professional volleyball players. *Sports Biomechanics*, *18*(5), 515–526. https://doi.org/10.1080/14763141.2018.1435712

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- A signed form that states the study was not previously published, nor has been submitted simultaneously for consideration of publication elsewhere, that states that all of the authors are in agreement with submission of the manuscript to MJSSM, and that, for studies that use animal or human individuals, authors must include information regarding their institution's ethics committee, and which identifies the official approval number;
- A signed form that there is no conflict of interest.

Name the files according to the family name of the first author. Authors submitting revised versions of the manuscript can use the identification number of their manuscript as provided by the Journal Office. *See* example:

- ✓ FAMILY NAME-manuscript.doc – (main manuscript file)
- ✓ FAMILY NAME-statement.PDF – (authorship statement)
- ✓ FAMILY NAME-declaration.PDF – (declaration of potential conflict of interest)
- ✓ FAMILY NAME-fig1.tiff – (Figure 1)

1.4. Peer Review Process

An original manuscript submitted for publication will be submitted to the review process as long as it fits the following criteria:

- The study was not previously published, nor has been submitted simultaneously for consideration of publication elsewhere;
- All persons listed as authors approved its submission to MJSSM;
- Any person cited as a source of personal communication has approved the quote;
- The opinions expressed by the authors are their exclusive responsibility;
- The author signs a formal statement that the submitted manuscript complies with the directions and guidelines of MJSSM.

The editors-in-chief, executive editor and associate editors will make a preliminary analysis regarding the appropriateness, quality, originality and written style/grammar of the submitted manuscript. The editors reserve the right to request additional information, corrections, and guideline compliance before they submit the manuscript to the ad-hoc review process.

MJSSM uses ad-hoc reviewers, who volunteer to analyze the merit of the study. Typically, one or two expert reviewers are consulted in a double-blind process. Authors are notified by e-mail when their submission has been accepted (or rejected). Minor changes in the text may be made at the discretion of the editors-in-chief, executive editor and/or associate editors. Changes can include spelling and grammar in the chosen language, written style, journal citations, and reference guidelines. The author is notified of changes via email. The final version is available to the author for his or her approval before it is published.

1.5. Open Access License and Publisher Copyright Policies

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The editors of MJSSM consider plagiarism to be a serious breach of academic ethics. Any author who practices plagiarism (in part or totality) will be suspended for six years from submitting new submissions to MJSSM. If such a manuscript is approved and published, public exposure of the article with a printed mark ("plagiarized" or "retracted") on each page of the published file, as well as suspension for future publication for at least six years, or a period determined by the editorial board. Third party plagiarized authors or institutions will be notified, informing them about the faulty authors. Plagiarism will result in immediate rejection of the manuscript.

MJSSM only publishes studies that have been approved by an institutional ethics committee (when a study involves humans or animals). Fail to provide such information prevent its publication. To ensure these requirements, it is essential that submission documentation is complete. If you have not completed this step yet, go to MJSSM website and fill out the two required documents: Declaration of Potential Conflict of Interest and Authorship Statement. Whether or not your study uses humans or animals, these documents must be completed and signed by all authors and attached as supplementary files in the originally submitted manuscript.

1.6. After Acceptance

After the manuscript has been accepted, authors will receive a PDF version of the manuscripts for authorization, as it should look in printed version of MJSSM. Authors should carefully check for omissions. Reporting errors after this point will not be possible and the Editorial Board will not be eligible for them.

Should there be any errors, authors should report them to the Office e-mail address **office@mjssm.me.** If there are not any errors authors should also write a short e-mail stating that they agree with the received version.

1.7. Code of Conduct Ethics Committee of Publications

MJSSM is hosting the Code of Conduct Ethics Committee of Publications of the **COPE** (the Committee on Publication Ethics), which provides a forum for publishers and Editors of scientific journals to discuss issues relating to the integrity of the work submitted to or published in their journals.

2. MANUSCRIPT STRUCTURE

2.1. Title Page

The first page of the manuscripts should be the title page, containing: title, type of publication, running head, authors, affiliations, corresponding author, and manuscript information. *See* example:

Transfer of Learning on a Spatial Memory Task between the Blind and Sighted People Spatial Memory among Blind and Sighted

Original Scientific Paper

Transfer of learning on a spatial memory task

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

[1]Middle East Technical University, Physical Education and Sports Department, Ankara, Turkey
[2]University of Montenegro, Faculty for Sport and Physical Education, Niksic, Montenegro

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S. Popovic
University of Montenegro
Faculty for Sport and Physical Education
Narodne omladine bb, 84000 Niksic, Montenegro
E-mail: stevop@ac.me

Word count: 2,980

Abstract word count: 236

Number of Tables: 3

Number of Figures: 3

2.1.1. Title

Title should be short and informative and the recommended length is no more than 20 words. The title should be in Title Case, written in uppercase and lowercase letters (initial uppercase for all words except articles, conjunctions, short prepositions no longer than four letters etc.) so that first letters of the words in the title are capitalized. Exceptions are words like: "and", "or", "between" etc. The word following a colon (:) or a hyphen (-) in the title is always capitalized.

2.1.2. Type of publication

Authors should suggest the type of their submission.

2.1.3. Running head

Short running title should not exceed 50 characters including spaces.

2.1.4. Authors

The form of an author's name is first name, middle initial(s), and last name. In one line list all authors with full names separated by a comma (and space). Avoid any abbreviations of academic or professional titles. If authors belong to different institutions, following a family name of the author there should be a number in superscript designating affiliation.

2.1.5. Affiliations

Affiliation consists of the name of an institution, department, city, country/territory(in this order) to which the author(s) belong and to which the presented / submitted work should be attributed. List all affiliations (each in a separate line) in the order corresponding to the list of

authors. Affiliations must be written in English, so carefully check the official English translation of the names of institutions and departments.

Only if there is more than one affiliation, should a number be given to each affiliation in order of appearance. This number should be written in superscript at the beginning of the line, separated from corresponding affiliation with a space. This number should also be put after corresponding name of the author, in superscript with no space in between.

If an author belongs to more than one institution, all corresponding superscript digits, separated with a comma with no space in between, should be present behind the family name of this author.

In case all authors belong to the same institution affiliation numbering is not needed.

Whenever possible expand your authors' affiliations with departments, or some other, specific and lower levels of organization.

2.1.6. Corresponding author

Corresponding author's name with full postal address in English and e-mail address should appear, after the affiliations. It is preferred that submitted address is institutional and not private. Corresponding author's name should include only initials of the first and middle names separated by a full stop (and a space) and the last name. Postal address should be written in the following line in sentence case. Parts of the address should be separated by a comma instead of a line break. E-mail (if possible) should be placed in the line following the postal address. Author should clearly state whether or not the e- mail should be published.

2.1.7. Manuscript information

All authors are required to provide word count (excluding title page, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References), the Abstract word count, the number of Tables, and the number of Figures.

2.2. Abstract

The second page of the manuscripts should be the abstract and key words. It should be placed on second page of the manuscripts after the standard title written in upper and lower case letters, bold.

Since abstract is independent part of your paper, all abbreviations used in the abstract should also be explained in it. If an abbreviation is used, the term should always be first written in full with the abbreviation in parentheses immediately after it. Abstract should not have any special headings (e.g., Aim, Results…).

Authors should provide up to six key words that capture the main topics of the article. Terms from the Medical Subject Headings (MeSH) list of Index Medicus are recommended to be used.

Key words should be placed on the second page of the manuscript right below the abstract, written in italic. Separate each key word by a comma (and a space). Do not put a full stop after the last key word. *See example:*

Abstract

Results of the analysis of…
Key words: spatial memory, blind, transfer of learning, feedback

2.3. Main Chapters

Starting from the third page of the manuscripts, it should be the main chapters. Depending on the type of publication main manuscript chapters may vary. The general outline is: Introduction, Methods, Results, Discussion, Acknowledgements (optional), Conflict of Interest (optional), and Title and Abstract in Montenegrin (only for the authors from former Yugoslavia, excluding Macedonians and Slovenes). However, this scheme may not be suitable for reviews or publications from some areas and authors should then adjust their chapters accordingly but use the general outline as much as possible.

2.3.1. Headings

Main chapter headings: written in bold and in Title Case. *See* example:

- ✓ **Methods**

Sub-headings: written in italic and in normal sentence case. Do not put a full stop or any other sign at the end of the title. Do not create more than one level of sub-heading. *See* example:

- ✓ *Table position of the research football team*

2.3.2 Ethics

When reporting experiments on human subjects, there must be a declaration of Ethics compliance. Inclusion of a statement such as follow in Methods section will be understood by the Editor as authors' affirmation of compliance: "This study was approved in advance by [name of committee and/or its institutional sponsor]. Each participant voluntarily provided written informed consent before participating." Authors that fail to submit an Ethics statement will be asked to resubmit the manuscripts, which may delay publication.

2.3.3 Statistics reporting

MJSSM encourages authors to report precise p-values. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Use normal text (i.e., non-capitalized, non-italic) for statistical term "p".

2.3.4. 'Acknowledgements' and 'Conflict of Interest' (optional)

All contributors who do not meet the criteria for authorship should be listed in the 'Acknowledgements' section. If applicable, in 'Conflict of Interest' section, authors must clearly disclose any grants, financial or material supports, or any sort of technical assistances from an institution, organization, group or an individual that might be perceived as leading to a conflict of interest.

2.4. References

References should be placed on a new page after the standard title written in upper and lower case letters, bold.

All information needed for each type of must be present as specified in guidelines. Authors are solely responsible for accuracy of each reference. Use authoritative source for information such as Web of Science, Medline, or PubMed to check the validity of citations.

2.4.1. References style

MJSSM adheres to the American Psychological Association 7th Edition reference style. Check the Publication Manual of the American Psychological Association (2019), Seventh Edition that is the official source for APA Style, to ensure the manuscripts conform to this reference style. Authors using EndNote® to organize the references must convert the citations and bibliography to plain text before submission.

2.4.2. Examples for Reference citations

One work by one author

- ✓ In one study (Reilly, 1997), soccer players…
- ✓ In the study by Reilly (1997), soccer players…
- ✓ In 1997, Reilly's study of soccer players…

Works by two authors

- ✓ Duffield and Marino (2007) studied…
- ✓ In one study (Duffield & Marino, 2007), soccer players…
- ✓ In 2007, Duffield and Marino's study of soccer players…

Works by three or more authors: cite only the name of the first author followed by et al. and the year

- ✓ Bangsbo et al. (2008) stated that…
- ✓ In one study (Bangsbo et al., 2008), soccer players…

Works by organization as an author: cite the source, just as you would an individual person

- ✓ According to the American Psychological Association (2000)…
- ✓ In the APA Manual (American Psychological Association, 2003), it is explained…

Two or more works in the same parenthetical citation: citation of two or more works in the same parentheses should be listed in the order they appear in the reference list (i.e., alphabetically); separated by a semi-colon

- ✓ Several studies (Bangsbo et al., 2008; Duffield & Marino, 2007; Reilly, 1997) suggest that…

2.4.3. Examples for Reference list

Works by one author
Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human Kinetics.

Works by two authors
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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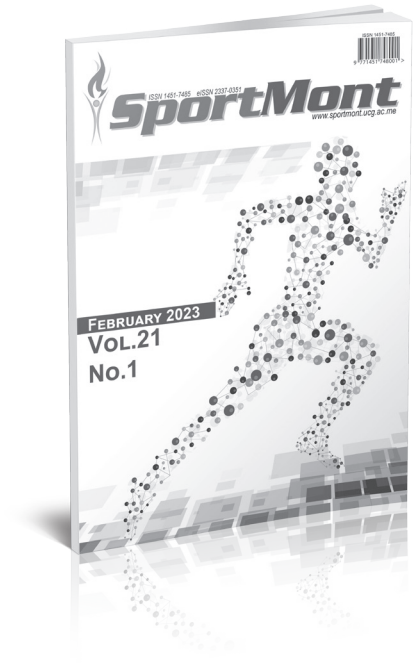

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Publication date: Summer issue – June 2023
Autumn issue – October 2023
Winter issue – February 2024

Montenegrin Sports Academy welcomes you to *Dubrovnik, Croatia*

KEY DATES

- **1st of July 2022, 24:00 CET**
  Abstract submission opening and opening of registration
- **1st of December 2022, 24:00 CET**
  Abstract submission deadline
- **15th of January 2023, 24:00 CET**
  Notification to authors about acceptance
- **1st of February 2023, 24:00 CET**
  Deadline for early-bird registration for presenting authors
- **15th of February 2023, 24:00 CET**
  Deadline for late registration for presenting authors

* CET = Central European Time

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MSA Dubrovnik 2023

20th Annual Scientific Conference of Montenegrin Sports Academy "Sport, Physical Activity and Health: Contemporary Perspectives"

MSA Dubrovnik 2023

20th - 23th April 2023

CONFERENCE VENUE

Hotel Croatia Cavtat, situated across the bay from the historic walls of Dubrovnik, Hotel Croatia Cavtat is a leading five-star resort and conference hotel on the southern part of Adriatic. Hotel Croatia's architecture blends seamlessly with its natural surroundings. Shaded by a pine tree forest, while offering spectacular sea views, all 487 accommodation units feature balconies which overlook the Adriatic Sea or Cavtat Bay. State-of-the-art facilities include numerous gourmet restaurants, a spa centre, and private beaches. Hotel Croatia is ideal for a broader experience of the Dubrovnik Riviera. Suited for business and relaxation alike, Hotel Croatia serves as an excellent base for exploring the city of Dubrovnik and the Dubrovnik Riviera.

WELCOME TO DUBROVNIK

Regardless of whether you are visiting Dubrovnik for the first time or the hundredth, the sense of awe never fails to descend when you set eyes on the beauty of the old town. Indeed it's hard to imagine anyone becoming jaded by the city's white limestone streets, baroque buildings and the endless shimmer of the Adriatic, or failing to be inspired by a walk along the ancient city walls that protected a civilised, sophisticated republic for centuries.

LANGUAGE

The official Conference language is English.

FIRST ANNOUNCEMENT

Dear Friends and Colleagues,

Montenegrin Sports Academy will mark its 20th Anniversary by organising the 20th Annual Scientific Conference during 20.-23. April 2023 in Dubrovnik Croatia. The 20th Anniversary Conference will be held in Hotel Croatia, Cavtat.

Reserve your calendars, let us gather in person after these turbulent times and make our conference even more prestigious. Guarantee for our further prosperity is our international partners and Montenegrin Sports Academy. See you in Dubrovnik next spring!

We look forward to seeing you in spring 2023,

Prof. Duško Bjelica, Conference President

Conference sub-themes include:

Adapted Physical Activity; Anthropology; Architecture and Urbanism; Biochemistry; Biomechanics; Coaching; Economics; Health and Fitness; History; Molecular Biology; Motor Learning; Neuromuscular Physiology; Nutrition; Olympism; Philosophy and Ethics; Physical Education and Pedagogics; Physiology; Physiotherapy; Psychology; Rehabilitation; Sociology; Sport Management and Law; Sport Statistics and Analyses; Sport Technology; Sport Tourism; Sports Medicine and Orthopaedics; Training and Testing; Traumatology; and other Multi- & Interdisciplinary Themes.

Look inside!

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Volume 6, 2022, 4 issues per year;
Print ISSN: 2636-569X, Online ISSN: 2536-5703

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Research scholars and students are invited to present their original work in any of the conference sub-themes. The list of the conference sub-themes is not exhaustive and, therefore, authors should not feel limited by them. Authors can submit their original work in the form of an ABSTRACT, free of charge. An author may submit only one abstract as the first author and two abstracts as the co-author. After undergoing the reviewing process, all authors will be notified about the condition of their submission (accepted or rejected). Presenters (= the first authors) must be registered and have paid registration fees for the conference to secure their oral or poster (not debated) presentation during the conference and the publication in Montenegrin Journal of Sports Science and Medicine that is abstracted/indexed in Emerging Sources Citation Index, SCOPUS and other database, under the condition that the first author has paid registration fee.

CALL FOR PAPERS

Full-length manuscripts may be submitted for publishing in the Sport Mont journal (see at HYPERLINK "http://www.sportmont.ucg.ac.me" www.sportmont.ucg.ac.me), an international peer-reviewed scientific journal, indexed in Scopus, DOAJ, SPORTDiscus, Index Copernicus, ERIH PLUS, et cetera. Full-length paper submission is free of charge but author(s) has to pay additional 50 euros per accepted full-length paper to cover publication costs. Full manuscripts should be submitted for consideration of publication by the 15th of March, 2023 and prepared according to the guidelines for authors.

REGISTRATION FEES

For participants 260 EUR (220 EUR early-bird)
For students 190 EUR (160 EUR early-bird)
For accompanying persons 140 EUR (110 EUR early-bird)

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.

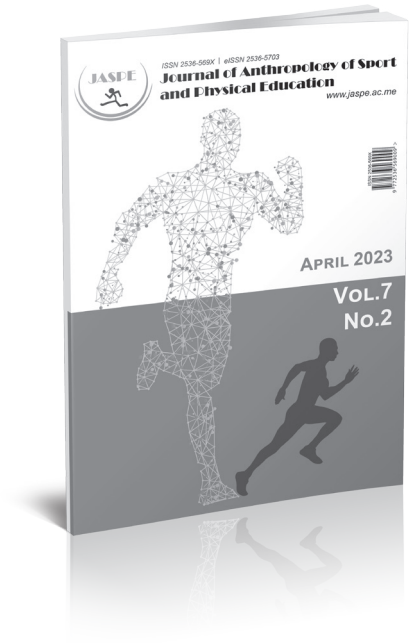
Annual conferences have been organized since the inauguration of the MSA in 2003. Today the MSA conference ranks among the leading sports scientific congresses in the Western Balkans. The conference comprises a range of invited lecturers, oral and poster presentations from multi- and mono-disciplinary 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 19th Annual Scientific Conference of Montenegrin Sports Academy “Sport, Physical Activity and Health: Contemporary Perspectives” to be held in Dubrovnik, Croatia, from 7 to 10 April, 2022. 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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JASPE is published four times a year, in January, April, July and October of each year. JASPE 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 Anthropology of Sport and Physical Education, as well as it can function as an open discussion forum on significant issues of current interest.

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from Montenegrin Sports Academy

We have expanded the quality of our journals considerably over the past years and can now claim to be the market leader in terms of breadth of coverage.

As we continue to increase the quality of our publications across the field, we hope that you will continue to regard MSA journals as authoritative and stimulating sources for your research. We would be delighted to receive your comments and suggestions, mostly due to the reason your proposals are always welcome.

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