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ORIGINAL ARTICLE

The fundamental motor skills and motor coordination performance of children in West Sumatera Province, Indonesia

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Good motor coordination is needed to achieve good fundamental motor skills. This study aimed to analyze and describe the relationship between fundamental motor skills and motor coordination performance of elementary school students aged 7 to 9 years old.

Material and Methods The subjects were elementary school students in grades 1, 2, and 3 with a total number of students was 478 (248 male students, and 230 female students) in 8 cities and regencies in West Sumatera, Indonesia. This study used a cross-sectional research design. The fundamental motor skills were examined using the Test of Gross Motor Development-Second Edition. This included assessing locomotor skills (running, galloping, sliding, leaping, hopping, and jumping) and object control skills (striking, catching, throwing, dribbling, rolling, and kicking). Motor coordination performance was assessed by using the Körperkoordinations Test für Kinder including balance beam, moving sideways, jumping sideways, and eye-hand coordination. The data were analyzed by using IBM SPSS statistic version 25.

Results Students in urban areas demonstrated certain levels in Gross Motor Quotients scores, while their counterparts in rural areas achieved marginally higher scores with slightly less variation. In schools where Physical Education teachers were present, students generally scored higher compared to schools without Physical Education teachers, albeit with a bit less variation in the latter. When comparing motor coordination performance, students in urban areas typically outperformed those in rural areas, exhibiting slightly more consistent scores. Similarly, students with access to Physical Education teachers showed better motor coordination performance than those without, though with a somewhat greater range in their scores. A noticeable trend was observed in the Gross Motor Quotients scores of Fundamental Motor Skills, which tended to decrease as age increased. Conversely, students' motor coordination performance generally improved with age. Supporting these observations, the result of the one-sample Kolmogorov-Smirnov test, obtained from Asymp. Sig. (2-tailed), was 0.200 > 0.05. Additionally, the Pearson correlation value between motor coordination performance and fundamental motor skills was 0.633 with a sig value of 0.000, indicating a significant relationship.

Conclusions Based on the study's findings, it is recommended to focus on enhancing motor skill programs for children in rural areas. Schools should invest in Physical Education teachers, especially where they are currently absent, to benefit children. Age-specific programs are needed to address the decline in Gross Motor Quotients with age in children. Regular monitoring and evaluation of these initiatives for children are essential.

Keywords: fundamental motor skills, locomotor, object control, motor coordination performance

Introduction

According to Clark in Korbecki, fundamental motor skills (FMS) enable motor skills to activate large muscle groups, upper limbs, and lower limbs [1]. Moreover, Pangrazi stated that fundamental motor skills construct the basic movement of humans [2]. FMS is the 'ABC' of motion [3]. Then, it is the building block for basic skills to do physical activities or special motor movements in the future [4. 5, 6, 7, 8].

Fundamental motor skills are classified into two groups. The first group is locomotor skills. It involves the movements of body parts from one place to another such as running, hopping, jumping, galloping, sliding, leaping, and skipping. The second group is object control skills. It is referred to as manipulative skills over an object through hands or legs such as kicking, catching, throwing, striking, and rolling balls [5].

Fundamental motor skills cannot develop on their own in accordance with the children's age, yet they have to be taught, and combined with other motions of any physical activities [9]. Li found that fundamental motor skills effectively improved for children aged 3 to 10 years [10]. Fundamental motor skills do not emerge and develop naturally, so they

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need to be taught and included in a structured program in the early years of childhood [11, 12].

To affirm the sufficient development of fundamental motor skills in the early years of childhood, it is obligatory for teachers to teach and improve students' basic movements to the more complex and difficult ones [13]. Motor skills at age 6 had a positive association with leisure physical activities at age 26. These longitudinal studies proved that the importance of mastering basic motor skills of children would have a correlation to their physical activities over the long-term period [14].

One of the factors influencing basic motor skills is regular physical activities [15]. Doing regular physical activities with the correct motions is considered to improve the organ functions of a body and fitness [16]. Previous studies revealed that fitter children had better academic performance than the less fit children [4, 17]. It was assumed that fit children are favorably active and skilful in any physical activities with various motoric experiences.

Numerous studies have shown that children with sufficient FMS development have more skilful motors and are consistently able to do healthful physical activities until they are adolescents [18, 19]. On the contrary, children with lower gross motor skills perform fewer physical activities [20]. It can be proved that children with better motor development will have better achievement than children with lower motor skills [21].

The importance of FMS development for children has been emphasized by policymakers around the world through physical education curricula at schools [22]. However, the importance of basic motor skills and motor experience in childhood has not been appreciated and supported by society, parents, and professionals who work directly with children [23]. In fact, more than half of children do have sufficient FMS competence when they graduate and leave primary school, in the United States [24, 25], in the United Kingdom [26], and in Australia [27]. Another fact is the mastery of basic motor skills in early childhood in Indonesia is low and not in line with their age level [28, 29, 30]. At elementary school age, students' basic motor skills (locomotor and object control) should be almost perfect or already perfect [5].

Motor skills require full development in all periods so the previous experience became the basic development in the next period. Therefore, motor skills are the result of the development process through the students' active participation [31]. Other studies showed that good FMS was supported by the ability to master gross motor skills (i.e., the use of large muscles to move the whole body, and maintaining the balance against gravity and interaction with certain objects) which will later support the specific skills of certain sports [32, 33].

Optimal motor skills are believed to be influenced by motor coordination performance due to the direct manipulation of an object (ball) with the upper and lower limbs. This characteristic brings up the increased complexity factors to contribute to research in motor and coordination competence [34]. Henderson and Sugden stated that the motor competence of somebody to do physical activities such as coordinating fine and gross motor skills to activity completion [35]. According to Faber, motor coordination is a result of performance combination from the quality of muscles, bones, and joints in producing one effective and efficient movement [36]. Pasce Ibara stated that the ability to study in coordination competence is highly recommended for childhood as the central nervous system develops firmly during this time [37].

According to Lych, physical education is the main area of learning in the curriculum focusing on students' motor competence development to participate actively and confidently in physical activities [38]. In order to enhance the quality of physical education learning in elementary schools, physical education teachers should comprehend and master the characteristics of children's development, and the suitable strategies for those children [39]. Gabbard stated over the years elementary schools and physical education have been identified as one of the most influential factors to promote and develop children's FMS and physical activities as well [40].

A research finding revealed that low FMS can be a barrier to learning additional skills and other sequential movements in childhood. Moreover, the high level of FMS will help achieve additional skills in transitional skills as well as more complex skills [41]. It is necessary to understand that it is important to seek a supporting program to improve gross motor skills.

Based on factual conditions in the field, it is important to conduct a study regarding the students' motor competence in West Sumatera, Indonesia. As far as the author is concerned, this issue has not been discussed and reported widely by other researchers it focuses on the fundamental motor skills and motor coordination performance of elementary students. In terms of publication, the findings of this study are expected to be an initial reference for teachers, parents, and principals to analyze the gaps and follow up the progressive action to overcome the pitiful condition of motor skill development in West Sumatera.

Materials and Methods

Participants

The study's population consisted of 478 elementary students (248 females and 230 males) from 1st, 2nd, and 3rd grades across West Sumatera.

These students, aged 7 to 9, were from diverse environments including urban, rural, highlands, lowlands, hills, and coastal areas. They represented 10 public schools in 9 urban/regencies: 26 from Bukittinggi City, 26 from Lima Puluh Kota Regency, 43 from Padang Panjang City, 136 from Agam Regency, 31 from Pasaman Regency, 55 from Solok Regency, 84 from Payakumbuh City, 35 from Padang City, and 39 from Tanah Datar Regency. The sample included students from 4 cities (118 students) and 5 regencies (290 students), with 299 having physical education teachers and 179 without. Headmasters, teachers, and parents have given the approval to collect the data.

Research Design

This study was a quantitative research employing a cross-sectional approach, an observational method to investigate data from a specific population at a single point in time [42]. The focus was on examining the fundamental motor skills and motor coordination performance of elementary students. Data analysis was conducted using the Bivariate correlation method to explore the relationship and contribution between coordination abilities and fundamental motor skills.

For assessing Fundamental Motor Skills (FMS), the study utilized the Test of Gross Motor Development second edition (TGMD-2). This systematic observation protocol involves using two trial videos to measure the gross motor skills of children aged 3 to 10 years. TGMD-2 consists of 12 subskills, divided into two sub-scales: 1) Locomotor skills, including running, galloping, leaping, hopping, sliding, and jumping; and 2) object control skills, including striking, catching, dribbling, throwing, under-rolling, and kicking [43]. Coordination abilities were examined using the Körperkoordinations Test für Kinder (KTK), which includes tests for balance beam, moving sideways, jumping sideways, and eye-hand coordination, as described by Kiphard & Schilling in Matos [34].

Statistical Analysis

In this study, statistical analysis was conducted using IBM SPSS Statistics version 25. The data were analyzed descriptively, focusing on the mean, standard deviation, and correlation to understand the underlying patterns and relationships. A normality test was an integral part of the process, used to assess the distribution of the data. This step determined whether parametric or nonparametric statistical methods were appropriate. In cases where the data did not follow a normal distribution, a nonparametric statistical test was employed.

Results

Fundamental Motor Skills and Motor Coordination Performance for Male and Female Students

Data analysis in general showed that the mean of Gross Motor Quotient (GMQ) of 478 students was low, the mean of students' locomotor skills was average, and the mean of students' object control skills was low. In addition, comparing to female students, male students had better performance with the mean of fundamental motor skill in below average level while the mean score of female students was low. On the other side, the mean of students' motor coordination performance was generally in average level. Both male and female students obtained almost the same scores in average level. The descriptions of the FMS and motor coordination data can be seen in Table 1.

Furthermore, result of data analysis indicated that the mean of 478 students (general, male and female students) based on Gross Motor Quotient (GMQ) in locomotor and object control skills was classified into seven categories such as very superior, superior, above average, average, below average, low and very low. These categories are presented in Table 2.

In terms of motor coordination performance, it was revealed that the mean score of 478 students was seen from general, male and female students. Each of result was classified into seven categories starting from very superior into very low. The data description is presented in Table 3.

Fundamental Motor Skills and Motor Performance based on School Locations (Urban and Rural Areas) and the Existence of Physical Education Teachers

The result of the data analysis showed that there was no significant difference between students in urban areas and those in rural areas in performing fundamental motor skills. However, male students obtained higher mean of Gross Motor Quotient of than female students. Furthermore, students who studied with physical education teachers had

Table 1. General description of FMS and motion coordination data obtained

Group	N	Fundamental motor skills					Motor coordination				
		Average	Std	Min	Max	Rating	Average	Std	Min	Max	Rating
General	478	78,68	10.7	52	137	Low	13,94	3.1	6	22	Average
Male	248	81,67	10.4	55	109	Below Average	14,63	3.2	6	22	Average
Female	230	75,30	10.4	46	137	Low	13,19	2.9	6	22	Average

Table 2. Results of gross motor quotient FMS, general, locomotor, object control (male & female)

Gross motor	FMS			Locomotor		Object Control		Descriptive
Quotient	General	Male	Female	Male	Female	Male	Female	Rating
> 130	0	0	0	0	0	0	0	Very Superior
121 - 130	1	0	1	1	0	0	0	Superior
111 - 120	0	0	0	24	4	0	0	Above Average
90 - 110	76	53	23	145	98	21	17	Average
80 - 89	117	73	44	52	75	88	46	Below Average
70 - 79	182	86	96	24	46	81	98	Low
< 70	102	36	66	2	7	58	69	Very Low

Table 3. Result obtained motor coordination, general, male and female

Scores motor Coordination	General	Male	Female	Descriptive Rating
> 20	14	9	5	Very Superior
18 - 20	39	30	9	Superior
15 - 17	153	97	56	Above Average
12 - 14	170	73	97	Average
9 - 11	80	28	52	Below Average
6 - 8	22	11	11	Low
< 6	0	0	0	Very Low

Table 4. Average achievement of FMS and motor coordination between urban, rural and school students with PE teachers and without PE teachers

Group		Fundamental motor skills					Motor coordination				
		Average	Std	Min	Max	Rating	Average	Std	Min	Max	Rating
Urban	General	78.34	11.4	46	109	Low	14.42	2.9	8	22	Average
	Male	81.18	10.6	55	109	Below Average	14.9	2.8	8	21	Average
	Female	75.11	11.4	46	109	Low	13.88	2.8	8	22	Average
Rural	General	78.77	10.5	52	109	Low	13.62	3.2	6	22	Average
	Male	82	10.2	55	106	Below Average	14.45	3.4	6	22	Average
	Female	75.4	9.7	52	109	Low	12.8	2.9	6	22	Average
PE Teacher	General	80.41	10.9	46	127	Average	14.25	3.2	6	22	Average
	Male	83.85	9.7	58	109	Below Average	15.01	3.2	6	22	Above Average
	Female	76.61	10.9	46	127	Low	13.42	3.1	7	22	Average
Teacher	General	75.58	10.1	55	106	Low	13.41	2.9	6	22	Average
	Male	77.90	10.5	55	106	Low	13.98	3	7	22	Average
	Female	73.13	9.1	55	106	Low	12.83	2.6	6	20	Average

bigger mean of Gross Motor Quotient score than those who studied with non-physical education teachers. In comparing of rural and urban areas, coordination motor performance of students in urban area was higher than those in rural area, and it was also seen that the higher score was obtained by school who had Physical Education teachers. Unlike students in urban area who had better motor coordination performance, students in rural area performed better fundamental motor skills, and they also obtained higher score when studying with physical education teachers. The data descriptions are presented in Table 4.

Students' achievement of fundamental motor skills is displayed in histogram in Figure 1. It can be revealed that the highest performance of fundamental motor skills was in average level followed by very low and below average levels for students in urban and rural areas, and students studied with physical education teachers and non-physical education teachers. Moreover, students' performance in motor coordination is presented in histogram in Figure 2. It can be tailored that the highest achievement was in superior level followed by average and above average levels.

Further data revealed that students in 7-year-old group were better at achieving fundamental motor skills than those in 8 and 9-year-old groups. The mean Gross Motor Quotient of students in 7-year-old-group was 81.1, that of students in 8-year-old group was 78.79, and that of students in 9-year-old group was 76.79. In terms of motor coordination, students in 7-year-old group was lower (12.57) than those in 8-year-old group (14.02) and those in 9-year-old group (14.90). The data description is presented in Figure 3.

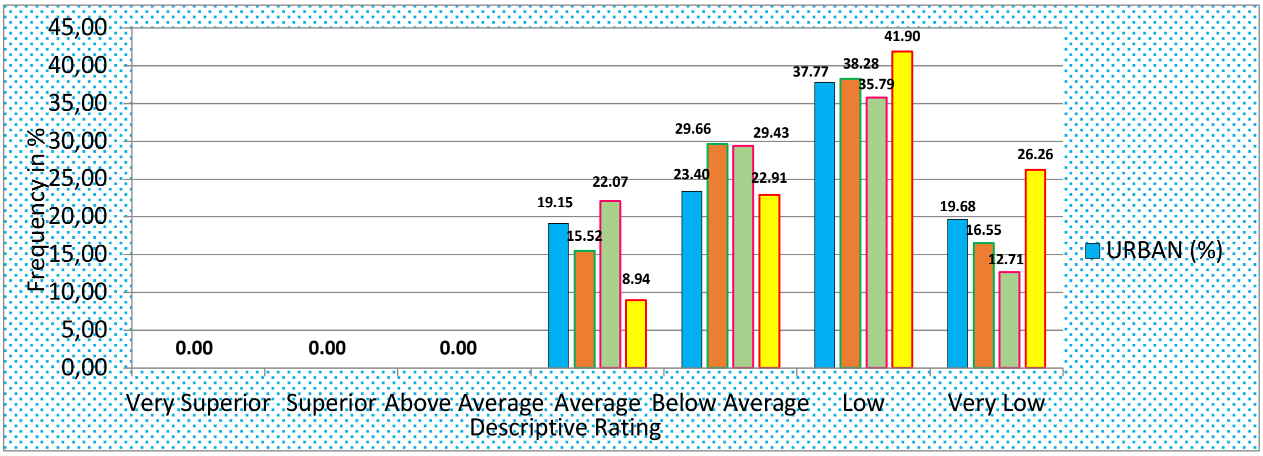

Figure 1. Comparison of average coordination between Urban, Rural students, PE teachers & general teachers

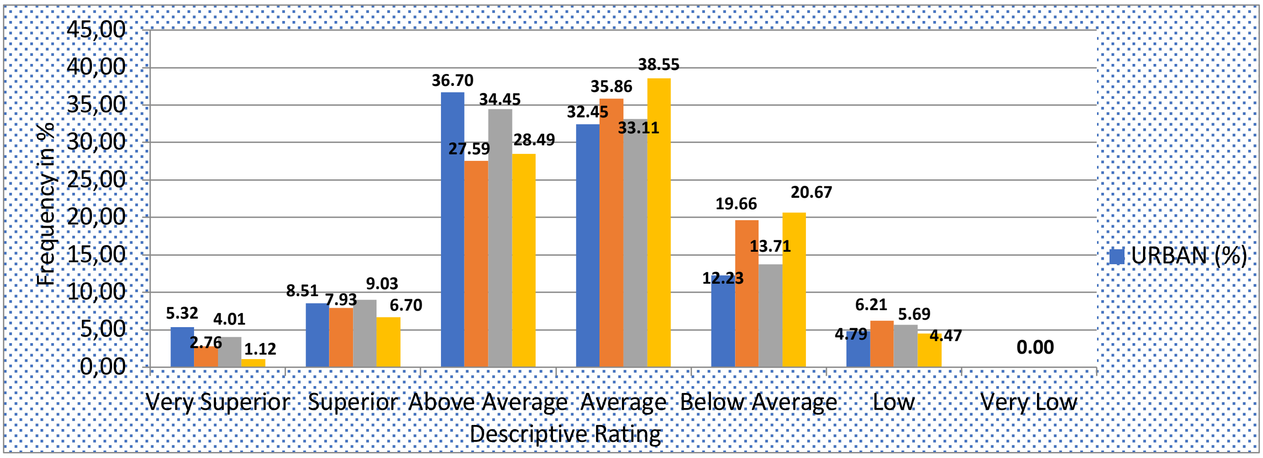

Figure 2. Comparison of average coordination between Urban, Rural students, PE teachers & general teachers

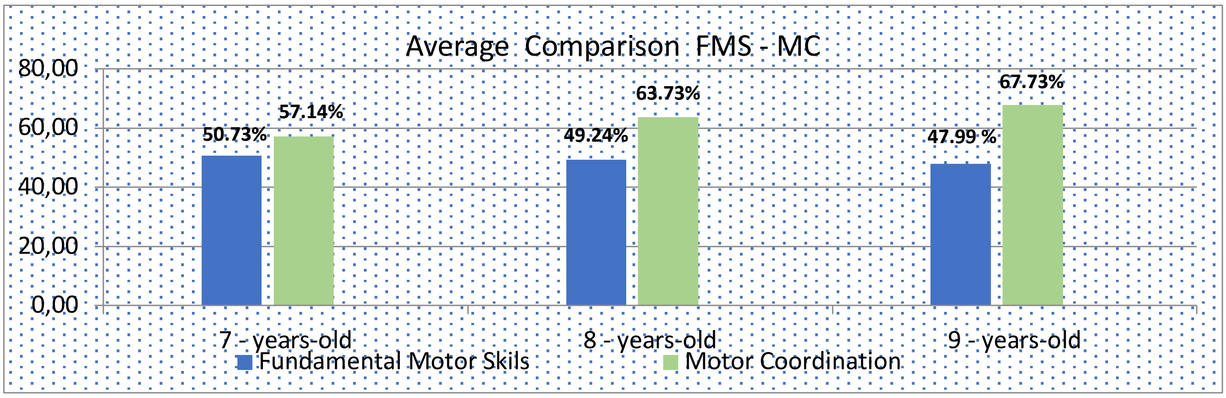

Figure 3. Comparative description of average FMS and coordination aged 7, 8 and 9 year

Normality testing was conducted by using the one-sample Kolmogorov-Smirnov test Asymp. Sig. (2-tailed) 0.200 > 0.05 of Statistic IBM SPSS version 25. Then, for the Bivariate correlation test, the result showed that the Pearson correlation test was 0.633 and the significant value was 0.000. It can be concluded that there was a significant relationship between motor coordination performance and fundamental motor skills of elementary students in West Sumatera. It can be also revealed that there were relationships and contributions of each group (Urban, rural, PE teachers, non-PE teachers) with the motor coordination performance and FMS. The correlation score of motor coordination performance and FMS for students in urban areas was 0.627 and the contribution score was 39.27%. The correlation score of motor coordination performance and FMS for students in rural areas was 0.564 and the contribution score was 42.76%. The correlation score of motor coordination performance and FMS for the PE teacher group was 0.628 and the contribution score was 39.41%. The correlation score of motor coordination performance and FMS for non PE teacher group was 0.618 and the contribution score was 38.24%. These data showed that there was a high correlation between coordinator ability and FMS of Elementary students in West Sumatera, Indonesia.

Discussion

This study revealed the factual condition of fundamental motor skills and motor coordination performance of Elementary students in West Sumatera. The researcher analyzed students' general competence in terms of gender, the location of the schools (urban or rural), and the existence of Physical Education teachers. Furthermore, the analysis was conducted to see the FMS and motor coordination performance of students in groups ages 7, 8, and 9. The result showed that there was a positive relationship between FMS and motor coordination performance. The more motor coordination performance students have, the higher the score of GMQ students get. It can be references to construct the hypotheses for deeper research, arrange the programs and learning models, and decide the policies and regulations in physics education.

Fundamental Motor Skills

The result of data analysis showed that there was no GMQ score in superior level, and above average level. The findings were that 21.34% of students were in very low level; 8.11% of them were in low level; 24.63% of them were in below average level; and 16% of them were in average level. None of them was in above average, and only 0.21% of them in superior level. It can be tailored that in general students' FMS was low, but the male students performed better than the female students did in the locomotor and object control skills. According to TGMD-2 rules, from 478 students observed, only 5 of them had basic motor development corresponding to their age level. Meanwhile, other 473 students, had motion delays including 80.02% delayed development of locomotor skills, and 98.95% delayed development of control object skills.

The male and female students had higher scores in locomotor skill assessment, but they got very low scores in object control skill tests. According to Goodway students at the Elementary level should perform very superior basic motor skills such as locomotor and object control skills [5]. However, the findings in the field revealed that their skill performance was in very low level. In line with the previous studies, the result showed that elementary students had low competence of FMS [44, 45]. Whereas a study argued that high FMS competence would increase skill development of transition ability and complex motor ability [41].

Other findings showed that students at the age of 7 years old had better motor skills than those at the age of 8 years old, and declined in the age of 9 years old. This result rebutted the assumption that FMS development was not in accordance with age development. It was also supported by Pang, Goodway, and Valentini. Rodrigues in his study figured out that children between the ages of 6 and 9 years old dealt with delayed development of their motor skills compared to the expected ideal development. Children's development in the age of 6 years old was in lower category, and that of 9 years old was in very low category. These results can be interpreted that the children may be prevented from further physical ability due to a lack of basic motor skills [31].

Students studying in rural areas had better average scores than those studying in urban areas, especially in locomotor skills. However, female students in urban and rural areas had almost the same competence in those two skills, but it was still lower than the male students. This finding was in line with a study conducted by Duarte, et. al. that lifestyles, environments, and habits of rural society in doing physical activities were beneficial for students to build and develop locomotor and control group skills. Furthermore, male students had higher intensities and mobilities of physical activities than female students did [46]. Since male students were dominated in physical activities, Melvin et. al. suggested giving more opportunities to female students in order to optimize the materials [47].

Students who studied in rural areas had higher locomotor skills than those who studied in urban areas. Nevertheless, for object control skills, students in urban areas got higher scores than students in rural areas. These findings are in line with the result of a study conducted by Bakhtian, physically students in rural areas actively moved such as walking to school so that they build good motor skills, meanwhile, students in urban areas were better at manipulative skills since they could afford the equipment's effortlessly [48]. Moreover, Budi et al stated that students got low motor quality due to the limited time allocation for sports subjects, and no time was adequate to hold the physical activities outside the class [49].

Grunseit suggested that teachers in urban areas should have classroom innovation to manage the limitation of physical activities so that it can effectively improve the locomotor skills of students [50]. To implement this idea, Papadopoulos et al figured out that the integration of short breaks to do physical activities can increase students' motor skill quality, and confidence, and specifically contribute to students' well-being to improve their FMS as well [51]. Doing physical activities through games also lead to a direct positive effect in upgrading students basic motor skills as it is applied in physical education learning at school [52].

There was also a finding related to the existence of physical education teachers to gain better scores than the non-physical education teacher did. Firstly, Salters et. al. believed that physical education teachers were more competent in demonstrating and experiencing movement and strategies, and were able to combine materials to improve students' FMS [53]. Secondly, da Silva stated that a well-structured subject would likely achieve better motor competence as the teacher should optimize the intervention in developing students' FMS [54].

In accordance with the analyses of the four groups in this study, the highest score of FMS was obtained from students who studied with physical education teachers. In other words, one way to boost students' motor skills was to advance physical education for students at school. Bolger et. al. stated that the physical activities of male and female students were determined by social and environmental factors such as family, peers, teachers, and physical environment [55]. Moreover, FMS competence was acquired through a combination of active performances and structured exercise programs designed by the teachers or coaches [7]. It was also recommended to have quality physical education that equipped students with a variety of appropriate physical and fitness exercises using effective learning strategies to exaggerate time learning and students' participation in physical education courses [56, 57].

Physical education teachers are the dominant alternative that plays an important role in developing and improving students' competencies through physical education at school. Equipping teachers with FMS skills and knowledge is an effort to enhance students' motor skills [58]. Physical Education teachers also need to understand students' developmental levels to figure out the legitimate approach that suits students' needs in FMS learning. Locomotor and object control skills evolve through the 'level' process which means a development process with certain development indicators. Generally, there are three to five levels of locomotor and object control skills. The understanding of basic motor skills will be useful for teachers to teach basic movement to students [5].

Samodra et. al. admitted that there were differences between the FMS of students living on the coasts, and the FMS of those living mountains, so a deeper analysis was needed to create FMS material for Elementary students [59]. In response to this finding, some interventions were implemented and succeeded in physical education programs at schools. FMS-based Afterschool program was successfully and effectively proven to promote FMS and physical activities for students at school [60]. Bardid claimed that Multimove intervention for children aged 3 to 8 years old was effective in increasing students' FMS in the school environment [61]. Bryce also stated that the implementation of motor intervention for 60 minutes a week in the Health and Physically Active School (HEPAS) program significantly improved students' motor skills [62]. Moreover, Yudanto et al applied some learning models to students who have high and low FMS scores toward the motor and psychosocial of soccer students. The results showed that the models were effective for students with high FMS scores [63]. Therefore, it is highly recommended that teachers manage to find suitable strategies to teach FMS effectively.

It is important to optimize the progress of Physical education through qualified teachers in realizing FMS learning at school. More than one approach and method can be used for certain materials and outcomes. Moreover, it is necessary to design relevant strategies focusing on the importance of FMS in elementary schools as an alternative way regardless of the low FMS score that will possibly limit students' physical activities [40]. Teachers' competence is also crucial in evaluating, and understanding the motoric level of students in order to make it easier to assess and implement FMS in the classroom. Some authors argue that the suitable learning model to use for elementary students is game-based learning [64]. Nopembri admitted that physical education with cooperative learning in game-based learning would increase problem-solving ability and cope with stress simultaneously [65]. This model can be used to develop students' FMS and it is recommended to implement game-based learning to have effective learning.

Motor Coordination

The data analyses revealed that in general students' motor coordination performance was in average level. Of 478 students, no student was in very low level, but 22 students were in low level. Only 80 students were in below-average level, and 170 students were in average level. there were 153 students in above average level, 39 students in superior level, and 14 students in very superior level. This study investigated the same students and compared their FMS and motor coordination performance scores. The result showed that good motor coordination performance tended to have high GMQ scores in FMS.

This study also examined the correlation between motor coordination performance and the result of the GMQ scores from the FMS test. It can inferred that the higher the students' motor coordination performance, the better the students' FMS performance. Barnet in Matos et. al. stated that one of the important aspects of the relationship between motor coordination performance and FMS was to have good motor performance, people need to have good coordination competence [34]. This finding is in accordance with the previous studies that the male students performed better coordination than the female students did, and it mostly affected the object control skill of the students. The male students ages 6 to 10 years old were superior in motoric coordination assessed with eye-hand coordination motoric from Faber [66]. It is assumed that male students are dominantly mobile themselves to take opportunities and explore movements to support their coordination.

Both male and female students in these sample groups showed different motor coordination performances in terms of age. The students' coordination movement will increase in line with the age development. Students at the age of 9 years old had better coordination than those at the age of 7 and 8 years old. Basic physiology and motor coordination were the coordination of nerves from its system [67]. Regardless of exercise intensity it was believed that older students had optimum neural systems. Students in urban areas had the highest motor coordination performance among students in rural areas, and two more samples. However, the highest coordination skills were obtained by male students studied with physical education teachers (average level). It can be implied that students in urban areas had more opportunities and facilities than students in rural students had [48]. The chances will be greater when the learning process is structurally facilitated.

There was a positive and significant relationship between motor coordination performance and FMS, so it is suggested that teachers necessarily provide more exercises related to coordination to the students. In other words, the higher the coordination score of students, the better the performance of FMS students. According to Bojwokski, the improvement of coordination motor skills is one of the most important factors in achieving learning goals [68]. Based on the theories above, motor coordination performance is the key to obtaining the competence of specific movements, especially if it is used in competitions and tournaments.

According to Vandorpe, coordination exercises in the early year of childhood is one of the factors to determine the competence and skills of students or athlete in any branch of sports tournament [69]. By doing bilateral coordination exercises for 10 minutes regularly, students' concentration and attention will focus rather than doing normal physical activities in the same duration [70]. Therefore, movement coordination contributes intrinsically to developing students' motor skills and concentration.

Regarding the explanations above, it is necessary to make a serious effort to build up students' fundamental motor skills in West Sumatera Province, Indonesia. First, the improvement of the physical education learning model is the most feasible solution as it is supported by previous studies that the interventions effectively improved the FMS of elementary students and young children. It is also important to manage some exercises related to movements and to program the relevant physical activities by the physical education teachers. Related findings revealed that there was a significant relationship between motor coordination performance and FMS score as empirical proof to be considered. It can be inferred that to enhance students' FMS significantly, their motor coordination performance should be developed through structured and unstructured physical activities inside and outside the classroom.

Lawson et. al. mentioned two valuable aspects of building students' competence; they are stability skills and coordination skills [71]. In addition, Han stated motor skills reflect the criteria of basic physical activities which can improve motor skills and maintain the physical and mental health of elementary students [72]. Johnson et. al. also suggested that physical education teachers construct proper interventions which equip students' needs based on their own characteristics to boost their FMS [73].

Conclusions

The results of this study lead suggestions to do interventions in optimizing physical education in elementary schools. Considering a variety of students' needs, it is advisable for physical education teachers to construct effective learning models to improve the basic motor skills of students. Additionally, incorporating unstructured physical activities alongside regular assessments can further aid in the holistic development of students' motor abilities.

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Conflict of interest

There is no conflict of interest

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ORIGINAL ARTICLE

Effect of mat pilates training program on functional fitness in older adults

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Abstract

Background and Study Aim — The increasing recognition of pilates as a comprehensive exercise regimen tailored to the needs of the elderly population underscores its growing importance. This shift in emphasis reflects a growing awareness of the potential benefits of pilates for older adults' overall well-being. Study Aim - to investigate the potential benefits of a six-week mat pilates training (MPT) program on the functional fitness of older adults.

Material and Methods — In total, a group of 30 elderly individuals (i.e., N_{Male}=18 and N_{Female}=12), who regularly frequented a local playground, participated in a quasi-experimental study. The study involved pre-test and post-test assessments and was conducted over a period of six weeks. Participants underwent an MPT program (six days a week for six weeks, 60 minutes per session). Were assessed for various functional fitness parameters: lower-body strength (LBS), upper-body strength (UBS), aerobic endurance (AE), lower-body flexibility (LBF), upper-body flexibility (UBF), agility (AG), and Body Mass Index (BMI). A paired-sample t-test was used for statistical analysis.

Results — The MPT resulted in significant ($p<0.001$) improvement in LBS (9.71%), UBS (8.33%), AE (7.11%), LBF (13.48%), UBF (98.78%) and AG (10.52%) post-intervention. However, no significant change was noted in the BMI.

Conclusions — A MPT program significantly enhances various dimensions of functional fitness in older adults, excluding BMI. The study results have profound implications for older individuals' well-being and quality of life. Given the global trend towards an ageing population, pilates emerges as an essential intervention for promoting active ageing, potentially improving daily functioning, reducing fall risk, and enhancing independence in the elderly.

Keywords: pilates, older adults, functional fitness, aerobic endurance, flexibility, strength, agility, ageing population

Introduction

In older age, the quality of life is intricately linked to the capability of performing day-to-day tasks without discomfort for as long as possible [1]. As advancements in medical science prolong life expectancy, the emphasis on sustaining physical fitness parallelly intensifies. Nevertheless, while technological innovations in medicine have augmented life expectancy, they have simultaneously played a role in cultivating a sedentary lifestyle, characterised by physical inactivity and subsequent health complications [2]. In earlier times, everyday activities such as stairs climbing or cultivating gardens provided inherent physical exertion [3]. Presently, however, technological conveniences, although advantageous, have inadvertently diminished these naturally occurring physical engagements, thus propagating health issues. It is of paramount importance, especially for the ageing population, to prioritise functional fitness, refers to the aptitude to undertake daily activities safely and independently without undue fatigue [4]. Various international governing bodies have recommended various physical activities to provide an overview of

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the benefits of physical activities for older people [5, 6, 7, 8]. Contrarily, empirical evidence indicates a substantial portion of older adults remain detached from sufficient physical exercises, possibly deterred by the potentially daunting ambiance of fitness centers or vigorous movement activities [9]. So, a question arises, "Is there any suitable and effective fitness training method available for older people?"

Since the development of the pilates physical training method, it has become one of the popular ways to be fit among fitness enthusiasts. Pilates cannot just be said as some bunches of exercises; it is a fun way of performing some particular movement [10]. It is an innovative way to increase vigour, enhance physical strength and flexibility, and control some psychological and psycho-physiological problems [11]. Pilates exercises are designed to involve the body's postural muscles, aiming to improve stability and strength within the core of the body, which can help them achieve overall body balance [12, 13]. It can help in reducing stress. Pilates can also help an individual to improve his sense of well-being and can help in focusing on day-to-day tasks [11]. Over the years, the principles and methods of pilates have been tried and tested by various professionals in various ways. Based on the equipment used and the level of difficulty, pilates exercises can be broadly categorised into six types, among which mat pilates training (MPT) involves body weight as resistance and is favorite among older adults due to its low-impact on body [14]. Though many different approaches to pilates exercises have evolved, the primary exercise method is based on six principles, i.e.: breath, concentration, control, precision, centre and flow [15]. These methods aim to increase the core strength of an individual. It also aims to lengthen the spine and build muscle tone, increasing awareness about an individual's physique [16] which can be a very effective method to develop the physical fitness of older people [15].

Researchers have conducted a numbers of investigations on the impacts of pilates exercises on the human body under various circumstances. One such investigation revealed that pilates exercises resulted positive outcomes in enhancing dynamic balance, flexibility, reaction time, and muscular strength while concurrently reducing the likelihood of falls in elderly women [17]. Another study focused on assessing the impact of pilates exercises on the overall health of women diagnosed with type 2 diabetes, deduced that pilates can be considered a viable and safe approach for ameliorating the general health of this specific patient demographic [18]. Review research concluded that pilates was a better intervention for chronic low back pain patients to reduce pain and disability; however, pilates was not better for short-term pain reduction than other types of practice [19]. Though so much research has been performed on pilates exercise, no one could clearly demonstrate the effect of MPT on the functional fitness of older adults.

The aim of the study is to provide new and valuable information on the potential benefits of pilates exercise on functional fitness in older adults.

Materials and Methods

Participants

A total of 30 older adults (N_{All}=30, N_{Male}=18, N_{Female}=12; Age_{All}=63.40±1.77, Age_{Male}=63.06±1.73 years, Age_{Female}=63.91±1.78 years) who regularly visited a local community playground for morning walk had voluntarily participated in the study, however towards the end of the study 3 male and 2 female didn't qualify or attended the post-test session (Figure 1). G*Power (version 3.1.9.2, University of Kiel, Kiel, Germany) was utilised to conduct a priori power analysis to determine the requisite sample size prior to participant selection. This analysis adopted an effect size of 0.80, an alpha error probability of 0.05, and a power of 0.95, in accordance with the methodology delineated by Kang [20]. The sample size determination test revealed a sample size of 23 for the study. However, to compensate for participant attrition, initially, 30 participants were considered as the sample for the study, which was further reduced to 25 at the final stage of the study. All the included participants of the study were aged 60 years and older and free from acute or chronic medical conditions. The participants possessing metallic implants or those with serious medical contraindications (hypertension, recent heart surgery, uncontrolled diabetes) or with significant cognitive impairments, as advised by physicians, precluding them from engaging in vigorous physical activities, were excluded from the study. The research received approval from the Institutional Ethical Committee of SRM Medical College Hospital & Research Centre, ensuring that it adhered to requisite ethical standards and guidelines (8498/IEC/2022). Furthermore, the study adhered to the guidelines outlined in the Declaration of Helsinki [21]. The participants had given written consent after thoroughly understanding the study's objectives, potential benefits, risks and future implications.

Research Design

The research employed a quasi-experiment utilizing a one-group pretest-posttest design Figure 1), citing the limited number of participants [22]. The participants were tested before and after the exposure to six weeks of MPT program. The participants were instructed not to be involved in any other types of physical interventions which might have influenced the sole effect of the MPT program. The pre-test was completed within three days before the start of the training program, whereas the post-test was completed within three days after the completion of the six weeks MPT program.

Training Intervention

The participants were trained inside a community hall six days a week for six weeks. The duration of each training session was 60 minutes. The training program was constructed to promote the holistic development of functional fitness. Each session commenced with a 10-minute limbering-up, using basic exercises like deep breathing and gentle stretches, preparing participants both mentally and physically. The main exercise section, spanning 40 minutes, served as the core of the intervention. Across the six weeks, the program introduced and progressively intensified exercises such as the Pelvic Curl, The Hundred, the Crisscross, and the Side Kick Series. Each week offered a combination of familiar exercises, ensuring consistent engagement and mastery while introducing new ones to challenge participants and prevent adaptability stagnation. Repetitions, sets, and rest intervals were methodically structured to balance exertion and recovery, optimising the benefits of each exercise. The sessions concluded with a 10-minute limbering-down, comprising stretches and relaxation techniques, aiding in muscle recovery and mental relaxation. The progression from week one to six was meticulously crafted to ensure participants not only improved their pilates technique but also experienced quantifiable improvements in their functional fitness. Table 1 displays the training intervention for the first week.

Testing protocol

Senior Fitness Test [23] items were employed to evaluate the functional fitness of the older adults. The test items exhibited high reliability and validity as elucidated by Rikli & Jones [23] . The testing procedures are explained below.

Lower-body strength (LBS): 30-second chair stand test for lower-body strength

The 30-second chair stand test, as explained by Rikli and Jones [23] , was employed to measure the LBS of the older adults. A chair was positioned against a wall and secured it using a nail for safety. Participants were instructed to position themselves centrally on the seat, ensuring their feet were flat and spaced shoulder-width apart. Additionally, they were directed to cross their arms at the wrists and keep them adjacent to the torso. The participants were asked to start from the seated position to fully stand up and then fully sit back down and were asked to repeat it for 30 seconds. The cumulative count of full chair stands was considered (one stand

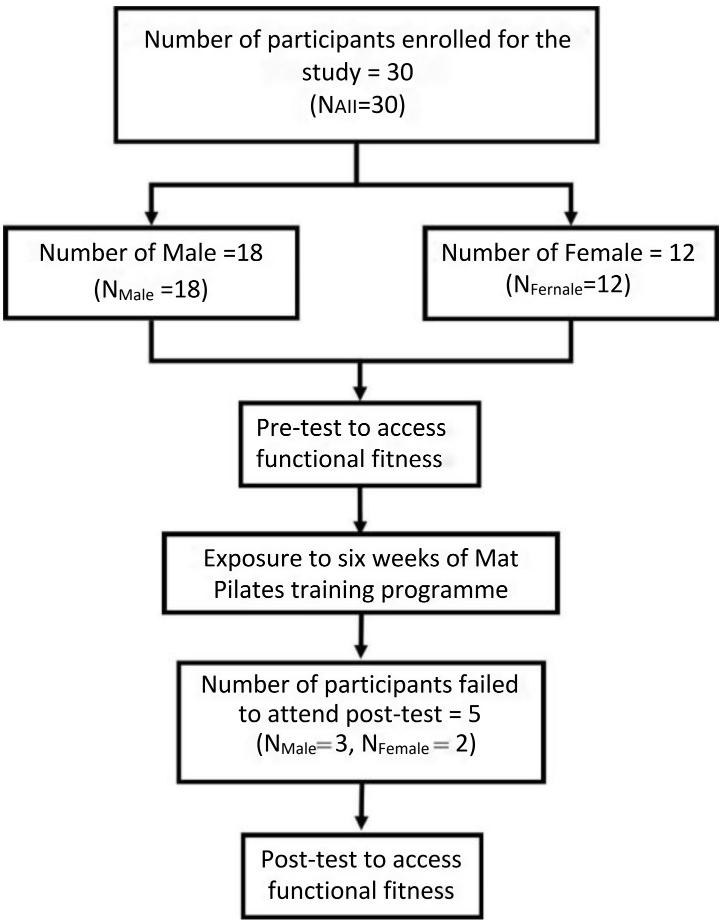

Figure 1. Flow of the experiment

Table 1. Pilate training intervention for first weeks*

WEEK 1				
Day	**Warm-Up (10m)**	**Main Exercises (40m) (Sets x Reps)**	**Rest (between sets/exercises)**	**Cool Down (10m)**
1	Deep Breathing, Pelvic Tilts, Cat-Cow, Gentle Spinal Rotations	Pelvic Curls (3x10), The Hundred (3x75 pumps), Spine Twist (3x12), Leg Circles (3x10 each leg), Single Leg Stretch (3x10 each leg)	30s/1m	Spinal twists, Child's Pose, Gentle Leg Swings
2	Leg swings, Dynamic leg stretches, Hip circles, Ankle Rotations	Standing Leg Lifts (3x10 each direction), Double Leg Stretch (3x12), Rolling Like a Ball (3x10), Scissors (3x10 each leg), Double Leg Lifts (3x10)	30s/1m	Hamstring, quad, calf stretch, Gentle Hip Rotations
3	Arm circles, Shoulder rolls, Neck tilts & turns, Wrist rotations	Arm Scissors (3x12), Push-Ups (3x12), Tricep Dips (3x12), Plank (3x40s), Side Plank (3x30s each side)	30s/1m	Shoulder stretch, Tricep stretch, Arm Swings
4	Deep Breathing, Side bending, Spinal rotations, Neck Rolls	The Saw (3x12), Spine Stretch Forward (3x12), Corkscrew (3x12), Open Leg Rocker (3x10), Single Leg Teaser (3x10 each leg)	30s/1m	Gentle Spinal Rolls, Neck Stretches, Forward Bend
5	Full body twist, Dynamic leg & arm stretches, Gentle Torso Twists	The Seal (3x10), Shoulder Bridge (3x12), Side Kick Series (2x10 each exercise), Double Leg Kicks (3x12), The Teaser (3x8)	30s/1m	Full Body Relax, Deep Breathing, Gentle Torso Twists
6	Gentle jog in place, Arm & leg dynamic stretches, Hip Rotations	The Hundred (3x100 pumps), Neck Pull (3x10), Jackknife (3x10), Rollover (3x8), Swimming (3x30s)	30s/1m	Gentle Side Stretches, Hamstring Stretch, Deep Breathing

* Only focused exercises are mentioned here. Notes: m, minute; s, seconds; reps, repetitions

includes both standing up and sitting down) as the test score.

Upper-body strength (UBS): 30-second arm curl test for upper-body strength

The 30-second arm curl test was utilized to assess the UBS of older adults [23]. Participants were instructed to sit on a chair and hold a weight with their dominant hand using a suitcase grip, wherein the palm faced their body. The upper arm remained stationary and braced against the body, positioned vertically beside the chair, allowing only the forearm to move. Participants were directed to elevate their arm, encompassing its entire range of motion, subtly rotating the palm upward. Subsequently, they lowered the arm through the same range, reverting it back to its initial posture. The arm should be completely flexed and subsequently fully extended at the elbow joint. Participants were instructed to repeat the action as many times as possible within 30 seconds. The score was determined by the total number of controlled arm curls completed in 30 seconds.

Aerobic endurance (AE): 2-minute step test for aerobic endurance

The 2-minute step test was employed to assess the AE of the older adults [23]. Participants were instructed to stand upright adjacent to a wall. A mark was established on the wall, positioned midway between the individual's patella and iliac crest. Subsequently, participants were directed to march on the spot for a duration of two minutes, ensuring their knees reached the height of the designated mark on the wall. Participants were permitted to rest or seek support by holding onto the wall or a sturdy chair if needed. The score for the test was determined by recording the total number of occurrences where the right knee raised to the level of the tape within the span of two minutes.

Lower-body flexibility (LBF): Chair sit-and-reach test for lower-body flexibility

The chair sit-and-reach test was used to assess the LBF of the older adults [23]. A chair was secured against a wall, with participants seated at the edge. Participants positioned one foot flat on the floor, knee bent, and extended the other leg forward, heel on the floor, and ankle at a 90° angle. Hands were stacked, middle finger tips aligned. Participants inhaled, exhaling while reaching towards their toes, bending from the hip, maintaining a straight back and elevated head, avoiding bouncing or overstretching. The final position, held for 2 seconds with a straight knee, determined the score based on the distance between fingertips and toes, measured to the nearest 1/2 inch. Touching the toes scored zero, not touching resulted in a negative score, and overlapping fingers and toes gave a positive score.

Upper-body flexibility (UBF): Back scratch test

To assess the UBF of the older adults, the back scratch test was utilized [23]. Participants stood upright, reaching one hand over their shoulder, palm against the body and fingers directed downward. The opposite hand went behind their back, palm out and fingers pointing upward, trying to touch or overlap the middle fingers of both hands. An assistant ensured proper alignment and measured the fingertip distance. A score of zero was given if fingertips touched; non-touching distances resulted in a negative score, while overlap was recorded as a positive score. After two practice tries, one test attempt was made, which could be stopped if pain occurred. The best result, rounded to the nearest 1/2 inch, determined the test score.

Agility (AG): 8-foot up-and-go test

The AE of elderly participants was assessed using the 2-minute step test [23] . A chair was positioned against a wall, and a marker was placed 8 feet in front of it. There were no objects in between the chair and the marker to obstruct the normal movement between them. Participants began the test seated with hands on their knees and feet flat. At the "Go" command, they swiftly and safely walked around a cone before returning to sit. The timer stopped once seated. After two attempts, the fastest time, rounded to the nearest $1/10^{th}$ of a second, determined the test score

Body Mass Index (BMI):

Height was measured using a stadiometer (SECA model 213, Hamburg, Germany), following the conventional method. Body mass was assessed using an electronic scale (SECA model 813, Hamburg, Germany) following the method used by Minu et al. [24]. BMI was calculated following the method described by Nuttall [25].

Statistical analysis

Descriptive statistics were first computed, with results being presented as mean±standard deviation for both pre and post-test measurements. To evaluate of the mean differences between pre and post-test measurements, the paired t-test was employed as the statistical technique. All statistical tests were calculated using the IBM SPSS version 27 [26]. Prior to the application of the t-test, the associated assumptions were rigorously examined. For the statistical calculations, the level of significance was set at $p<0.05$. In addition to the t-test results, the effect size was ascertained using Cohen's d, and the 95% Confidence Interval (CI) was delineated. Moreover, the percentage changes relative to pertinent variables were also calculated. A correlation coefficient (ICC) was calculated for each variable using before and post-test data from the MPT group. According to Koo & Li [27], test-retest reliability was calculated using two-way mixed models and expressed as ICCs. According to [27], in general, ICCs below 0.5 indicate poor reliability, 0.75 to 0.9 indicate moderate reliability, and over 0.90 indicate excellent reliability. All examined parameters' ICC values are shown in Table 2. Whenever there is a pre-test or post-design for intervention studies, reliability is crucial as a sign of measurement error.

Results

The results of the statistical tests are displayed in Table 3. Paired-sample t-tests were conducted to assess changes in functional fitness variables from pre-test to post-test separately for male, female and combined group. The results indicated a statistically significant increase in LBS both among males ($p=0.015$) and females ($p=0.002$), with an overarching significant increase in the combine group ($p<0.001$). The UBS demonstrated significant improvements in males ($p=0.002$) and, importantly, in the combine group ($p<0.001$), while the female group did not achieve statistical significance ($p=0.117$). The AE witnessed marked enhancements across all

Table 2. Intraclass correlation coefficients (ICCs) for all analysed variables using pre and post data of the participants

Variables	ICC	95 % CI
Lower-body strength (number)	0.92	0.838-0.969
Upper-body strength (number)	0.95	0.897-0.980
Aerobic endurance (number)	0.97	0.951-0.991
Lower-body flexibility (inches)	0.99	0.995-0.999
Upper-body flexibility (inches)	0.96	0.928-0.986
Agility (seconds)	0.95	0.894-0.979
BMI ($kg.m^{-2}$)	0.98	0.967-0.994

Notes: BMI, Body mass Index; ICC, intraclass correlation; CI, confidence interval.

Table 3. Mean differences between pre and post-test performance of functional fitness variables

Variables	Mean (±SD)			Mean Difference (Post-Pre)	t-value	Sig. value (p)	Cohen's d	Percentage change
LBS (number)	Male	Pre	14.73±2.84	1.07±1.49	-2.779	0.015	1.49	7.26
		Post	15.80±3.03					
	Female	Pre	12.90±2.28	1.80±1.32	-4.323	0.002	1.32	13.95
		Post	14.70±2.54					
	Combine	Pre	14.00±2.74	1.36±1.44	-4.723,	0.001	1.44	9.71
		Post	15.36±2.84					
UBS (number)	Male	Pre	16.67±3.94	1.47±1.51	-3.773	0.002	1.51	8.76
		Post	18.13±4.07					
	Female	Pre	13.40±2.27	1.00±1.83	-1.732	0.117	1.83	7.46
		Post	14.40±3.03					
	Combine	Pre	15.36±3.70	1.28±1.62	-3.949	0.001	1.62	8.33
		Post	16.64±4.07					
AE (number)	Male	Pre	82.80±13.64	5.80±4.06	-5.537	0.000	4.06	7.00
		Post	88.60±13.45					
	Female	Pre	79.80±9.14	5.80±2.39	-7.660	0.000	2.39	7.27
		Post	85.60±8.96					
	Combine	Pre	81.60±11.92	5.80±3.43	-8.460	0.001	3.43	7.11
		Post	87.40±11.74					
LBF (inches)	Male	Pre	1.70±2.48	0.31±0.21	-5.779	0.000	0.21	18.24
		Post	2.01±2.37					
	Female	Pre	3.21±1.11	0.31±0.18	-5.471	0.000	0.18	9.66
		Post	3.52±1.00					
	Combine	Pre	2.30±2.15	0.31±0.19	-8.027	0.001	0.19	13.54
		Post	2.62±2.05					
UBF (inches)	Male	Pre	-1.62±2.04	0.98±0.77	-4.922	0.000	0.77	-60.49
		Post	-0.64±1.53					
	Female	Pre	0.37±1.02	0.57±0.27	-6.754	0.000	0.27	154.05
		Post	0.94±0.96					
	Combine	Pre	-0.82±1.95	0.82±0.64	-6.329	0.001	0.64	-99.03
		Post	-0.01±1.53					
AG (seconds)	Male	Pre	4.89±0.77	-0.54±0.36	5.775	0.000	0.36	-11.04
		Post	4.35±0.63					
	Female	Pre	5.26±0.85	-0.51±0.28	5.746	0.000	0.28	-9.70
		Post	4.75±0.86					
	Combine	Pre	5.04±0.80	-0.53±0.33	8.099	0.001	0.33	-10.48
		Post	4.51±0.74					
BMI ($kg.m^{-2}$)	Male	Pre	23.51±0.92	0.07±0.22	-1.199	0.251	0.22	0.30
		Post	23.58±0.89					
	Female	Pre	24.18±0.67	0.04±0.21	-0.618	0.552	0.21	0.17
		Post	24.22±0.77					
	Combine	Pre	23.78±0.88	0.06±0.21	-1.346	0.191	0.21	0.24
		Post	23.84±0.89					

Notes: LBS, lower-body strength; UBS, upper-body strength; AE, aerobic endurance; LBF, lower-body flexibility; UBF, upper-body flexibility; A, agility; BMI, body mass index; SD, standard deviation.

categories, with males, females, and the combine group showing p-values of less than 0.001. Both LBF and UBF experienced significant increases from pre to post-test measurements across all gender and combined group (all $p<0.001$). Notably, AG underwent a significant decrease in the post-test measurements for males, females, and the overall group, all with p-values less than 0.001, indicating improved agility. In contrast, BMI exhibited negligible changes across genders and combined data, with the overall change not reaching statistical significance ($p=0.191$).

Discussion

The present research aimed to understand the potential benefits of a six-week MPT program on the functional fitness of older adults. This objective emerged from the growing acknowledgement of pilates as a holistic exercise program with potential implications for enhancing physical capabilities, especially among the elderly population. Our findings provide substantial evidence that MPT can be a valuable intervention in promoting several dimensions of functional fitness in older adults, except BMI.

A cornerstone finding of this study was the significant improvement in both lower- and upper-body strength. The gains in LBS and UBS corroborate prior research that has reported the potential of Pilates-based exercises in enhancing muscular strength. Campos de Oliveira et al. [28] conducted an extensive study on older adults and observed that those who practised pilates regularly displayed marked improvements in muscle strength and posture. Similarly, our research aligns with this trend, suggesting that the structured and controlled movements in pilates, which emphasise core stability and alignment, are particularly effective for this demographic. The ageing process typically results in a gradual decline in muscle mass and strength, a phenomenon known as sarcopenia [29]. Pilates, with its focus on controlled resistance and full range of motion, may offer an effective countermeasure against this natural decline.

Our results demonstrated a noteworthy improvement in aerobic endurance following the pilates intervention. This aligns with the findings of Fernández-Rodríguez et al. [30] and Lim & Yoon [31], who argued that consistent pilates practice can have a positive impact on cardiovascular health. The unique combination of rhythmic movements, coupled with deep, controlled breathing emphasised in pilates, can enhance oxygen utilisation and improve cardiovascular efficiency [16]. Moreover, as cardiovascular diseases remain a leading cause of morbidity among older adults [32], the potential of pilates to bolster heart health cannot be understated.

Flexibility is an often-overlooked aspect of fitness that plays a pivotal role in the daily functioning and overall quality of life of older adults. Our findings highlighted significant advancements in both lower- and upper-body flexibility post-intervention. This is consistent with previous studies that have emphasised the stretching and lengthening movements inherent in pilates as being especially effective in enhancing flexibility [33]. An increase in flexibility can reduce the risk of injuries, alleviate joint pain, and improve overall mobility [34], all of which are essential for maintaining independence and high quality of life in older age [35].

The improvement in agility, as reflected in our study, underscores another dimension of functional fitness. Agility involves not just speed but also balance, coordination, and spatial orientation [36, 37], all crucial for daily activities and preventing falls in older adults [38, 39]. Donath et al. [40] and Rodrigues et al. [41] emphasised that agility training, as offered through dynamic pilates movements, can significantly reduce the risk of falls, which remains a prevalent concern among the elderly. By enhancing agility, pilates not only improves physical capabilities but potentially offers psychological benefits by boosting confidence in movement and reducing fear of falls [42, 43].

While the MPT program manifested significant improvements in most functional fitness parameters, BMI remained largely unchanged. This observation is in line with prior research. Aladro-Gonzalvo et al. [44] and Sharma [45] asserted that while pilates offers numerous functional and health benefits, it may not be the primary choice for weight management. The calorie expenditure in a typical pilates session might not be as substantial as more aerobic-centric programs [46]. However, it's essential to understand that BMI alone is not a comprehensive indicator of health, especially in older adults, where muscle mass and functional capabilities are of paramount importance [47].

It is evident that a MPT program offers a multifaceted approach to enhancing functional fitness in older adults. The benefits span from muscular strength to cardiovascular health, flexibility, and agility. Such comprehensive improvements have profound implications for the well-being and quality of life of older individuals. With the challenges of ageing, such as sarcopenia, reduced cardiovascular efficiency, and decreased flexibility, interventions like pilates can play a pivotal role in not just halting but potentially reversing some of these declines. Furthermore, given the non-significant change in BMI, it might be beneficial to integrate pilates with other aerobic exercises for older adults aiming for weight management.

Conclusions

With the global population ageing, our research highlights a pressing social imperative to prioritise interventions that promote longevity and quality of life. Pilates, as our study demonstrates, emerges as a pivotal solution. Beyond individual improvements in muscular strength, cardiovascular health, flexibility, and agility, pilates offers older adults tangible benefits such as improved daily functionality, diminished fall risks, and a bolstered sense of independence and confidence. These outcomes pave the way for older adults to remain active and engaged in various social and recreational activities, combating feelings of dependency or isolation. From a broader vantage point, these findings bear significant implications for healthcare systems, policy formulations, and community engagement. The study recommend for the inclusion of pilates in rehabilitation programs, the establishment of community-based pilates workshops, widespread awareness campaigns detailing its myriad benefits for the elderly, and a continued commitment to research, exploring the comprehensive advantages of pilates in the area of public health.

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ORIGINAL ARTICLE

Investigation of maximal strength performance in terms of training time routine

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim In recent years, there has been a growing interest in understanding the relationship between daily training time, circadian rhythms, and athletic performance. The connection between daily training time, circadian rhythms, and athletic performance continues to be a subject of research debate. Therefore, the aim of this research is to investigate whether maximal strength performance is affected by daily training time routines.

Material and Methods This cross-sectional study involved a total of 36 male bodybuilding athletes, who were divided into three equal groups (n=12); Noon Group, Afternoon Group, and Evening Group. The distinguishing feature amongst the groups was that they had been training at different times of the day for the past 6 months, and within each group, athletes had been training at the same time of day (Noon Group 12:00-14:00; Afternoon Group 17:00-19:00; Evening Group 21:00-23:00). A one-repetition maximum squat test was administered to each group with there being a 72-hour interval between the tests.

Results The findings from the research indicate that there is a relationship between athletes' daily training time routines and maximal strength performance. Athletes perform at their best during the time that corresponds to their daily training routine. The analysis reveals a statistically significant advantage in 1-RM squat performance for athletes adhering to their daily training time routines at various times of the day ($p < 0.001$). Notably, Group Noon, Group Afternoon, and Group Evening achieved their highest 1-RM squat performance when following their respective daily training time routines.

Conclusions Results underscore the importance of aligning training schedules with athletes' natural rhythms, enhancing performance optimization strategies. It is believed that effective planning for training time by coaches and conditioning experts, taking into account competition times, would be a valuable strategy.

Keywords: daily training time, circadian rhythm, athletic performance, maximal strength, workout timing, training routines

Introduction

In the realm of sports sciences, numerous studies have consistently highlighted the multifaceted nature of athletic performance, suggesting that it is intricately influenced by a combination of endogenous (internal) and exogenous (external) mechanisms [1, 2, 3]. Researchers in this field have made concerted efforts to elucidate these phenomena by drawing connections to the body's biological clock or circadian rhythm.

The central biological clock, residing within the suprachiasmatic nucleus (SCN) of the hypothalamus, serves as the cornerstone of these intricate processes [4, 5, 6]. This pivotal biological clock demonstrates remarkable adaptability, responding to environmental cues, particularly the light-dark cycle [4, 7]. Within the domain of biological rhythms, there exist various categories, with the circadian rhythm, which operates on a 24-hour cycle, standing out as the most prominent [4, 5, 6, 8].

While ultradian rhythms, featuring periods of shorter than 20 hours, and infradian rhythms, characterized by cycles exceeding 28 hours, also exist, it is the circadian rhythm that garners the most attention in research endeavors. This preference stems from the alignment of the 24-hour circadian rhythm with the natural life cycles of humans. Furthermore, a multitude of physiological processes, including blood pressure

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regulation, body temperature fluctuations, hormonal secretion, and energy metabolism which are all intricately tied to nutrient intake, operate on approximately 24-hour cycles. Consequently, these processes are believed to wield considerable influence over athletic performance outcomes [6]. It is this interplay between circadian rhythms and physiological functions that has directed research focus towards the circadian rhythm as a paramount determinant of athletic performance within the realm of sports sciences.

Most studies in the literature investigating circadian rhythms and their impact on athletic performance, both among professional and amateur athletes, have consistently indicated that the time frame of approximately 16:30-19:00 in the afternoon is associated with peak athletic performance levels [9, 10, 11, 12]. This observed enhancement in athletic performance during this period is often attributed to the synchronization of various physiological, psychological, and metabolic rhythms [13, 8]. Consequently, it is widely acknowledged that, in alignment with circadian rhythms, the most optimal time for engaging in physical exercise falls within the window of approximately 16:30-19:00 [3, 14, 15].

While the temporal dimension of physical performance is of paramount importance, it is imperative to consider additional temporal factors that may influence athletes, such as chronotype – an individual's inherent propensity towards morningness, eveningness, or neither [16, 17, 18]. Ayala et al. [3], in a comprehensive review encompassing eight studies, underscored that the question of how chronotype interacts with the timing of physical activity and its effects on physical performance remains ambiguous and inconclusive within the existing body of research. Moreover, their review emphasized that the majority of chronotype-related studies have primarily focused on the distinction between morning-chronotype and evening-chronotype individuals, with limited exploration of intermediate-chronotype individuals.

Although sparse, there are notable exceptions. For instance, a study on weightlifters reported an improvement in strength performance at around 02:00, with a perceived decrease in effort exerted [19]. Conversely, Ayala et al. [3] have contended that the time of day exerts a more substantial influence on sports performance than athletes' training time routines. However, despite the existing body of research on circadian rhythms and chronotypes, a clear and well-established relationship between daily training time routines and athletic performance, particularly concerning maximal strength performance, remains elusive.

In light of this, it becomes evident that there exists a significant gap in the research literature regarding the intricate interplay between circadian rhythms, chronotypes, and strength performance. Consequently, this topic warrants further comprehensive investigation. Therefore, the principal objective of this study is to elucidate whether maximal strength performance is indeed impacted by the temporal aspects of daily training time routines. The hypothesis of this research is that 'Maximal strength performance in male bodybuilding athletes is influenced by their daily training time routines, with athletes who train during their preferred times of the day (Noon, Afternoon, Evening) demonstrating significantly higher maximal strength compared to those training at non-preferred times'.

Materials and Methods

Participants

The sample size for this research was determined using the G*Power analysis program (version 3.1.9.3, Germany). According to the results of the power analysis (confidence level= 0.95, alpha value= 0.05, beta value= 0.80, and effect size= 0.60) [20], it was determined that a minimum of 12 athletes should be included in each group. A total of 36 male athletes met the inclusion criteria and therefore participated in the study, with three groups designated as Group Noon (n=12), Group Afternoon (n=12) and Group Evening (n=12).

Research Design

This cross-sectional study was conducted following the approval of the Ethics Committee of Inonu University Faculty of Health Sciences (Decision No: 2023/4937) and in accordance with the Helsinki Declaration. Informed consent was obtained from all participants before the research commenced, and they were included in the study after providing their voluntary consent. Participants were divided into three groups based on predefined inclusion criteria. Demographic information, including age, height, and body weight, was collected from all participants. Each group performed the One-Repetition Maximum Squat Test (1-RM) on different days and at different times of the day, with a 72-hour interval between each session. Prior to the 1-RM test, all participants engaged in warm-up activities, including dynamic stretching techniques. The 1-RM performance data was obtained at different time intervals for each group and was recorded and subsequently analyzed. Experimental schematic design is shown in figure 1.

The inclusion criteria are as follows

For all groups, being healthy individuals over the age of 18 and being actively involved in bodybuilding for the last 3 years. In terms of groups, having trained regularly at noon (12:00-14:00) for the last six months for Group Noon, and having trained regularly in the afternoon (17:00-19:00) for the last six months for Group Afternoon, and having trained

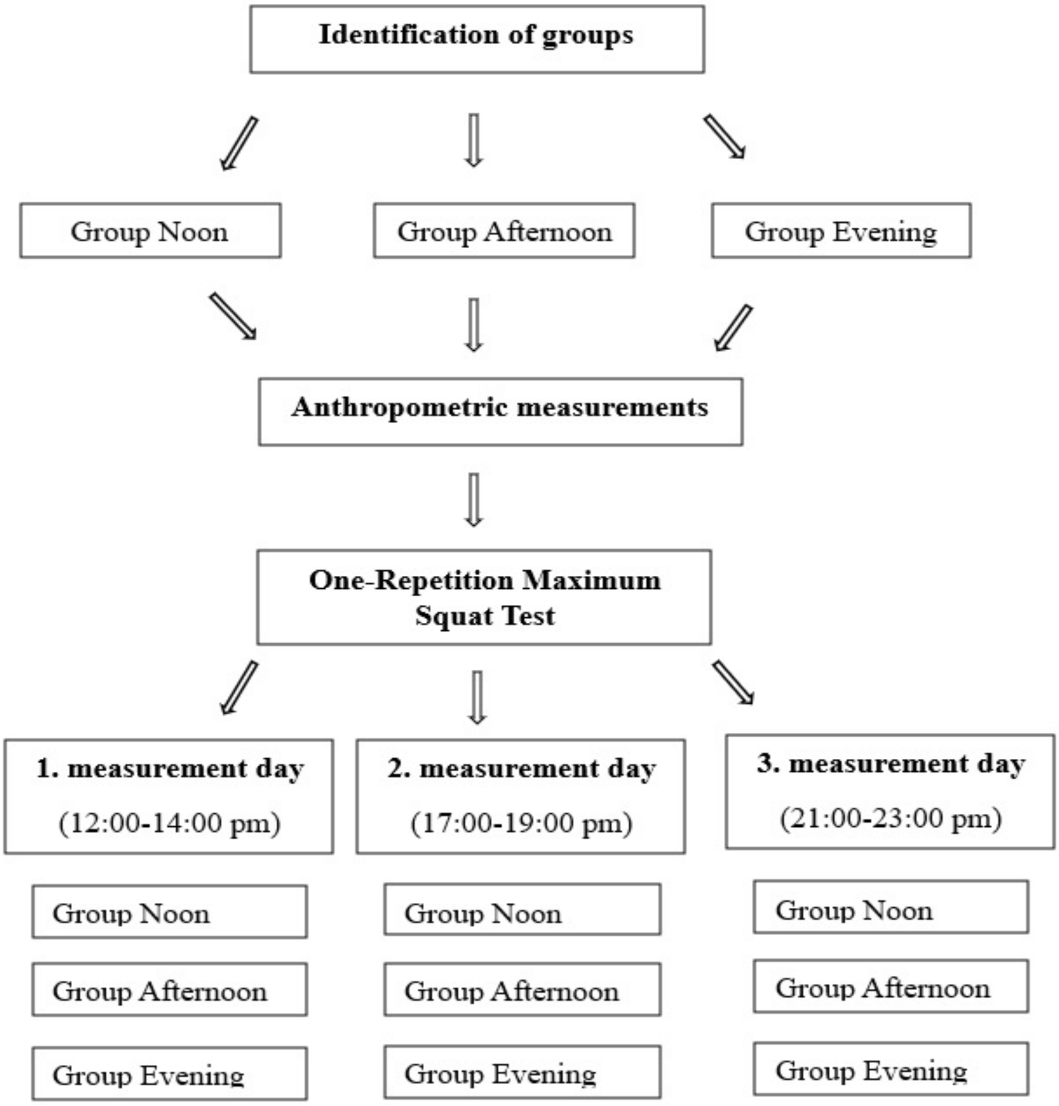

Figure 1. Experimental schematic design

regularly in the evening (21:00-23:00) for the last six months for Group Evening.

Anthropometric measurement

Body mass and height measurements were made in accordance with the ISAK (International Association for the Advancement of Kinanthropometry) protocol [21]. In this context, participants' heights were measured by a wall-mounted stadiometer (Holtain Ltd., England), and their body weights were measured by an electronic scale (Seca, Germany). All measurements were taken between 09:00-09:30 in the morning.

Height measurement: The subject stood upright with his back against a board. The subject's feet were together, and their heels, hips, shoulders, and back of the head were touching the wall. The subject's head was upright and they were looking straight ahead. The stadiometer was gently lowered over the subject's head and recorded in cm after ensuring that it was positioned at the highest point (vertex) [22].

Body Mass Measurement: The subject was in minimal clothing (underwear) and no shoes. The subject stood in the middle of the scale platform and distributed his weight evenly between both feet. The subject hung his hands freely by his sides and looked straight ahead. The subject's body mass was recorded on an electronic digital scale to the nearest 0.1 kg (or 100 grams) [22]. The results of the anthropometric measurements for the participants are presented in Table 1, which displays the mean and standard deviation for each group. Participants were given instructions to refrain from engaging in different types of exercises on the day preceding the measurements, to avoid consuming stimulating beverages such as tea, coffee, alcohol, and carbonated drinks, and to have their last meal at least 2 hours before the measurements were conducted, following the guidelines outlined by Kafkas et al. [23].

Maximal Repetition Squat Test (1-RM)

Prior to the 1-RM test, all participants engaged in warm-up exercises which included dynamic stretching techniques, as outlined by Kafkas et al. [23]. Participants were given the autonomy to select their initial weights for the 1-RM test according to their personal preference. However, it was strongly recommended that the participants commenced the 1-RM test with approximately 30-40% of their body weight, following the guidelines proposed by Baechle and Earle [24]. This precautionary measure was taken to mitigate against the risk of potential muscle injuries occurring during the test. Participants executed the free squat movement with their chosen weights, and additional weight (ranging from 2.5 to 5 kg) was incrementally added based on the lifted weight and perceived level of difficulty, allowing them to perform the movement again. The process of adding weight continued until participants reached the point at which they could no longer complete a single repetition. The test concluded once participants indicated their inability to lift any more weight. All test results were documented in kilograms, in accordance with the procedures described by Kafkas et al. [23]. Each group conducted the 1-RM test on a separate day and at varying time intervals, with there being a 72-hour gap between each session. The squat test was performed using free weights.

Statistical Analysis

The data obtained from the research was analyzed using the IBM Statistics software (SPSS version 26.0, Armonk, NY). To determine the effect of different times of day on 1-MR squat performance, a “Repeated Measures ANOVA” was conducted, and for identifying which time of the day favored performance, multiple comparison tests such as the “Bonferroni” analysis were applied. Mauchly’s Test was used to check the homogeneity of variances, and the Greenhouse-Geisser correction factor was employed for variance correction when necessary. Additionally, “partial eta squared” (ES) was calculated to determine the percentage of the effect size of the time of day on performance.

Results

Table 2 below presents the 1 maximal repetition squat performance values of the participants in terms of different time periods are presented. After analyzing Table 2, it has been determined that there is a statistically significant effect favoring the daily training time routine on the applied 1-RM squat

Table 1. Anthropometric measurement results of the participants on the basis of groups

Groups	n	Parameter	Mean±SD	Range
				Min. Max.
Group noon	12	Age	25.16±2.91	21.00-29.00
		Height (cm)	178.50±5.72	167.00-185.00
		Body mass (kg)	75.50±6.94	60.00-85.00
Group afternoon	12	Age	25.50±2.67	20.00-29.00
		Height (cm)	180.00±7.54	167.00-190.00
		Body mass (kg)	81.00±6.68	70.00-90.00
Group evening	12	Age	26.00±1.80	22.00-29.00
		Height (cm)	173.00±4.80	165.00-180.00
		Body mass (kg)	76.50±5.16	70.00-85.00

Table 2. 1 Maximal Repetition Values of Participants in Different Time Periods

Group	Time	Mean ± SD	F	p	Bonferroni	ES
Group noon	12:00-14:00 (1)	120.41±15.58	77.000	.001*	1>2 1>3	%87
	17:00-19:00 (2)	115.83±15.78				
	21:00-23:00 (3)	115.00±14.11				
Group afternoon	12:00-14:00 (1)	122.29±17.62	35.265	.001*	2>1 2>3	%76
	17:00-19:00 (2)	130.20±16.73				
	21:00-23:00 (3)	123.12±17.90				
Group evening	12:00-14:00 (1)	125.62±10.66	26.455	.001*	3>1 3>2	%70
	17:00-19:00 (2)	127.50±11.77				
	21:00-23:00 (3)	132.50±10.97				

Note:*=p<0.001

performance at different time periods of the day ($p < 0.001$). In this context, it is observed that Group Noon, which featured those who have been training between 12:00-14:00 for the past six months, achieved their highest 1-RM squat performance when they followed their daily training time routine, which is between 12:00-14:00. Similarly, Group Afternoon, those who have been training between 17:00-19:00 for the past six months, achieved their highest 1-RM squat performance when they adhered to their daily training time routine, which is between 17:00-19:00. Finally, Group Evening, those who have been training between 21:00-23:00 for the past six months, achieved their highest 1-RM squat performance when they maintained their daily training time routine, which is between 21:00-23:00.

Discussion

In this study, which aimed to investigate whether the maximal strength performance of bodybuilders was influenced by their daily training time routines, a relationship between maximal strength performance and daily training time routines has been established. Based on the data obtained in the study, it has been statistically determined that the highest 1-RM squat performance in all groups occurred during their respective daily training time routines ($p < 0.001$). It is believed that the reason for the participants achieving their highest 1-RM squat performance during their daily training time routines is associated with their chronotype.

The Morningness-Eveningness Questionnaire (MEQ) scale is commonly employed to assess the chronotypes of individuals [16]. Although the MEQ scale was not utilized in this study, it is noteworthy that the participants had been consistently training at the specified times over the past six months. This can be viewed as an indication that the groups may have distinct chronotypes.

In several studies utilizing the MEQ to determine chronotypes, findings have indicated that individuals with an M-chronotype perceive less effort during strenuous physical activities conducted in the morning, whereas those with E-chronotype and N-chronotype tend to perceive greater effort and experience higher levels of fatigue during morning-intensive sports activities [25, 26, 27]. Additionally, it has been reported that individuals with an E-chronotype produce more torque in the afternoon or evening in comparison to the morning [28]. Vitale and Weydahl [4], in a comprehensive review, noted that individuals with an M-chronotype exhibited higher performance levels in activities such as half marathons and full marathons [29], 2000-m rowing sprints [30], and 200-m swimming trials [27] when compared to individuals with "N" and "E" chronotypes. However, they also emphasized that this trend was not consistently observed during self-paced physical tasks [26] and maximal ergometer tests [31, 32].

While differences in psychophysiological responses to physical activity may be attributed in part to the distinction between objective and subjective variables [4], the mechanisms underlying chronotype remain incompletely elucidated. Nevertheless, it is evident that an individual's daily habitual training time can have an influence on physical performance [27, 29]. The findings from our study similarly support the notion that daily habitual training time can impact physical performance.

Considering the observed variation in the perceived difficulty of exercise amongst individuals with different chronotypes, the capacity to augment training intensity during their preferred time of day may serve as an indicator for enhancing training adaptation specific to that time window [7]. Furthermore, in a study conducted by Brown et al. [30], it was reported that nearly half of the rowing athletes experienced a deviation from their initial chronotypes after three training sessions, which was attributed to the early morning training regimen.

The limitations of this study include the exclusive focus on male bodybuilding athletes, with the absence of female participants. Additionally, the use of self-selected weights by participants, the lack of a standardized test protocol, and the restriction to a specific age range of participants are noteworthy constraints to consider.

Conclusions

As a result of this study, a significant relationship has been established between athletes' daily training time routines and maximal strength performance. Athletes demonstrated their peak performance during their respective daily training time routines. These findings highlight the substantial influence of training session timing on athlete performance, emphasizing the importance for coaches and conditioning experts to plan training schedules in alignment with competition times. Future studies should consider expanding participant group sizes, to include female athletes, and to assess the chronotypes of participant groups. Furthermore, it is advisable for future research in this field to encompass diverse sports disciplines and to customize investigations to target various athletic performance parameters.

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ORIGINAL ARTICLE

Swim start and performance in 50 m freestyle in different age categories of competitive swimmers

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim	In international races, the winners are decided by hundredths of a second, which is why the swim start plays an important role, especially in the sprint disciplines. The aim of the study is to reveal the differences in kinematic parameters of start and performance in the sprint 50 m freestyle discipline based on gender in different age categories of competitive swimmers at international competitions organized in Slovakia.
Material and Methods	The sample consisted of 180 females and 189 males who were divided into age categories (K1, K2, K3). SwimPro cameras and Dartgish software were used to monitor kinematic parameters. The parameters monitored were - block time (BT), time (FT) and distance (FD) of flight, time (UWT) and distance (UWD) underwater, time to 15 m (T15), 25 m (T25) and 50 m (T50). Data were tested by Shapiro-Wilk, Kurskal-Wallis ANOVA and Mann-Whitney U test in Statistica 13.5.
Results	In the phase above water level, there were greater differences ($p<0.01$) in females than in males. Inter-sex differences ($p<0.01$) were evident in FT in K3, K2 and in FD across all categories. In the underwater phase, differences ($p<0.01$) were evident in both sexes. Inter-sex differences were more evident in UWT ($p<0.01$) than UWD ($p<0.05$). There were inter-sex differences ($p<0.01$) in ST and SD between all categories except K3. At T15, T25 and T50, differences ($p<0.01$) were most pronounced between K3 and K2, K1 in females and between all categories in males. Inter-sex differences ($p<0.01$) were also evident across all categories.
Conclusions	The study highlighted differences in 50m freestyle start and performance between age groups and gender, so coaches are advised to design training sessions for swimmers separately.

Keywords: kick start, kinematic analysis, sprint swimming, biomechanics

Introduction

All winners in sprint events need to have the best possible starts, free swimming, turn and finish. Therefore, swimmers need to be continuously analysed, for example using video, to receive relevant information about their performances [1, 2, 3] More studies have focused on track swimming as an acyclical movement such as a start or a turn [2, 4, 5], but there are also studies that have addressed these phases [6, 7, 8].

The 50 m sprinting event should be considered as a whole, a performance that involves many variables that contribute to the success of the sprinter [9]. It is therefore a multifactorial performance. From this point of view, the start is one of the essential phases of any sprinter's discipline, as the other phases will depend on this phase. The start can be characterized as the time from the sounding of the sound signal until the swimmer crosses the 15 m distance with the head [10, 11]. One of the key parameters of the 15 m start is the horizontal take-off velocity (81%). The parameter should be paid attention to by coaches and swimmers [10], yet all parameters that contribute to the performance in the start should be monitored. Some studies have also looked at various changes on the starting block such as changing the back support or the position of the centre of gravity on the starting block. Others have focused on the preferred or dominant lower limb on the front edge of the starting block or the width of the stance. Each of these studies showed some results that were particularly valid for elite swimmers, as they were the study population in most of the studies. The flight phase accounted for 65% of the 5 m start distance performance, with the key parameters being the angle of the kick-off and the time to 2 m distance [11]. At 15 m distance, this phase contributed 5% [10]. During this phase it is important to note that the swimmer's body already has some momentum. Swimmer starts to flex in the pelvis and enter the water. It means that the body is transitioning from air to liquid where it starts to have water resistance. Therefore, the angle of entry is very important [12, 13]. In a study by [14], the entry angle has been shown to affect the phase of gliding,

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its depth, and the average velocity of the phase underwater. When entering the water, swimmers perform a butterfly kick just before their feet are submerged in the water [15]. Other studies [16, 17, 18] point out the optimal phase of gliding, which can be divided into the gliding phase and the first strokes until the swimmer begins to swim above the water surface [19.20]. In a study by [21], they compared three levels of underwater trajectory below the water surface. Results revealed that swimmers should swim longer and perform their first kick slightly later, at 6.6 m when reaching a depth of -0.92 m. It resulted in minimizing the loss of velocity during the underwater phase. [19] reviewed studies dealing with the underwater undulatory swimming cycle. Information about the determinants of underwater undulatory swimming cycle performance was inconsistent due to inconsistencies in the definition of kinematic parameters. The swim phase up to 15 m distance (start) accounts for 28% of the total time for this distance [10]. Previous knowledge suggests that with a shorter swim phase, swimmers perform better in the start [22]. From the perspective of competitive swimming at top events where swimmers compete against each other in individual sprint events, we can see minimal difference in performance between competitors [2, 23, 24, 25]. Nevertheless, the short duration induces, and the maximum intensity induces a decrease in velocity over the entire track [26]. For example, some results from the 2021 European Championships show increasing performance in the 100 and 200 m events from heats to finals [27]. Authors suggest that swimmers were saving their energy for the finals, where the medal is already decided, as opposed to heats [25]. Inter-sex differences were found at the 2016 European Championships. In the freestyle, men were faster ($p<0.05$) compared to women in the start (start reaction time, flight time, under water time, time to 15 m). A similar pattern was observed at the 2021 European Championships in Budapest [25].

Most studies have focused on elite swimmers. From our point of view, studies should also look at the performance of swimmers in different age categories. Therefore, the aim of the study is to reveal the differences in kinematic parameters of start and performance in the sprint 50 m freestyle discipline. Differences are based on gender in various age categories of competitive swimmers at international competitions organized in Slovakia. It was hypothesized, that start and swim performance would improve over the age categories, and that these changes would be a consequence of the improvement in the start and swim performance variables.

Materials and Methods

Participants

The sample of 180 female swimmers was divided according to age categories as follows - K1 - year of birth 2007 and older, K2 - year of birth 2008 and 2009 and K3 - year of birth 2010 and 2011. The swimmers were mainly from the Slovak Republic, Czech Republic, Estonia, and Ukraine. The pool of 189 swimmers was divided into categories K1 - year of birth 2006 and older, K2 - year of birth 2007 and 2008 and K3 - year of birth 2009 and 2010. The swimmers were mainly from the Slovak Republic, Czech Republic, Estonia, Luxembourg, and Ukraine (Table 1).

Research Design

The monitored event was the 50 m freestyle event at the Orca Cup in Bratislava 05.-07.05.2023. The pool was an 8 lane, 50 m with a lane width of 2.5 m. There was also a warm-down swimming pool available, which was in the next building. The timing was electronic - SwissTiming Quantum Aquatics.

At the start of the day everyone had a warm-up swimming according to the categories K3 - 7.50 - 8.10am, K2 - 8.10 - 8.30am and K1 - 8.30 - 9.00am. Warm-up swimming was for both sexes. The 50m freestyle was the first event on the schedule (06.05.2023) and was divided into 25 women's and 24 men's heats according to performance, which were swum consecutively. Thus, a total of 369 starts were made. One female and one male from the K3 category were disqualified. Starts were taken from OSB 11 start blocks, which were linked to the SwissTiming Quantum Aquatics system. A SwimPro camera system was used to measure kinematic parameters. The camera system was located above the water surface. The first camera was at 1.6 m, the second at 10 m, the third at 15 m and the fourth at 25 m from the pool wall where the start blocks are located. All cameras were at a height of 4.5 m. The pool was illuminated by halogen bulbs. The camera system operated at 50Hz with a shutter speed of 1/1000 s. The phases monitored were the above-water, underwater and swim phases on the track. The kinematic parameters monitored were above-water phase - block time, flight time, flight distance;

Table 1. Characteristics of the research sample

Participant characteristics	Female			Male		
Categories	K1	K2	K3	K1	K2	K3
n	57	64	59	56	68	65
Entry time (s)	33.78±4.12	30.69±2.10	30.32±4.50	31.29±2.94	27.93±2.20	25.19±1.45

underwater phase - underwater time, underwater distance (gliding and first swimming strokes); swim phase - time to 15 m; time to 25 m; time to 50 m (Table 2).

Parameters such as start reaction at the starting block and time to 50m were provided by the event organisers and resulted from the SwissTiming Quantum Aquatics electoral system for swimming. All resulting 50 m distance times are available on the internet either on the swimrankings [28]. To assess kinematic parameters, we used Dartfish software (Dartfish ProSuite 4.0, Switzerland), which meets all validity and reliability criteria for measuring kinematic parameters recorded in 2D space [29, 30].

Statistical analysis

We used the Shapiro-Wilk test to assess the normality of the observed selected kinematic variables in each category. We assessed the significance of differences in the observed launch and 50 m power parameters between the K1, K2 and K3 categories using the Kruskal-Wallis ANOVA test. Differences between sexes in the individual K1, K2 and K3 categories were assessed by the Mann-Whitney U test. Tests were assessed at 1% ($p<0.01$) and 5% ($p<0.05$) levels of statistical significance. Statistics were processed using Statistica 13.5 software.

Results

The men percentage contribution of start phases

The above-water phase accounted for 12-14% of the total start (15 m distance), depending on gender and category. For females, BT and FT accounted for 9% and 3% on average, respectively. For men, BT accounted for an average of 10% and FT 4%. The phase underwater accounted for 41% and 42% of the start for women and men, respectively. The swim phase accounted for 47% of the start in women and 44% in men (Table 3).

Above-water phase – block and flight phase

In the female category, the shortest BT was in the K1 category. FT was the shortest in the K3 category, while the largest FD was registered in K1. Significance of differences ($p<0.01$) between female categories was evident in BT between K3-K1 and FD between K3 and K2-K1 categories. For males, the results above-water level was the same. The shortest BT was in the K1 category. FT was the shortest in the K3 category, while the largest FD

Table 2. Detailed description of the above-water, underwater and swim phases parameters

Phase	Variables		Definition
Above-water	Block time (BT)	(s)	The time from the sounding of the starting signal to the swimmer's feet leaving the starting block at the rebound.
	Flight time (FT)	(s)	The time from the time the swimmer's feet leave the starting block at the rebound to the first contact of the swimmer's hands with the water surface.
	Flight distance (FD)	(m)	The distance from the time the swimmer's feet leaves the starting block at the rebound to the first contact of the swimmer's hands with the water surface.
Underwater	Underwater time (UWT)	(s)	The time of the first contact of the swimmer's hands with the surface of the water until the swimmer's head breaks the surface of the water.
	Underwater distance (UWD)	(m)	The distance of the first contact of the swimmer's hands with the surface of the water until the swimmer's head breaks the surface of the water.
Swim	Swim time to 15 m (ST)	(s)	The time of the swim from the time the swimmer's head crosses the surface of the water until the swimmer's head has again crossed the 15 m distance
	Swim distance to 15 m (SD)	(m)	The distance of the swim from the time the swimmer's head crosses the surface of the water until the swimmer's head has again crossed the 15 m distance
	Time to 15 m (T15)	(s)	The time from the sounding of the start signal until the swimmer's head has crossed the water surface at the 15 m distance.
	Time to 25 m (T25)	(s)	The time from the sounding of the start signal until the swimmer's head has crossed the water surface at the 25 m distance.
	Time to 50 m (T50)	(m)	The time from the sounding of the start signal until the swimmer's head has crossed the water surface at the 50 m distance.

was registered in K1. Significance of differences (p<0.01) between categories was only evident in FD and this was between all categories. There were no inter-sex differences in the K3-K1 categories in BT. In FT, inter-sex differences (p<0.01) were evident in K3 and K2. In FD, there were inter-sex differences (p<0.01) between all categories (Table 4).

Underwater phase

The longest UWT and UWD in females were observed in the K1 category. Significance of differences (p<0.05) in UWT was observed between the K3-K1 and K2-K1 categories. Significance of differences (p<0.01) in UWD was observed between the K3 and K2-K1 categories. In males, K2 achieved

Table 3. Percentage of phases at the start of both gender in K3-K1

Phases	Variables	Categories	Female		Male	
			%	∑%	%	∑%
Above-water	BT (s)	K3	9		9	
		K2	9	9	10	10
		K1	9		11	
	FT (s)	K3	3		3	
		K2	3	3	4	4
		K1	3		5	
Underwater	UWT (s)	K3	37		34	
		K2	40	41	44	42
		K1	46		47	
Swim	ST (s)	K3	52		53	
		K2	48	47	42	44
		K1	41		37	

Note: BT – block time; FT – flight time; UWT – underwater time; ST – swim time to 15 m; s - second

Table 4. Kinematic parameters of start and performance in females and males 50 m breaststroke

Variables	Sex	Categories	M	StD	Shapiro-Wilk test		Kruskal-Wallis test		Mann-Whitney U test	
					W	p	H	p	U	p
BT (s)	F	K3	0.75	0.11	0.97	0.21	8.3	K3-K1**	K3FM 1470.00	n.s.
		K2	0.71	0.10	0.98	0.22				
		K1	0.69	0.08	0.98	0.45			K2FM 2019.00	n.s.
	M	K3	0.71	0.13	0.97	0.07	4.68	n.s.		
		K2	0.71	0.09	0.98	0.22			K1FM 1572.00	n.s.
		K1	0.68	0.06	0.96	0.05				
FT (s)	F	K3	0.23	0.08	0.99	0.79	2.17	n.s.	K3FM 1046.00	**
		K2	0.25	0.07	0.99	0.73				
		K1	0.24	0.07	0.98	0.52			K2FM 1588.00	**
	M	K3	0.27	0.08	0.99	0.72	0.34	n.s.		
		K2	0.29	0.08	0.96	0.04			K1FM 1834.00	n.s.
		K1	0.31	0.07	0.98	0.36				
FD (m)	F	K3	2.72	0.17	0.80	0.00	22.02	K3-K2** K3-K1**	K3FM 181.00	**
		K2	2.80	0.11	0.98	0.17				
		K1	3.21	2.02	0.21	0.00			K2FM 468.50	**
	M	K3	2.93	0.11	0.96	0.04	57.29	K3-K2** K3-K1** K2-K1**		
		K2	3.04	0.19	0.89	0.01			K1FM 487.00	**
		K1	3.25	0.28	0.90	0.00				

Count. Table 4.

Variables	Sex	Categories	M	StD	Shapiro-Wilk test		Kruskal-Wallis test		Mann-Whitney U test	
					W	p	H	p	U	p
UWT (s)	F	K3	3.16	0.91	0.97	0.09		K3-K1*	K3FM 987.00	**
		K2	3.14	0.76	0.93	0.00	7.79	K2-K1*		
		K1	3.56	1.19	0.74	0.00			K2FM 2138.00	**
	M	K3	2.72	0.75	0.94	0.00		K3-K2**		
		K2	3.14	0.71	0.96	0.03	14.25	K3-K1*	K1FM 1364.00	**
		K1	2.96	0.50	0.99	0.85				
UWD (m)	F	K3	5.47	1.59	0.98	0.27			K3FM 1181.00	*
		K2	6.28	1.47	0.97	0.37	19.76	K3-K2** K3-K1**		
		K1	6.51	2.75	0.72	0.00			K2FM 1702.00	*
	M	K3	5.12	1.51	0.96	0.03		K3-K2**		
		K2	6.81	1.49	0.97	0.09	64.76	K3-K1**		
		K1	7.52	1.09	0.94	0.01		K2-K1**	K1FM 1684.00	n.s.
ST (S)	F	K3	4.41	1.16	0.97	0.16			K3FM 1785.00	n.s.
		K2	3.76	0.91	0.15	0.00	29.81	K3-K2** K3-K1**		
		K1	3.17	1.29	0.87	0.00			K2FM 1538.00	**
	M	K3	4.24	0.93	0.96	0.03		K3-K2**		
		K2	2.95	0.90	0.98	0.46	87.54	K3-K1**		
		K1	2.35	0.69	0.99	0.96		K2-K1**	K1FM 719.00	**
SD (m)	F	K3	6.79	1.66	0.97	0.19			K3FM 1865.00	n.s.
		K2	5.92	1.48	0.19	0.00	23.02	K3-K2** K3-K1**		
		K1	5.27	1.61	0.97	0.29			K2FM 1085.00	**
	M	K3	6.95	1.53	0.96	0.03		K3-K2**		
		K2	5.15	1.52	0.96	0.07	72.33	K3-K1**		
		K1	4.23	1.12	0.96	0.09		K2-K1**	K1FM 954.00	**
T15 (s)	F	K3	8.55	1.03	0.92	0.01			K3FM 95.50	**
		K2	7.86	0.52	0.95	0.01	37.96	K3-K2** K3-K1**		
		K1	7.66	0.63	0.95	0.02			K2FM 790.50	**
	M	K3	7.95	0.70	0.97	0.35		K3-K2**		
		K2	7.09	0.66	0.96	0.02	107.31	K3-K1**		
		K1	6.31	0.41	0.97	0.26		K2-K1**	K1FM 1239.00	**
T25 (s)	F	K3	15.10	1.50	0.9	0.00			K3FM 72.50	**
		K2	13.73	1.75	0.53	0.00	39.04	K3-K2** K3-K1**		
		K1	13.67	1.01	0.94	0.01			K2FM 701.00	**
	M	K3	14.02	1.12	0.98	0.23		K3-K2**		
		K2	12.55	0.98	0.96	0.02	110.55	K3-K1**		
		K1	11.38	0.65	0.97	0.21		K2-K1**	K1FM 1171.00	**
T50 (s)	F	K3	33.67	3.54	0.91	0.01			K3FM 124.00	**
		K2	30.80	1.90	0.91	0.00	43.47	K3-K2** K3-K1**		
		K1	30.24	2.24	0.95	0.01			K2FM 498.50	**
	M	K3	30.93	2.70	0.97	0.16		K3-K2**		
		K2	27.76	1.88	0.96	0.03	101.94	K3-K1**		
		K1	25.56	1.90	0.82	0.00		K2-K1**	K1FM 1074.50	**

Note: M – mean, StD – Standard deviation; BT – block time; FT – flight time; FD – flight distance; UWT – underwater time; UWD – underwater distance; ST – swim time to 15 m; SD – swim distance to 15 m; s – second; m – meter; F – female; M – male; K1-K3 – category the longest UWT. The longest UWD was achieved by the K1 category. Significance of differences (p<0.05; p<0.01) in UWT was evident between the K3-K1 and K3-K2 categories. Significance of differences (p<0.01) in the parameter was evident among all parameters. Inter-sex differences (p<0.01) in UWT were evident in each category. In UWD, inter-sex differences (p<0.05) were evident in K3 and K2 categories (Table 4).

Swim phase

The shortest ST and SD in females were registered in the K1 category. This category also obtained the shortest time in T15, T25 and T50. Significance of differences (p<0.01) was evident in ST between all categories and in SD between K3 and K2-K1. Significance of differences (p<0.01) was evident in T15, T25 and T50 between K3 and K1. In men, results were similar between categories. The shortest ST and SD were registered in the K1 category. The K1 category also achieved the shortest time at T15, T25 and T50. In all parameters in male swim phase, we observed significant differences (p<0.01) between all studied categories. There were no sex differences in K3 categories in ST and SD. In K2 and K1 differences were significant (p<0.01). At T15, T25 and T50, inter-sex differences (p<0.01) were evident in all categories (Table 4).

Discussion

Currently, the swimming rules do not allow for repeated starts. All swimmers start on the starting signal and a swimmer who starts early or makes a move on the starting block before the starting signal is disqualified [31]. Therefore, in swimming and especially in sprint events where hundredths of a second are decisive, it is necessary to have mastered all phases. Improving one phase in the 50 m sprint, or any of the determining parameters, could be decisive for finishing positions or medals [32]. The fastest 50 m freestyle sprint takes approximately 20-21 s for men and 23-23.5 s for women, depending on the length of the pool [33]. From this perspective, it is a very short time duration of the individual phases, where optimisation of the phases is necessary for the best performance. As mentioned above, most of the studies have focused on elite swimmers, while from our point of view, studies should also look at the performance of swimmers in different age categories. The aim of the study is to reveal the differences in kinematic parameters of start and performance in the sprint 50 m freestyle discipline based on gender in different age categories of competitive swimmers at international competitions organized in Slovakia.

Each start begins with a kick start from the starting block and can be characterized as a distance up to 15 m [10, 11]. This phase in swimming is specific and differs from other phases. The swimmer is in the air (the start block phase and the flight phase), where after jumping off the start block, he enters the water. In the phase above the water surface the swimmer's body reaches the highest acceleration. In terms of the percentage of duration of each start phase, the above-water phase contributes the least (12-14%) compared to the underwater phase (41-42%) and the swim phase (44-47%), depending on sex and age category. In general, it can be stated that the underwater and swim phases are more involved in the performance in the start because these phases have a longer duration than the above-water phase. We compare our results with the study by [10], where elite swimmers, Olympic Games and World Championship participants were assessed. The difference was 1% in the proportion of BT, 1% in FT in the above-water phase, 13-14% in the underwater phase, and 16-19% in the swim phase. The differences underwater are mainly due to the longer underwater phase, compared to our research sample, which had a longer swim phase. All these differences were also due to the age categories, as for example in the K1 male and female category the differences were smaller. The difference in K1 females was 2% in the BT, 1% in the FT in the above-water phase, 6% in the underwater phase and 8% in the swim phase. For men, the 1% difference in BT and FT was the same in the above-water phase, and the 14% difference was in the underwater and swim phases.

Performance in kick start, block time was shorter in the K1 category for both sexes, with significance of differences only in females between the youngest K3 and the oldest K1 category. All categories had faster BT (e.g., females K1 0.08s; males 0.04s) than in the study by [10]. The differences could also be due to the readiness of the competitors to perform only one start and not repeated starts as in the study by [10, 34, 35] and others. Also, in other studies [35, 36, 37, 38] where laboratory research on swim starts was conducted, male and female swimmers achieved longer BT. On the other hand, results from the 2016 European Championships also show a longer BT compared to our study [26], where the start conditions were the same as in our study. On the other hand, at the European Championships in Budapest in 2021, both men and women had a faster BT compared to our oldest K1 category [25]. In the above studies, but also in ours, the finding that males achieved faster BT than females were confirmed, although the differences were minimal. We think that behind the faster BT, there may be an increasing number of new OSB start blocks or their imitations every year. In Slovakia, the number of pools where swimmers can perform kick start has increased. It may also help the training process in the start.

In the FT phase of the flight, times in the K1 category for men and women were similar with other studies, either dealing with kinematic analysis in laboratory conditions [10, 34, 35, 39] or directly at the race [2, 25]. The longer duration of male and female FT was also reflected in longer distance in FD, with inter-sex differences ($p<0.01$) demonstrated in every category except the K1 category in FT. The same inter-sex differences in flight phase parameters in the K1 category were found in the [10].

In the underwater phase, our swimmers achieved longer UWT and UWD in the older categories compared to the younger ones ($p<0.05$; $p<0.01$), with males achieving longer UWT and UWD than females. Greater significance of inter-sex differences ($p<0.05$; $p<0.01$) was evident in UWT than UWD. Inter-sex differences were also evident underwater in the butterfly kickers in the study by [20]. At the 2016 and 2021 European Championships, swimmers still achieved slightly longer UWT and UWD compared to our oldest K1 male and female categories. For elite Australian swimmers, the values were even greater [10]. In a study by [39], 4 parameters (FD, average speed between 5 m and 10 m distance, maximum hip depth) were shown to be suitable predictors of optimal gliding that should be addressed by coaches and swimmers. In the swim phase, the older categories achieved shorter ST and SD, with males achieving shorter values ($p<0.01$) than females, except for inter-sex differences in the K3 category. The T15, T25 and T50 performances were achieved with shorter times in the older K1 categories, with inter-sex differences ($p<0.01$) in favour of males in all categories. Other studies [2, 10, 25] have also confirmed inter-sex differences. In a comparison of start times between the 100 m swimming modes at the 2016 European Championships, men achieved shorter start times in the butterfly compared to the freestyle, with no significance of differences confirmed. The women had the fastest start in the freestyle and then in the butterfly. The significance of the differences between freestyle and butterfly was not confirmed here either. Similar values were also measured at the European Championships in 2021. However, in the T25 and T50 the values were already in favour of the freestyle over the butterfly for both sexes [25].

To optimize the kick start in the 50 m freestyle discipline, it is currently necessary to use available methods, such as a camera system, which can be used to evaluate the above and underwater phases and the swim phases individually (depending on age and gender) and thus get relevant information about the start and performance that can be used to adjust the correct training, which can result in an improvement of the 50 m freestyle time.

Conclusions

Evaluating the kinematic analysis of the sprinters' starts directly from the race can help not only coaches but also swimmers in each category. An important part of the evaluation is the inter-sex differences. In terms of the percentage of each phase at the start in the men's and women's 50m freestyle, the underwater phase and the swim versus the above-water phase proved to be longer lasting. In the above-water phase, we found significant differences ($p<0.01$) especially between the K3-K1 categories in the FD, as well as inter-sex differences. The results suggest that we recommend performing this phase separately.

Similar findings were in the underwater phase. We recommend coaches to lead the underwater training process based on age categories and gender. The reason for this recommendation is that the oldest K1 category achieved longer UWT and UWD compared to the youngest K3. In the swim phase, we observed the largest differences ($p<0.01$) between the K3-K1 category in both males and females, therefore we do not recommend a shared training process for this phase. In contrast, there were no significant inter-sex differences in the K3 category, therefore we think that this category could perform this phase together.

Significant differences were also evident at T15, T25 and T50 between all categories and gender. The largest differences ($p<0.01$) were again between the K3-K1 categories for both males and females, so here again the training process should be approached separately.

All the above differences of swimmers are to some extent caused by sport age in each category, gender differences, technical level, etc. Based on the above results, we recommend approaching the improvement of start and performance in 50 m freestyle separately using kinematic analysis, which will allow to optimize the performance.

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ORIGINAL ARTICLE

High-intensity interval training on unstable vs stable surfaces: effects on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics

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Abstract

Background and Study Aim	This study compares the effects of high-intensity interval training (HIIT) on unstable and stable surfaces on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics.
Material and Methods	A nonrandomized trial study was conducted on twenty-seven well-trained male vault players who were assigned into 3 equal groups, a HIIT unstable group (UG), a HIIT stable group (SG), and the control group (CG). The training period for the subjects lasted eight weeks, with 3 sessions each week. All of the aforementioned variables were assessed both before and after the training period.
Results	The main findings indicate that both UG and SG showed greater improvement than the CG on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics (ES= 0.52 to 0.68, P<0.05). In addition, there were significant differences between the UG and SG in explosive strength, balance and Tsukahara vault performance (P<0.05) favoring UG, while no significant differences between UG and SG in agility. However, the UG as compared to the SG in agility had only limited additional effects. The UG and SG significantly increased all tests from pre- to post-test (ES= 1.10 to 4.78, 0.98 to 3.53), respectively (P<0.05). The CG significantly increased the explosive strength and Tsukahara vault performance tests from pre- to post-test ((ES= 0.77 to 0.78, P <0.05), while there were no significant differences in the balance and agility tests (P > 0.05).
Conclusions	HIIT with unstable surfaces can be used as an alternative method to improve explosive strength and balance. Also, it can be used alongside stable surface exercises when developing agility.

Keywords: HIIT, bosu ball, functional training, exercise, artistic gymnastics.

Introduction

Tsukahara vault, one of the vaulting skills in artistic gymnastics, is depended on a complicated movement structure and a high level of effort that can be performed in a short period [1, 2]. A Tsukahara vault consists of a faster run, a springboard take-off, a first-quarter turn in the pre-flight phase, a push-off from the vault table followed by a Corbett action, and a salto with longitudinal/transversal turn [1, 3]. Preparation for this vault includes, in addition to technical training, a substantial part of physical training [1]. To achieve an improvement in sports performance, It is critical to comprehend the relationships that are established between the various components of speed and strength during sprints or jumps [4]. The literature has indicated gymnasts must possess sufficient explosive strength to execute the various needed jumping skills while keeping body control [5, 6]. Others confirmed that the acrobatic elements depend on the development of explosive strength, which is why it is a crucial criterion in the selection model for these sports [7]. It refers to the jumps as an example of the lower limbs' explosive strength and the throw of the apparatus as the explosive strength of the upper limbs [8]. Hence, the dominant element in the Tsukahara vault performance is explosive strength, because, if its level is not sufficiently high, athletes are not able to correctly perform certain technical elements [1].

The Tsukahara vault movement relies not only on explosive strength but also on balance and agility [1, 2]. Balance entails the synchronization of many body muscles as well as the integration of sensory information [9]. Depending on the physical demands and circumstances of each sport, athletes must meet varying balancing criteria [10]. When athletes do a vault, they face situations where their balance changes with every move. In addition, agility is very important for completing the technical stages

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that the player goes through while performing the Tsukahara vault quickly and with high efficiency. So, balance and agility are very critical for enhancing Tsukahara Vault performance, minimizing injury risk, and achieving higher sports scores.

A sort of physical activity known as high-intensity interval training (HIIT) alternates short bursts of intense exercise with active recovery or rest intervals. According to the literature, many sports employed it in their training regimens, including cyclists [11], swimmers [12], Middle-distance runners [13], badminton players [14], and taekwondo players [15]. All of them have proven efficient in improving physical abilities compared to traditional training.

Bosu, which stands for "both sides utilized," is a gym tool that enhances the strength and stability of muscles. It has an air-filled hemisphere and a level surface [16]. The two guiding principles of bosu ball training are time efficiency during the up/down movement and left and right-side balancing. Enhancing these two essential skills contributes to improving the efficiency of all movements [17]. Research has demonstrated that training on moving surfaces causes an increase in resistance because of higher neuromuscular load tension. This could lead to improvement in Muscle strength and neuromuscular coordination [18]. Recently, the bosu ball has grown in popularity among medical and fitness personnel. Injury rehabilitation [19], rehabilitation after surgery [20], core strength [21, 22, 19], trunk stability, burning cardio, physical and physiological parameters [23], balance [24], accuracy [25], growth hormone and building muscle and EMG activity [22, 26] are all aspects of bosu ball training study that have piqued the interest of many scholars.

On the other hand, numerous studies have compared the effect of the Bosu ball with other unstable surfaces on the balance and strength of the core muscles. for example, a wobble board [27], a swiss ball [28], and balance disc [29]. All showed the same improvement or increase in bosu ball training. Very few studies have focused on the effect of BOSU balls in sports that require excellent explosive strength, balance, and agility. For example, the training performed with a bosu exercise and wobble board had significant improvements in dynamic balance and core stability in recreational runners [27]. Another research found that the Bosu ball training after 6 weeks helped increase male football players' single-leg hop distance and vertical jump height [30]. An improvement in balance and accuracy was observed after 18 circuit training sessions with bosu ball in archery athletes aged between 14-17 years [25]. Simec et al. reported that 10-week balance training improved explosive strength in physically active men [31]. The bosu ball serves a vital role in increasing balance and functional fitness in the elderly population [32]. Another study discovered that training with a balancing disk and a bosu ball enhanced the strength of both the plantar flexor and ankle dorsiflexor muscles in sedentary children after 8 weeks [29].

To our knowledge, the literature has not determined whether HIIT on unstable or stable surfaces is more efficient for gymnasts, and which one is best suited to improve explosive strength, balance, agility, and Tsukahara vault performance. It is crucial to choose the training that is most beneficial for gymnasts. Thus, the goal of this study was to compare the effects of HIIT on stable and unstable surfaces on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics.

Materials and Methods

Participants

The Participants consisted of Twenty-seven male vault players selected from Portsaid gymnastics region Clubs. Before beginning the study, they had received extensive training in the Tsukahara vault skill. Following that, they were divided into three equal groups: a control group (CG), a HIIT unstable group (UG), and a HIIT stable group (SG). Each participant had to meet the following three requirements: (i) be able to perform the Tsukahara vault with proficiency; (ii) be willing to engage in the training and continue it; and (iii) have no musculoskeletal problems or preexisting disease that would affect their ability on performance. The procedures and goals of the study were explained to the participants. Before the pre-test, each participant filled out a written consent form. The study was approved by Portsaid University (code: 202314013). The subjects' equivalence is described in Table 1.

Table 1. General characteristics of subjects (mean ± SD) and p-value between groups.

Groups / Variables	unstable group (n=9)	Stable group (n=9)	control group (n= 9)	F	P value	Sig
	Mean ± SD	Mean ± SD	Mean ± SD			
Height (cm)	164.44± 5.96	164.67± 4.69	163.11± 7.25	0.174	0.842	NS
Body mass (kg)	54.67± 6.60	55.22± 5.80	56.11± 7.17	0.111	0.895	NS
Age (year)	16.11± 0.93	16.22± 0.97	16.00± 0.87	0.130	0.878	NS

n = sample size; NS= No statistically difference between groups

Research Design

Using pre-and post-tests, the authors performed a nonrandomized trial investigation on three groups: UG, CG, and SG. This investigation was split into 4 phases: (i) Phase 1 consisted of a one-week preliminary study meant to acquaint the candidates with the tasks and examinations. Furthermore, during this stage, the validity of the instruments and tests employed in the research was confirmed. Demographic data was collected at the familiarization meetings; (ii) a week of pre-testing was part of Phase 2; (iii) participants completed eight weeks of training in Phase 3; and (iv) a week of post-testing was part of Phase 4. The pre-test and post-test procedures were the same protocol.

Testing procedures

Pre- and post-tests were administered to all participants before and after eight weeks of intervention. The individuals were requested to abstain from caffeine-containing beverages and to refrain from exercising for 48 hours before the test. Moreover, abstain from heavy meals for a few hours before the tests. Three separate sessions for pre-testing were held at 48-hour intervals. Two tests were administered during the first session: the medicine ball throw test and the vertical jump test. The star excursion balancing test and the handstand test were the two assessments conducted in the second session. The gymnastics-specific shuttle run test and the Tsukahara vault performance test were the two assessments that were conducted during the third session. The tests were spaced 45 minutes apart. Low-intensity workouts, such as stretching and jogging, were done for ten minutes to warm up before the tests started. The following procedures were followed when conducting the tests:

The lower limbs' explosive strength was evaluated using the vertical jump test (VJT). The gymnast applies a thick layer of chalk on his fingertips before the jump test to take precise measurements. The gymnast performs a vertical jump with both legs while standing with his dominant side toward the wall, marking a chalk mark on the wall at the top of his jump. The jump needs to be executed by evenly pushing off from both lower limbs. After the jump, the gymnast stands flat-footed with the dominant side facing the wall, reaching directly overhead to touch the wall and make a chalk mark at the highest point. The examiner uses a tape measure to measure and record, to the closest centimeter, the distances between the tops of the two chalk markings in a line perpendicular to the floor. This test is credible and legitimate field-based [33, 34, 35].

The medical ball throw test (MBTT) was designed to measure the upper limbs' explosive strength. The participants' backs are pressed up against a wall as they sit on the floor with their legs completely stretched. Using both hands, the sitting participants propel the medicine ball explosively from their chest as far forward as they can at a 45-degree angle. The score was determined by measuring the distance between the front of the sitting line and the ball's landing place. To the closest centimeter, the measurement is recorded. A three-kg medicine ball is used to perform three measurements for these tests. The measurement with the best results out of the three will be considered. This field-based test is regarded as credible and genuine [36, 37].

The head-down inverted balance was evaluated using the handstand test (HST). On a low beam, the participants begin the handstand with their hands comfortably apart. When a gymnast reaches the handstand, timing starts, and timing ends when any other part of their body contacts the floor. If one of their hands deviates from their starting positions, timing also comes to an end. Time is expressed to the closest 0.01 second. This test consists of two trials for the participant, and the longest time will be used to determine the score. This test is credible and legitimate field-based [33, 34, 38].

The star excursion balance test (SEBT) was used to assess balance and muscular control. Testing should be conducted with subjects either barefoot or wearing gymnastics slippers. The dominant foot, or stance foot, should be positioned so that the great toe lines up with the grid's anteriorly projected line and the heel lines up with the grid's center. The participants are instructed to maintain a single-leg stance on the stance leg while extending as far as possible down the designated grid line with the opposite lower limp-to-toe touch. The participant then returns to the bilateral stance. The examiner marks the place where the participant touched it and measures it manually with a measuring tape. This procedure is repeated on all eight grid lines. Then, the distances of all eight reached were added. The total of the eight distances attained is divided by the length of the gymnast's leg to get the test score. This test is credible and legitimate field-based [34].

A gymnastics-specific shuttle run test (GSRT) as described by Sleeper et al. [33], was used to measure agility. Two cones were put diagonally at the corners of a gymnastics competition floor measuring 12m x 12m. Gymnasts ran five straight 17-meter shuttle sprints over the gymnastics floor's diagonal length. A digital stopwatch was used to time how long it took to complete the five sprints. Athletes participated in two trials, with the best time being used for further analysis. This test is credible and legitimate field-based [33, 34].

The Tsukahara vault performance test (TVP) was calculated according to International Gymnastics Federation Rules, code of points (2022-2024), and Men's Artistic Gymnastics [39].

The training program

Beginning on June 18, 2023, the training intervention ran for eight weeks. 24 sessions, i.e., three sessions each week, were completed by the unstable and stable groups. Every training session had a duration of around 75 to 80 minutes and was conducted at the same time every day of the week. Before every session, the participants warmed up for ten minutes by running and performing stretches [40]. Then, HIIT using on stable or unstable surfaces was carried out lasting from 15 to 25 min, and details of HIIT Program intervention are shown in Table 2. After that, participants practiced Tsukahara vault skills for 35 to 40 minutes. Cooling down took up the last 10 minutes of the session. Meanwhile, the control group went about their regular exercise routine.

HIIT on unstable and stable surfaces protocol. The experimental (Unstable and stable) groups performed three HIIT stations, where each one consisted of 8 movements that lasted 6 minutes. The eight-movement HIIT was implemented using the 30-second working and 15-second active recovery interval approach. The UG performed HIIT exercises using an unstable surface (bosu ball). The movements details in the three stations of the bosu ball are shown in Table 3. The stable group performed the same HIIT stations and exercises but using the stable surfaces, i.e.,step platforms or the floor.

Both groups performed HIIT movements for each session in the two sets during the first to third weeks at 85% HRmax, three sets during the fourth and fifth weeks at 90% HRmax, and four sets during the sexth to eighth weeks at 95% HRmax. There was a two-minute break in between each set.

Statistical Analysis

The Shapiro-Wilk and Levene tests were used on each variable to verify data normality and equal variance. Means and standard deviations (SD) are used to represent data. To identify differences between groups, tukey post hoc testing in conjunction with one-way ANOVA was used to investigate the baseline-post change. The use of paired sample t-tests allowed for the determination of significant group differences. Also, the change ratio (%) was utilized to determine percentage of improving between pre and post tests. The magnitude of effect size for (η2) is classified as

Table 2. Details of 8-Week HIIT Program intervention (HIIT using on stable or unstable surfaces).

8-Week HIIT Program intervention								
weeks	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Stations	1-2	1-3	2-3	1-2-3		1-2	1-3	2-3
station duration	6 minutes							
(Workload – Recovery) time	(30 sec - 15 sec)							
sets per station	1					2		
Sets duration	6 x 2 = 12 minutes			6 x 3 = 18 minutes		6 x 4 = 24 minutes		
Rest between sets	2 minutes							

Table 3. The movements details in the three HIIT stations of the bosu ball.

Stations		**Station 1**	**Station 2**	**Station 3**
Movements	1	Squats over bosu ball	Back flips from bosu ball	Handstands over bosu ball
	2	One leg squats over bosu ball	Push-ups over bosu ball	Jump to back handspring from bosu ball to bosu ball and return to front handspring from the bosu ball to bosu ball
	3	Get down get up over the bosu ball	Front flips from bosu ball	Cartwheels over bosu balls
	4	One leg squats over bosu ball	Power line push-ups over bosu ball	Forward and backward leg swings over bosu ball
	5	drop and pop over bosu ball	Back flips from bosu ball	Handstand push-ups over bosu ball
	6	One leg squats over bosu ball	Plank up and down over bosu ball	Forward and backward leg swings over bosu ball
	7	Knee pulls over bosu ball	Front flips from bosu ball	Handstands over bosu ball
	8	One leg squats over bosu ball	Back flips from bosu ball	Jump to back handspring from bosu ball to bosu ball and then return to front handspring from the bosu ball to bosu ball

small ⩾ .01, moderate ⩾ .06, and large ⩾ .14, while Cohen's d was interpreted as small ⩾ 0.2, moderate ⩾ 0.5, and large ⩾ 0.8. The significance level of $p < 0.05$ was applied to all findings that were presented. IBM SPSS Statistics version 27.0 was employed for analysis.

Results

Baseline data

A one-way ANOVA showed that there were no significant differences between the groups at the pre-test for any of the variables [F= 0.121 to 0.947, p= 0.402 to 0.886 (P>0.05)]. Every participant followed the instructions and showed up for each of the 24 scheduled training sessions.

The effects of training intervention after 8-week

The effect on explosive strength

Between the groups, there was a significant difference for VJT (F= 13.492, P= < 0.001, η2= 0.677) and MBTT (F= 12.328, P= < 0.001, η2= 0.661). Post hoc analyses revealed that the differences were statistically significant in favor of both UG and SG compared to the CG in both tests. Additionally, we discovered significant differences between the UG and SG in VJT and MBTT in favor of the UG. The groups significantly increased VJT and MBTT from Pre[(UG 43.01±3.56 cm and 4.40±0.55 m; SG 42.63±4.04 cm and 4.28±0.43 m; CG 42.03±2.86 cm and 4.22±0.39 m), respectively] to Post [(UG 47.74±2.12 cm, Δ% = 11.38%, Cohen's d= 2.258, P= < 0.001<0.05 and 5.12±0.39 m, Δ% = 17.75%, Cohen's d= 3.325, P = < 0.001<0.05; SG 45.49±2.77 cm, Δ% = 7.30%; Cohen's d= 1.03, P= 0.015 <0.05 and 4.71±0.23 m, Δ% = 10.59%, Cohen's d= 1.89, P< 0.001<0.05; CG 43.13±2.74 cm; Δ% = 2.82%; Cohen's d= 0.772, P= 0.049 <0.05 and 4.33±0.32 m, Δ% = 2.79%, Cohen's d= 0.793, P= 0.045<0.05), respectively] (Fig.1).

The effect on balance

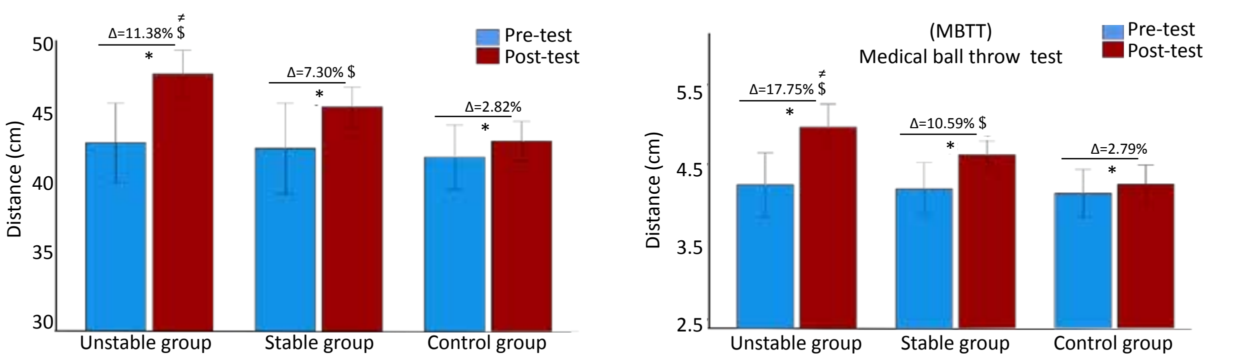
Between the groups, there was a significant difference for HST (F= 19.716, P= < 0.001, η2=0.622) and SEBT (F= 12.683, P= < 0.001, η2= 0.514). Post hoc analyses revealed that the differences were statistically significant in favor of both UG and SG compared to the CG in both tests. Additionally, we discovered significant differences between the UG and SG in HST and SEBT in favor of the UG. The UG and SG significantly increased HST and SEBT from Pre[(UG 44.09±6.19 sec and 727±48.48 cm; SG 42.53±6.70 sec and 714.22±50.56 cm), respectively] to Post [(UG 56.93±4.86 sec, Δ% = 30.22%, Cohen's d= 4.781, P = < 0.001<0.05 and 804.67±41.71 cm, Δ% = 10.80%, Cohen's d= 4.367, P= < 0.001<0.05; SG 50.59±3.67 sec, Δ% = 20.50%; Cohen's d= 2.450, P= < 0.001<0.05 and 762.33±34.93 cm, Δ% = 6.91%, Cohen's d= 2.588, P= < 0.001<0.05), respectively]. No significant differences were found in HST and SEBT from Pre (41.21±7.05 sec and 707.33±37.45 cm, respectively) to Post in CG (42.91±5.52 sec, 4.95%, P= 0.063 >0.05 and 720.11±29.08 cm, 1.89%, P= 0.076 >0.05 respectively) (Fig. 2).

The effect on agility.

Between the groups, there was a significant difference for GSRT (F= 12.857, P= < 0.001, η2= 0.517). Post hoc analyses revealed that the differences were statistically significant in favor of both UG and SG compared to the CG in both tests. The UG and SG significantly increased GSRT from Pre (UG 18.30±1.03 sec; SG 18.93±1.18 sec) to Post (UG 17.23±0.64 sec, Δ% = 5.61%, Cohen's d= 1.099, P = 0.019 <0.05; SG 17.92±0.39 sec, Δ% = 4.63%; Cohen's d= 0.981, P= 0.023 <0.05). No significant differences were found in GSRT from Pre (18.98±1.10 sec) to Post in CG (18.7±0.78 sec, 1.22%, P= 0.072 >0.05) (Fig. 3).

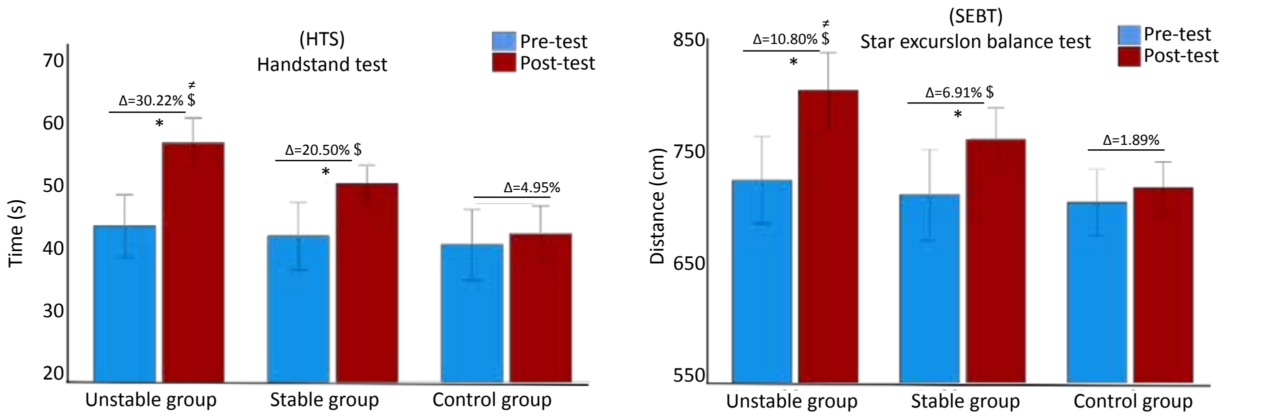
The effect on Tsukahara vault performance.

Between the groups, there was a significant difference for TVP (F= 23.885, P= <0.001, η2= 0.666). Post hoc analyses revealed that the differences were statistically significant in favor of both UG and SG compared to the CG in both tests. Additionally, we discovered significant differences between the UG and SG in TVP in favor



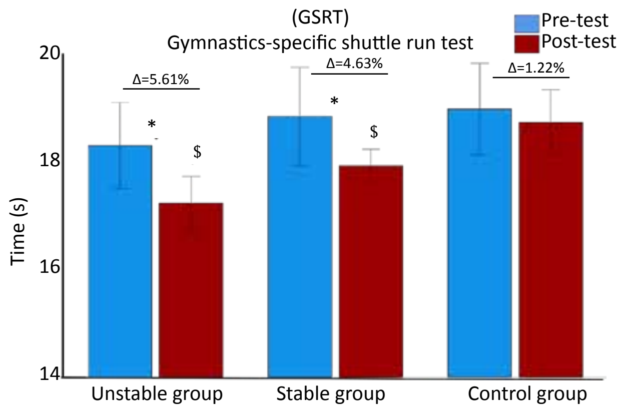
Note. * Significant difference from the pre-test. $ Significant difference from the control group. ≠ significant difference from the stable group. Δ Change ratio % from pre-test.

Figure 1. The effect of training intervention on VJT and MBTT.



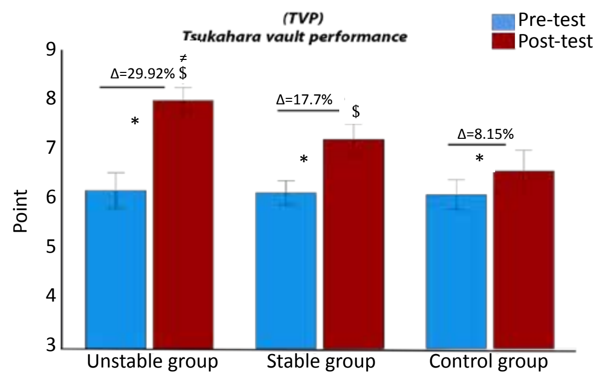
Note: * Significant difference from the pre-test. $ Significant difference from the control group. ≠ significant difference from the stable group. Δ Change ratio % from pre-test.

Figure 2. The effect of training intervention on HST and SEBT.



Note: * Significant difference from the pre-test. $ Significant difference from the control group. Δ Change ratio % from pre-test.

Figure 3. The effect of training intervention on GSRT.



Note: * Significant difference from the pre-test. $ Significant difference from the control group. ≠ significant difference from the stable group. Δ Change ratio % from pre-test.

Figure 4. The effect of training intervention on TVP.

of the UG. The groups significantly increased TVP from Pre (UG 6.21±0.47 point; SG 6.17±0.32 point; CG 6.13±0.39 point) to Post (UG 8.05±0.34 point, Δ% = 29.92%, Cohen's d= 4.632, P = < 0.001<0.05; SG 7.25±0.41 point, Δ% = 17.7%; Cohen's d= 3.533, P= < 0.001<0.05; CG 6..61±0.55 point, Δ% = 8.15%; Cohen's d= 0.792, P= 0.045 <0.05). (see Fig.4)

Discussion

The findings of this study indicate that after eight weeks, both HIIT on unstable and stable groups showed greater improvement than the control group for explosive strength, balance, agility, and Tsukahara vault performance in gymnastics. HIIT seems to be necessary to provoke additional improved explosive strength, balance, and agility because of the high-intensity exercises that were performed with a 30-second working and 15-second rest interval. In addition, HIIT on unstable surfaces improves explosive strength and balance better than HIIT on stable surfaces, while HIIT on unstable surfaces improves agility almost similarly to HIIT on stable surfaces.

Regarding explosive strength, our study showed that HIIT on unstable surfaces has better training effects on explosive strength compared with HIIT on stable surfaces. Where the HIIT on unstable surfaces had a large effect on explosive strength [Cohen's d= VJT (2.258) and MBTT (3.325)] by increasing the VJT (11.38%) and MBTT (17.75%), which outweighed the HIIT on stable surfaces improved by 7.30% and 10.59% and control groups by 2.82% and 2.79%, respectively, creating a large effect size between 3 groups [η2= VJT (0.677) and MBTT (0.661)]. When it is focused on an unstable surface literature review, we came upon a paper that was carried out by Romero-Franco et al., which found significant improvement in jump strength in sprinters after 6 weeks of proprioceptive training with unstable tools, i.e., bosu ball and Swiss ball [41]. Caglayan et al. observed increased vertical jump in wrestler athletes after plyometric training on an unstable surface, i.e., bosu ball and trampoline

[42]. In a study conducted on athletic children, it was found that strength training with bosu balls improved vertical jump and standing long jump [43]. Another study on adolescent children found that core strength training on unstable and stable surfaces for 6 weeks caused a significant increase in explosive strength test data and unstable surface training showed an improvement compared to stable surfaces [44]. These outcomes are consistent with the measurements we collected after eight weeks, which may support increased explosive strength in the unstable group better than the stable group. Thus, exercises executed using unstable surfaces could improve explosive strength in Tsukahara vault players better than stable surfaces.

As to balance, we found a large effect [Cohen's d= HST (4.781) and SEBT (4.367)] upon the unstable group by the improved HST (30.22%) and SEBT (10.80%). This data was greater than the stable group improved by 20.50% and 6.91% and the control group by 4.95% and 1.89%, respectively, creating a large effect size between groups [$\eta 2$= HST (0.622) and SEBT (0.514)]. Upon reviewing the research pertaining to unstable exercises and their effects on balance, our result was aligned with Prasetyo et al., who reported significantly improved balance after 18 sessions of circuit training with a bosu ball in young archery athletes [25]. It also agreed with Nugraha et al.'s study, which reported significant differences in balance for basketball players after being given bosu ball exercise treatment compared to the TheraBand exercise [45]. Similarly, A, Elfateh's study found a significant increase in balance after 10 weeks of bosu ball exercises applied to university students [46]. Most likely, throughout the eight weeks of training, neurological adaptations occurred, which led to an increase in balance in our research. Our findings are consistent with literature demonstrating the benefits of proprioceptive and vestibular stimulation from rebounding exercises utilizing Bosu balls for postural control and balance [47]. Thus, we believe that HIIT on unstable surfaces has a positive effect on balance because it increases the number of motor units that function to maintain equilibrium and activates the synergist muscle groups more efficiently.

In terms of agility, our study found no significant differences between unstable and stable groups. However, the unstable group as compared to the stable group had only limited additional effects. The unstable group increased the GSRT by (5.61%), while the stable group increased by 4.63%, with a large effect size (Cohen's d= 1.099 and 0.981), respectively. Compared to the control group, this improvement was significantly higher with 1.22%, creating a large effect size between 3 groups ($\eta 2$= 0.517). Upon reviewing the literature on unstable exercises, we found only studies that focused on unstable exercises and their effect on agility, which corroborated our findings. Where Cressey et al., observed no significant improvement in the agility of collegiate males' soccer players after 10-week lower-body exercises performed between unstable surfaces group and the control group, but significant improvements were observed within groups [48]. It is believed that the changes in explosive strength, balance, and agility following high-intensity interval training applied to unstable and stable groups, which were shown to be superior to the control group in the current study, are brought on by the heavy usage of high-intensity, repetitive movements.

The present study showed that HIIT on unstable surfaces had a large effect size on Tsukahara vault performance (Cohen's d= 4.632) by the increased TVP points (29.92%). This was greater than the stable group improved by 17.7% and the control group by 8.15%, creating a large effect size between 3 groups ($\eta 2$= 0.666). In our opinion, the improvement of explosive power, balance, and agility is the reason for the increase in Tsukahara vault performance.

Conclusions

The goal of this study was to assess how HIIT affected gymnasts' explosive strength, balance, agility, and Tsukahara vault performance on unstable vs stable surfaces. According to our research, HIIT on unstable surfaces maximized explosive strength and balance more effectively than HIIT on stable surfaces. While HIIT on unstable surfaces enhances agility almost as much as it does on stable surfaces. As a result, if the goal of training is to enhance agility, then HIIT on unstable surfaces has limited advantages over HIIT on stable surfaces. In all variables, the HIIT unstable and stable groups fared better than the control group. Because HIIT can enhance players' explosive strength, balance, and agility and free up more practice time for other areas, we advise gymnastics coaches to give it some thought. Additionally, an alternate technique to enhance explosive strength and balance is to utilize HIIT on unstable surfaces. Additionally, it may be utilized alongside exercises on stable surfaces when enhancing agility.

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Conflict of interest

There was no declared conflict of interest by the authors.

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REVIEW ARTICLE

Teaching grassroots soccer: a systematic review of literature

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim	The process of soccer training for children and young people involves systematic exercise over an extended period to build a strong foundation of motor skills. These skills are designed to be both versatile and specific to the sport. The purpose of this research is to conduct a systematic review of literature related to the process of teaching grassroots football. This review aims to contribute to a better understanding of the strategies and methods employed in the development and training of young athletes.
Material and Methods	To conduct this review, studies were searched in the Web of Science (WOS) and Scopus databases from 2012 to 2022. The search focused on scientific articles addressing soccer teaching for children and girls up to 14 years old, using the keywords "children AND (football OR soccer) AND teaching." The sample was limited to research in Spanish and English. The search yielded 149 articles, from which 19 studies were selected based on their titles and abstracts.
Results	The findings revealed two main categories: teaching methods and their impact on technical and tactical skills in grassroots football, and factors affecting technical-tactical performance in this context. The most significant findings emphasize the importance of a comprehensive approach to teaching grassroots football, which involves the coordination of knowledge, skills, strategies, decision-making, and technical abilities.
Conclusions	The review concludes that a variety of teaching approaches should be considered, and methodologies should be constantly evaluated to train future footballers with a deep understanding of the game.

Keywords: children, youth soccer, grassroots soccer, soccer teaching, soccer training, systematic review

Introduction

Soccer is one of the most popular sports in the world, and it has followers in all towns [1]. Since its creation, the sport has continued to evolve, and currently several issues related to the selection of talents, the training of athletes and the management of football teams are under discussion, particularly the teaching processes in beginner or grassroots soccer [2, 3]. In contemporary soccer, where all players must attack and defend, it is the union of skills that will define a good player, since talent will be measured by the articulation between physical, technical, tactical and psychological aspects [4, 5, 6].

In line with the above, the concern of professionals who act in this area should be to train the athlete comprehensively, developing them in a balanced way in all aspects [7]. To achieve this, each stage of the motor development of the child and adolescent must be respected and used, so that the individual develops in the best possible way, avoiding early specialization [8]. In addition to the motor aspects, the psychological, emotional, social and cultural values of athletes must also be taken into account [9, 10]. On the other hand, coaches must be careful when applying a certain methodology, so that the athlete's development is harmonious and satisfactory, increasing the probability of successful training [5].

The numerous forms of pressure that fall prematurely on children and adolescents in the world of football reverse the logic of comprehensive protection and create the following dilemma "what will be the best way to integrate the practice of sport and its beneficial effects in training and development of the young athlete." The literature reports that for this the child should not dedicate himself to competition erected in dogma, but rather the competition must be adapted to childhood and its specific characteristics [11, 12]. Associated with this, the pressure for results and good performance in each training session and match, inherent to competitive sport, is very present in the daily reality of grassroots football, an issue that must be discussed and reflected on, in search of a comprehensive education of the child [7].

With regard specifically to this area, which is grassroots football, it is necessary to highlight that, associated with the importance of technical and physical training, the predisposition of the child and adolescent to practice is relevant, that is, knowing how to play. This is demonstrated by the research

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findings of Kopelovich [13], Machado et al. [14] and Fernández et al. [15]. The above, since in the area of grassroots football a set of skills is required in pursuit of the young formation of the footballer, such as flexibility, autonomy, ability to work in a group, proactive posture, emotional control, among others, which are not established only with technical football training, but are related to the personal and emotional development of the child and that require being addressed in the teaching-learning processes of the discipline [10, 16].

Regarding motor development, it is known that in childhood children begin to develop a set of skills, called fundamental motor skills, which are composed of object control skills and locomotor skills [17, 18]. In general, it is around 6 to 8 years that most children have the potential to perform in most fundamental motor skills and begin the transition to the phase of development of specialized motor skills. According to the author, specialized motor skills correspond to mature exercises of fundamental movement, adapted to the specific needs to develop daily, recreational or sports activities [18]. The literature reports that sports activities that require different coordination abilities, such as soccer, are of great importance for the development and increase of a child's motor repertoire [8, 19, 20]. In this line, the acquisition of multiple skills generates the development of a high level of coordination, which will positively influence learning and the improvement of the coordinative abilities that are the basis of good sensorimotor coordination. The higher the level, the faster and more safely the child will be able to learn complex soccer movements [21, 22].

The development of the various stages of grassroots football includes technical, tactical, physical and psychological aspects. At this age, children have greater control over themselves, which makes this period more favorable for exploring coordination abilities, such as balance, rhythm, reaction speed or orientation in space [13, 23]. In this sense, it is at this stage when athletes begin to be taught the basic technical and tactical elements of the respective modality, such as dribbling, feints, interception and protection of the ball. Therefore, it is in this final period of basic training when the adaptation of athletes to more specific positions begins and more value is given to the tactical and strategic component, such as the principles of organization and the culture of the game [24, 25]. In this context, the objective of the present systematic review is to analyze the teaching process of grassroots football, to contribute to an understanding of the strategies and methods that allow the development and sports training of children and young people.

Materials and Methods

Search strategy

The study followed the PRISMA guidelines for systematic reviews [26], which includes a 27-part verification process, and a four-phase flow chart [27]. Specifically, for this systematic review, studies were searched in the Web of Science (WoS) and Scopus databases, covering the years 2012 to 2022. The search focused on scientific articles, that addressing the topic of teaching soccer, to boys and girls up to 14 years old. The search therms used were children AND (football OR soccer) AND teaching. Additionally, research in both Spanish and English was used to delimit the sample.

Inclusion criteria

The inclusion criteria were publications between 2012 and 2022, focused on boys and girls up to 12 years old, and empirical studies on soccer teaching (Table 1).

Data extraction

Out of the total documents found (N=149), 19 articles were identified as meeting the established inclusion criteria. Duplicate articles (n=19) were eliminated by applying the corresponding exclusion criteria (Figure 1), and a study selection process was developed based on the title, abstract, and on the complete reading of the text. As a result, 130 documents were excluded, and 19 articles specifically focused on teaching soccer to boys and girls under 14 years of age and met the inclusion criteria established in the review.

To establish the categories or themes of analysis of the descriptive data, the guidelines proposed by Guest et al. [28] were applied. Through a

Table 1. Elements of the search strategy and selection process

Filters		Criteria	
Scopus	**WoS**	**Inclusion**	**Exclusion**
Text content: TITLE-ABS-KEY Subject Area: soccer teaching Document type: article	Field Labels: TS Citation Indexes: SSCI Document type: article	Field names, abstract Articles: qualitative, quantitative and mixed approaches Reports of the last 10 years 2012-2022 Published in English, Spanish and Portuguese RS and EI concepts in the title or abstract Research that contributes to the theoretical body of soccer teaching	Duplicate studies Gray literature, such as dissertations, presentations or proceedings Items targeting children over 14 years old

process of thematic analysis, initial codes were generated based on the explicit semantic content of the studies, which were subsequently grouped into two categories. To ensure the validity of the process, coding was carried out simultaneously and independently by two researchers from the group, strengthening the reliability and validity of the search.

Results

Using the search equation described in the previous section, 149 articles were found in the WoS and Scopus databases. To refine the selection of documents, the following inclusion criteria were considered: peer-reviewed articles, in English and Spanish and published between 2012 and 2022. Subsequently, a reading of titles and abstracts was carried out, this operation allowed 19 studies to be defined, which were read and reviewed in their entirety by the authors. Below, Table 2 presents a synthesis of the publications considered in this systematic review.

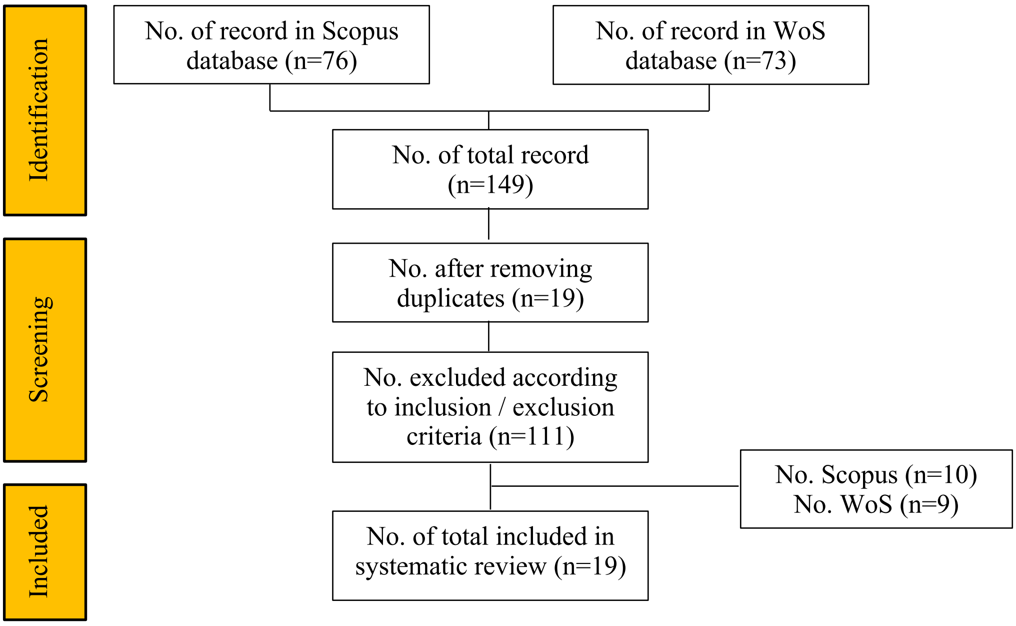

Figure 1. Diagram of the process of information flow through the different phases of the systematic review.

Table 2. Findings from the literature review

N°	Reference	Study objective	Participants	Methodology	Main findings
1	2	3	4	5	6
1	Barquero-Ruiz et al. [29]	Compare the effect of global and analytical training-learning methodologies on fundamental technical skills in beginner football.	88 children	Quantitative	The three tactical levels have a relationship with success in the attack and defense phase, however, the individual and team tactical level explained a higher percentage of achievement.
2	Bernal-Reyes et al. [30]	Compare the effect of global and analytical training-learning methodologies on fundamental technical skills in beginner football.	110 children	Quantitative	There is no significant difference between both methodologies. Both are effective in improving technical skills.
3	Díaz et al. [31]	To analyze perceptions about the didactic model of game action competencies after an intervention.	15 children	Qualitative	The participants positively value the experience based on the model, pointing out that it facilitates the learning of tactical and technical soccer skills through games.
4	Fanarioti [32]	Present the effects from a theoretical and practical point of view of the direct and indirect teaching method, to decide which is more appropriate for beginner soccer players.	50 children	Quantitative	The direct teaching method generates better results in the development of movement skills.

Table 2 (continued)**.**

N°	Reference	Study objective	Participants	Methodology	Main findings
1	**2**	**3**	**4**	**5**	**6**
5	Folgado et al. [33]	Identify how collective tactical behavior varies with age, in different formats of small-scale soccer games.	30 children	Quantitative	Age, length, width and distance to the center of the field affect the tactical performance of reduced play.
6	García-Angulo et al. [34]	Analyze the impact of a learning methodology based on "Non-Linear Pedagogy" on the levels of physical activity related to health in soccer players.	32 children	Quantitative	A methodology based on "Non-Linear Pedagogy" positively impacts physical activity levels.
7	Garcia-Ceberino et al. [35]	Quantify and compare, according to the genre and teaching methodology ("Tactical Games Approach" and "Direct Instruction"), the external and internal load and the perceived effort index resulting from the application of two programs for teaching soccer.	41 children	Quantitative	The "Tactical Games Approach" generated higher values of internal load and more time in high-intensity activities. Men recorded higher values of external and internal load and perceived effort than women.
8	Greve et al. [36]	Identify how they experience and interpret the use of digital media for teaching football using the "Teaching Games for Understanding (TGfU)" teaching approach.	96 children	Qualitative	Participants perceive the use of digital media as an aid to learning, however, some consider it not very useful or use it to clarify controversial situations.
9	Holt et al. [37]	To measure the effects of coach intervention on performance and peer learning during technical practice in groups.	5 children from 10 to 12 years old and 1 coach	Quantitative	The delivery of results, feedback and reinforcement improve performance, improving practice, learning and evaluation of footballers' progress.
10	Motato and Quilindo [38]	Analyze the teaching methods from the discourse and practice of the coaches of two football schools.	9 coaches	Qualitative	Coaches use various teaching methods, however, the analytical method and traditional interaction mediated by competitive interest prevail.
11	Napolitano [39]	To verify whether a systematic "modeling" approach using video analysis and field activities generates significant changes in the learning of technical skills in child soccer players.	20 children	Quantitative	The use of video analysis as a teaching and evaluation tool allows improving technical soccer skills.
12	Pastor-Vicedo et al. [40]	To analyze and compare the effectiveness, number and duration of decision-making units in talented soccer players.	97 children	Quantitative	The efficiency must be greater than 80% to consider a child talented. The efficiency and speed of play increases with age.
13	Práxedes et al. [41]	Analyze the effect of a comprehensive teaching program, based on questioning decision-making and execution in football.	18 children	Quantitative	The application of the program generated better decision making in passing and dribbling. In addition, the execution of the passing action improved.
14	Prontenko et al. [42]	Determine the connection between the psychophysical state and technical preparation in football and describe a computer program that can determine possible individual norms of the movement capabilities of football players.	212 children	Quantitative	The implementation of the "E-journal Football" computer program improved the psycho-emotional health, motor functions and some technical skills of the children.

Table 2 (continued).

N°	Reference	Study objective	Participants	Methodology	Main findings
1	2	3	4	5	6
15	Quintero et al. [43]	Evaluate “Behavioral Skills Training” as a method to correctly teach heading technique in soccer.	3 children and 1 coach	Quantitative	“Behavioral Skills Training” increased the percentage of correct passes executed with the heading technique.
16	Sánchez et al. [44]	Determine which football teaching-training model can generate greater enjoyment in the players.	101 children	Quantitative	A training program based on tactical application games generates greater enjoyment, compared to a technical training program.
17	Sierra-Ríos et al. [45]	Compare the effects of the “Direct Instruction” and “Teaching Games for Understanding” programs on decision making, execution and physical activity levels in soccer.	30 children	Quantitative	The games for understanding teaching program improved decision making, execution and increased levels of light physical activity.
18	Valencia and Arias [46]	Compare the learning effects of the “Game Action Competencies Didactic Model” with the “Direct Instruction Didactic Model” on tactical performance, motivation and perception of skill in soccer players.	36 children	Quantitative	The “Game Action Competencies Didactic Model” promotes better tactical performance, greater intrinsic motivation and perception of skill.
19	Vega-Orozco et al. [47]	Determine the influence that equality versus numerical inequality has on technical aspects during a soccer training program.	15 children	Quantitative	Training with numerical equality significantly improved driving. While numerical inequality improved driving and dribbling.

Discussion

The aim of this study is to analyze the teaching process of grassroots football, in order to contribute to an understanding of the strategies and methods that facillitate the development and sports training of children and young people. According to information prersemnted in Table 3, we can observe two main categories emerge: 1.- Teaching methodologies for grassroots soccer, and 2.- Strategies for technical-tactical work in grassroots soccer.

Table 3. Elements of the search strategy and selection process

Category	Authors
Teaching methodologies for grassroots soccer	[30, 31,32, 34, 35, 37, 38, 41, 43, 44, 45, 46]
Factors that affect the technical-tactical performance of grassroots soccer	[29, 33, 36, 39, 40, 42, 47]

This research provides information on teaching methods in grassroots soccer and emphasizes the need for a systematic evaluation of training methodologies, to meet the changing demands of the game and the individual needs of players. This discussion has been present in other studies, where it is observed that coaches' behaviors are often derived from sports traditions, their beliefs and previous experiences [48, 49]. Practitioners tend to follow traditional legacy methods rather than adopt new evidence-based approaches associated with athlete development [50].

Category “Teaching methodologies for grassroots soccer”.

The training process of soccer players must be approached in the long term, considering the harmonious and comprehensive development of children's abilities. Training for children and young people is a long-term systematic exercise process, which offers multifunctional and modality-specific motor forms, to constitute a stage of development for the final objectives that are normally located in adulthood [51, 52]. Regarding teaching methods in grassroots football, the systematic review allows us to affirm that the global or analytical method can be used in teaching, both being effective for the development of technical skills [31]. However, an important group of coaches report using the analytical method and traditional teaching, with emphasis on the competitive aspects of the sport [39]. On the other hand, within the selected studies it is observed that the use of active (or alternative) methodologies improves decision-making based on the game's own foundations [32, 41, 45], which coincides with what was observed by Sánchez et al. [44] where the distance between the execution of the fundamentals and the moment of their use (decision making) affects the final result of sports performance.

In the methodological and training field of grassroots soccer, it is necessary to evolve to promote a more dynamic and sustainable game over the years. In this sense, the respective evolution inevitably involves an improvement in the pedagogical process of teaching the technical and tactical aspects of the game, as has been demonstrated in the studies by Quintero et al. [43]; Valencia and Arias [46], studies that reinforce the idea of the player's ability to learn, understand, observe and analyze, especially tactical issues and game intelligence, which is related to cognitive abilities, such as perception, anticipation, decision making and creativity that improve through the use of games [31].

The literature reports that grassroots soccer is developed from the coordination of knowledge, skills, strategies, decision-making power, tactical and technical skills, understanding the teaching of the game in a global way [37]. In this context, the young athlete will participate in training that will provide the promotion, in a systematic and graduated manner, of better technical and tactical performances, better physical response and greater understanding and tactical and strategic understanding of the game and an increasing level of physical activity as demonstrated by the research findings of García-Angulo et al. [34] and García-Ceberino et al. [35]. The theoretical-pedagogical conception that supports the aforementioned studies is based on teaching that seeks to provoke improvements in motor, psycho-emotional, technical and tactical performance in practitioners.

Regarding the category analyzed, it can be noted that research on teaching methods and their impact on the development of technical and tactical skills in football has reported that teachers and coaches use a "traditional" approach [53, 54], assuming that technique must be mastered a priori and before the game, and can create a separation between technique and tactics. In contrast to traditional approaches, alternative approaches have gained popularity in recent years, since, in their structural characteristics, the authentic recreation of the sports context is present that increases the motor, cognitive development and emotional commitment of the students [55]. Notwithstanding the above, this review allows us to demonstrate that the diversity of approaches is complementary in the teaching of grassroots football, allowing the development of technical-tactical skills from a global and complex perspective.

Category "Factors that affect the technical-tactical performance in grassroots soccer".

The results of this research show that the teaching of technique and tactics has been of significant interest to various researchers [29, 33, 39, 40, 47]. In recent years, work has been developed that provides more evidence precisely along these lines, identifying the implications of various factors that affect the development of beginner football [56, 57, 58]. Regarding the training of technical aspects, it has been confirmed that the incorporation of technology can contribute to improving the learning of some fundamentals. Specifically, Napolitano [39], it was demonstrated that video analysis has positive effects as a tool to model the execution of technical gestures, strengthening the motor skills of children between 9 and 10 years old. The use of this strategy has had similar results at different ages and also in other sports disciplines [39, 59].

Additionally, in another study developed by Vega-Orozco et al. [47] demonstrated that numerical equality or inequality in the development of some exercises can positively impact the development of some technical skills. In situations of numerical inequality, for example, improvements were detected in dribbling and driving the ball in a straight line, findings similar to those reported by Sánchez et al. [44]. Regarding the teaching of tactics, it has been discussed how the interaction between players, age and use of space represent important aspects to consider. According to Barquero-Ruiz et al. [29], actions involving the majority of the team's players, a small group or an individual play, achieve similar percentages of effectiveness in the attack phase. On the other hand, individual plays have a greater probability of success in the defensive phase. This suggests the need to address a combination of strategies that favor both individuality and collective play, as both promote a positive outcome of the plays [60, 61].

In this review, key factors that affect technical-tactical performance in grassroots football have been identified. Furthermore, the age of the players has emerged as an influential factor in the tactical disposition on the playing field, which has been corroborated by studies such as that of González-Rodenas et al. [62]. On the other hand, the study by Greve et al. [36] used a football teaching process with digital support, and the participants perceive the use of digital media as an aid to learning. Along these lines, the study by Prontenko et al. [42], demonstrated that the implementation of a computer program improved psychoemotional health, motor functions and some technical skills in young soccer players. In the study developed by Folgado et al. [33], it was observed that individual play is used more frequently on the playing field, especially in the minor categories (Sub 9). These results align with the findings of Nunes et al. [63], who identified that at early ages personal actions prevail over collective actions, a product of the dispersion and static position of the players. Age influences the tactical disposition on the playing field, specifically, the minor categories tend to extend longitudinally on the field, advancing quickly from goal to goal [62]. At advanced ages, using the sides of the field becomes more important. Finally, it is worth mentioning that the study of decision making emerges as a relevant factor in the development of technical and tactical aspects of the players, and its influence is also modulated by the age of the footballers [40].

Conclusions

This systematic review, analyzed the scientific evidence on the teaching of grassroots soccer, to contribute to the understanding of strategies and methods for developing and training children and young people. The research identified two categories: 1. Teaching methodologies for grassroots soccer and 2. Factors that affect the technical-tactical performance of grassroots soccer. These categories provided significant findings that expand the way technical and tactical skills are addressed and developed in grassroots soccer.

Regarding teaching methods in grassroots football, the review revealed relevant information on the effectiveness of two main approaches: the global method and the analytical method. Both methods have proven effective in developing the technical skills of young footballers. These findings highlight the need to promote continuous evaluation and evolution of training methodologies, to adapt to the changing demands of football and the individual needs of players. This also implies an emphasis on continuous training of coaches and evolving pedagogical approaches to keep up with the ever-changing demands of the game and the needs of players. In the field of grassroots football training, the importance of promoting a more dynamic and sustainable game over the years has become evident.

Finally, this literature review emphasizes the importance of considering a variety of approaches in teaching grassroots soccer to promote comprehensive development of technical and tactical skills. It also emphasizes the need for constant evaluation of methodologies and adaptation to the individual characteristics of the players, with the aim of training future footballers with high technical and tactical performance, as well as a deep understanding of the game. This knowledge contributes to the advancement and improvement of the training of young talents in soccer, effectively preparing them for the challenges they will face in their sporting development.

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ORIGINAL ARTICLE

Does basketball training increase balance scores in children?

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Abstract

Background and Study Aim Balance is a motor skill that enables children to perform physical activities fluently and regular physical activity is needed for the development of balance skills. In this context, the problem of which physical activity should be directed to the balance development of children arises. The study is aimed to determine the effect of basketball training on balance skills in children aged 7-10 years.

Material and Methods The participant group of the study consisted of 24 children aged 7-10 years with a mean age of 9.25±0.94 who did not regularly perform physical activity and lived in rural or non-rural areas. Participants living in non-rural areas were included in the exercise group (n=12) and participants living in rural areas were included in the control group (n=12). The exercise group received basketball training for 8 weeks, two days a week, while the control group did not receive any intervention. Before and after the training process, all participants were tested at Level 1 in TOGU Challenge Disc and software to determine static and dynamic balance levels. As a result of the balance test, participants' static balance score (SBS), dynamic balance score (DBS), general balance score (GBS) and dynamic balance sub-parameter scores as right and left dynamic balance score (RL-DBS), superior inferior dynamic balance score (SI-DBS), horizontal plane dynamic balance score (HP-DBS), vertical plane dynamic balance score (VP-DBS), clockwise (C-DBS) and opposite clockwise dynamic balance score (OC-DBS) were taken as percentage. Descriptive statistics, Skewness, Kurtosis and Kolmogorov-Smirnov values, paired sample t-test and independent sample t-test were used to analyse the data. Statistical significance level was determined as $p<0.05$.

Results In the study, no difference was found between the exercise group and the control group in terms of pre-test results, which indicated that the participant groups showed homogeneous characteristics. In the exercise group, a significant increase was found in DBS, RL-DBS, SI-DBS, C-DBS, GBS levels after 8 weeks of basketball training. In the control group, there was a significant decrease in SBS and a significant increase in DBS, RL-DBS, SI-DBS, C-DBS and OC-DBS levels at the end of 8 weeks.

Conclusions As a result, regular basketball training provided an increase in dynamic balance level and general balance scores. Moreover, basketball training can slow the decrease in static balance that may occur as a result of growth spurts in children aged 7-10 years. Children targeted to develop balance skills can be directed to basketball training.

Keywords: basketball training, static balance, dinamic balance, balance score, child

Introduction

The World Health Organisation recommends that children and adolescents aged 5-17 years should engage in moderate to intense physical activity for at least one hour a day for optimal health [1]. However, studies have emphasised that the motor skill development of children who are more active in terms of physical activity is supported by physical activity [2, 3, 4]. Moreover, starting from childhood, it is assumed that high motor skill proficiency levels are an important factor that directs individuals to physical activity participation. Therefore, childhood is considered a critical period for the development of motor skills [5, 6].

Proficiency in basic motor skills such as locomotor, manipulative skills and balance is essential for the development of physical activity and sport-specific movement skills [7, 8]. In addition to the fact that balance and motor skills are considered prerequisites for physical competence and sportive performance [9], studies emphasise that they also form an important basis for children's physical development [10, 11, 12]. Therefore, a good physical condition is needed for children and one of them is balance [13].

The balance system of humans matures with age and the balance adjustment mechanism of 7-year-old children is similar to adults [14]. A good balance enables a person to perform movement effectively and efficiently with minimal risk of falling. Balance is analysed in two ways as static and dynamic [13]. Static balance is the body's ability to maintain its balance in a stationary position by standing on one leg or standing on a balance board [15], while dynamic balance is defined as the ability to maintain and regain a fixed position on moving or flat surfaces [16, 17, 18]. When body balance is not given the necessary importance, serious problems such as lack of development of sportive performance may occur.

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While the necessity of balance training for basketball has been accepted by studies [19, 20], the effect of basketball training on balance has not been revealed in the literature. Basketball, which is a sport that exercises the whole body, requires a combination of both static and dynamic balance as it includes a series of movements such as running, jumping, dribbling, passing and shooting in its dynamics. For example, while shooting the ball in basketball, static balance is needed for the ability to complete the movement correctly by maintaining the position of the body, while dynamic balance is needed during movements such as running or dribbling. However, there is no study on the effect of basketball training on the development of balance skills in children.

In this context, considering that balance skill is a basic motor skill that is necessary for children in the process of growth and development [21], this study aimed to reveal whether children who were directed to physical activity for balance development should be directed to basketball exercises or not. Besides, since the participants were selected from rural and non-rural areas and it was known that the movement diagrams of children living in rural areas were more active according to their living conditions, it was aimed to reveal to what extent this situation differentiated their balance skills according to regular basketball exercises.

Materials and Methods

Participants

The study included 24 participants aged 7-10 years. Participants were included in the study on a voluntary basis and the content of the study was explained to the participants and their parents and an informed consent form was signed. The exercise group (n=12) of the study was selected among children residing in a non-rural settlement and not regularly participating in any physical activity, while the control group (n=12) was composed of village children not regularly participating in any physical activity. Exclusion criteria included failure to meet inclusion criteria, failure to comply with study procedures, and desire to leave the study.

Research Design

The study aimed to determine the effect of 8-week basketball training on the changes of balance, which was one of the biomotor abilities of children aged 7-10 years, in static and dynamic states. In the study, age, gender, height and weight values of the participants were recorded in the personal information form. Then, the balance test was performed with the TOGU Challenge disc balance machine. Afterwards, the basketball training specified in Table 1 was applied to the exercise group for 8 weeks. At the end of the eighth week, the balance test was retaken with the same equipment.

Table 1. Weekly Basketball Training Plan

Week	Training Plan
1	Ball handling exercises Ball handling Basketball basic posture Stop exercises with and without ball (single and double time)
2	Ball handling Stop exercises with and without ball (single and double time) Passing exercises (chest pass, floor pass, overhead pass)
3	Ball handling Fundamental studies (Drippling) Passing exercises (chest pass, floor pass, overhead pass)
4	Fundamental studies (Drippling) Right-Left lay up
5	Fundamental studies (Drippling) Left Lay Up Right Lay Up Shot practices
6	Fundamental studies Direction change studies -Crossover -Reverse
7	Fundamental studies Direction change studies -Crossover -Reverse Shot and lay-up exercises after changing direction
8	Fundamental studies Direction change studies -Speed deception -Reverse Shooting and lay-up exercises after changing direction

Ethics committee permission for the research was obtained from Yalova University Human Research Ethics Committee on 2023 with protocol number 2023/77. Participants were included in the study on a voluntary basis. During the current research, the "Higher Education Institutions Scientific Research and Publication Ethics Directive" was followed.

-Basketball Training Programme

The participants in the exercise group were given weekly basketball training sessions determined in Table 1 for 8 weeks, two days a week. Before the training, warm-up exercises including educational games (15 minutes) and cool-down exercises including educational games (15 minutes) were performed. Total training time was limited to 60 minutes. No intervention was made in the control group. At the end of eight weeks, the training and control groups were given a balance test again and their second measurements were taken.

-Data Collection and Instrument

In the study, the level 1 balance test in the "Training" mode of the TOGU Challenge Disc was applied to make static and dynamic evaluations of the participants (Figure 1). This test was applied before and after the 8-week basketball training sessions and balance data were collected. The pre and post test balance data were statistically analysed.

The Togu Challenge Disc is a device produced by MFT Body teamwork that uses games and visual targets to train balance and track the user's movements. The device consists of a balance disc and software with a gamified exercise interface [22]. Within the device, there are games that require balance with increasing difficulty from level one to level five. In balance games, static and dynamic balance levels of individuals are given from the system as a percentage at the end of the game. As the percentage of the score obtained at the end of the game increases, the balance level of the person increases. The device provides static balance score (SBS), dynamic balance score (DBS), dynamic balance sub-parameter scores and general balance score (GBS) results. Dynamic balance sub-parameter scores include right and left dynamic balance score (RL-DBS), superior inferior dynamic balance score (SI-DBS), horizontal dynamic balance score (HP-DBS), vertical plane dynamic balance score (VP-DBS), clockwise dynamic balance score (C-DBS) and opposite clockwise balance score (OC-DBS).

Within the scope of the test, the device and computer connection was provided and then the participant information was entered into the device software. The balance test to be performed was explained to the children in advance, and a 20-second balance test in the device was applied to the participants for practice before the main test. Then the 1st level training mode was selected from the software. Then the participants stood on the balance disc. In Level 1 of the training mode, there are 9 exercises that evaluate dynamic and static balance in a mixed way. Between the exercises, a 10-second waiting time is given for rest and preparation for the next exercise. The exercise ends with the completion of each step by moving the disc so that the small green circle follows the large blue circle. The aim is to keep the green circle in the centre of the large blue circle, which is in motion or in a stationary position. In the application, static balance and sub-parameter scores are given together with the total score for each participant who completes the 9-step Training Level 1 mode (Figure 1). Level training mode takes a total of 3.26 minutes. At the end of the test, SBS, DBS, RL-DBS, SI-DBS, HP-DBS, VP-DBS, C-DBS, OC-DBS, and GBS data were obtained and evaluated.

Statistical Analysis

The data was analyzed on SPSS 26 packet program [23]. Normal distribution of the data was showed by Shapiro-Wilk test results and the skewness and kurtosis values. Mean, standard deviation, and percentage changes were determined as descriptive statistics. Paired Samples T Test and intra-group pre-test and post-test comparisons were used to determine the difference between the pre-test and post-test values of the groups. Statistical significance level was set at $p \leqslant 0.05$. Effect size (Cohen's d) was analysed in the study. The effect size was calculated with the formula d = [(mean 1- mean 2) / common standard deviation] and defined as small (0.2- 0.49), medium (0.5-0.79), and large (>0.8) [24].

Results

The study included 24 participants, 12 girls and 12 boys with a mean age of 9.25±0.94 years, among children who did not regularly engage in physical activity. Participants living in non-rural areas were included in the exercise group (n=12) and participants living in rural areas were included in the control group (n=12). Demographic data of the participants presented in Table 2.

The normality distribution of the balance data of the participants was examined with Skewness and

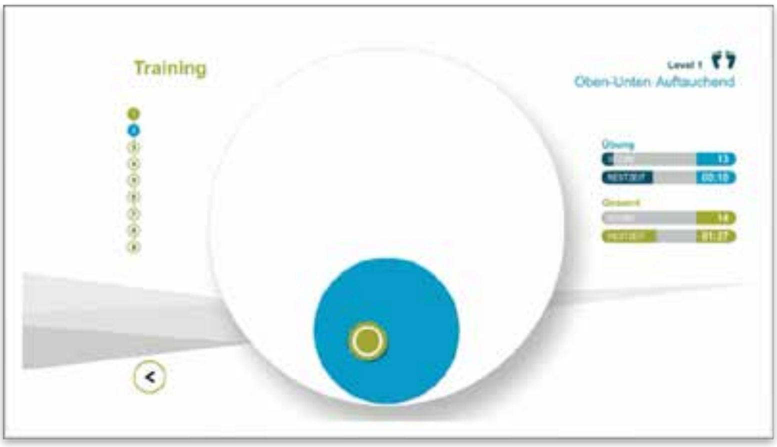

Figure 1. Togu Balance Disc Level 1 Balance test visualisation (produced from MFT Body teamwork device).

Table 2. Demographic data of the participants

Variables	n	Min	Max.	Mean ± sd.
Weight (kg)	24	19.20	46.70	29.50 ± 7.32
Height (cm)	24	116.20	157.00	129.94 ± 8.98
Years	24	7.00	10.00	9.25 ± 0.94

Values are expressed as means ± standard deviations. Min = minimum, Max = maximum

Table 3. Differences between the pre-tests of the exercise group and the control group

Variables	Group	n	Mean ± sd.	t	df	*p*-Value
SBS	Exercise	12	86.18 ± 12.10	-0.165	22	0.871
	Control	12	86.92 ± 10.14			
DBS	Exercise	12	51.25 ± 6.55	-0.362	22	0.721
	Control	12	52.50 ± 10.01			
RL-DBS	Exercise	12	33.33 ± 8.82	-0.128	22	0.899
	Control	12	33.92 ± 13.08			
SI-DBS	Exercise	12	38.83 ± 11.04	0.964	22	0.345
	Control	12	33.25 ± 16.74			
HP-DBS	Exercise	12	71.67 ± 13.50	-1.007	22	0.325
	Control	12	76.50 ± 9.71			
VP-DBS	Exercise	12	76.08 ± 15.75	0.653	22	0.520
	Control	12	71.92 ± 15.50			
C-DBS	Exercise	12	38.83 ± 8.35	-2.028	22	0.055
	Control	12	48.50 ± 14.24			
OC-DBS	Exercise	12	48.67 ± 12.55	0.262	22	0.796
	Control	12	47.25 ± 13.94			
GBS	Exercise	12	628.92 ± 77.83	-0.184	22	0.856
	Control	12	635.42 ± 94.28			

Values are expressed as means ± standard deviations. SBS = static balance score, DBS = dynamic balance score, RL-DBS = right-left dynamic balance score, SI-DBS = superior-inferior dynamic balance score, HP-DBS = horizontal plane dynamic balance score, VP-DBS = vertical plane dynamic balance score, C-DBS = clockwise dynamic balance score, OC-DBS = opposite clockwise dynamic balance score, GBS = general balance score

Kurtosis values and it was determined that the values were in the range of (+2)-(-2) and thus the data fit the normal distribution [25]. Therefore, parametric tests were preferred in statistical analysis.

When the pre-test scores of the control and exercise groups were analysed for each balance parameter, no significant difference was found between the two groups (Table 3) ($p>0.05$). This situation showed that the two groups included in the study were not statistically significantly different from each other in terms of balance parameters and supported that the two groups were similar to each other.

When the difference between the pre and post test values of the exercise group was examined, a significant difference was found in dynamic balance scores, right and left movement, up and down movement, clockwise movement, dynamic balance scores and general balance scores ($p<0.05$). It was determined that the post-test values were higher in these parameters (Table 4). The effect of basketball training on balance scores was calculated using Cohen's d. It was found that basketball training had a significant effect on DBS, RL-DBS, C-DBS. Cohen's d values were found to be 1.00, 1.52, 1.44, respectively. When the effect of basketball training on SI-DBS and GBS values was analysed, Cohen's d values were found to be 0.75 and 0.56, respectively, and the effect level was found to be moderate.

The pre-test and post-test values of the exercise group did not differ significantly ($p>0.05$) in terms of static balance and dynamic balance scores obtained in horizontal, vertical and opposite clockwise movements.

When the pre-test and post-test measurements of the control group were compared, it was determined that the scores of static balance, dynamic balance, dynamic balance in right and left movement, dynamic balance in up and down movement, dynamic balance in clockwise and

Table 4. Comparison of mean scores of pre-post test measurements in the exercise group

Variables	n	Mean ± sd.	t	df	*p*-Value
Pre test SBS	12	86.17 ± 12.10	0.418	11	0.648
Post test SBS	12	84.92 ± 8.70			
Pre test DBS	12	51.25 ± 6.55	-5.141	11	0.000*
Post test DBS	12	58.17 ± 7.27			
Pre test RL-DBS	12	33.33 ± 8.82	-4.578	11	0.001*
Post test RL-DBS	12	44.83 ± 6.12			
Pre test SI-DBS	12	38.83 ± 11.04	-2.251	11	0.046*
Post test SI-DBS	12	46.17 ± 8.46			
Pre test HP-DBS	12	71.68 ± 13.50	-1.458	11	0.173
Post test HP-DBS	12	76.58 ± 11.34			
Pre test VP-DBS	12	76.08 ± 15.75	0.173	11	0.866
Post test VP-DBS	12	75.50 ± 11.61			
Pre test C-DBS	12	38.83 ± 8.35	-7.046	11	0.000*
Post test C-DBS	12	52.50 ± 10.50			
Pre test OC-DBS	12	48.67 ± 12.55	-1.105	11	0.293
Post test OC-DBS	12	52.92 ± 15.58			
Pre test GBS	12	628.92 ± 77.83	-2.587	11	0.025*
Post test GBS	12	670.17 ± 68.39			

Values are expressed as means ± standard deviations. SBS = static balance score, DBS = dynamic balance score, RL-DBS = right-left dynamic balance score, SI-DBS = superior-inferior dynamic balance score, HP-DBS = horizontal plane dynamic balance score, VP-DBS = vertical plane dynamic balance score, C-DBS = clockwise dynamic balance score, OC-DBS = opposite clockwise dynamic balance score, GBS = general balance score,* $p < 0.05$

opposite clockwise movements differed significantly ($p<0.05$). It was determined that this difference occurred with a decrease in the static balance score and an increase in the scores of other parameters in the post-tests (Table 5). In the control group, no difference was found between the pre-test and post-test values of dynamic balance scores in horizontal and vertical movements and general balance scores ($p>0.05$) (Table 5).

Discussion

The study was aimed to determine the effect of 8-week balance exercises on static and dynamic balance scores in children aged 7-10 years. Static and dynamic balance scores were evaluated with Level 1 training mode on TOGU Balance Disc device. As a result of the evaluation, in addition to static balance (SBS), dynamic balance (DBS), general balance score (GBS), dynamic balance scores were obtained in right left movement (RL-DBS), superior inferior movement (SI-DBS), vertical plane movement (VP-DBS), horizontal plane movement (HP-DBS), clockwise movement (C-DBS), opposite clockwise movement (OC-DBS) as sub-parameters of dynamic balance.

The study included 24 participants and the research population was selected from the age range of 7-10 years. The effect of basketball training on balance was examined in order to make the participants gain regular physical activity habits. The participants were divided into two groups as exercise group (n=12) and control group (n=12). The control group included village children living in rural areas and the exercise group included children living in non-rural areas. The children in the two groups were selected among those who did not regularly engage in physical activity. In addition to the effect of basketball on balance by selecting two different groups here, it will also be ensured to reveal whether the lack of regular physical activity of village children can be covered by higher movement capacities in living conditions and whether this situation supports the development of balance skills. Even if it was thought that the training and control groups in the study were in different populations, the pre-test results were analyzed with the Independent sample t-test to determine whether there was a difference between the two groups in terms of balance and to support the homogeneity of the two groups. As a result of the statistical analysis, the fact that no significant difference was found between the groups in the pre-test results ($p>0.05$) supports that the participant groups were similar in terms of the variables to be examined in the study.

Balance was considered to be the basic element

Table 5. Comparison of mean scores of pre-post test measurements in the control group

Variables	n	Mean	t	df	*p*-Value
Pre test SBS	12	86.92 ± 10.14	2.558	11	0.027*
Post test SBS	12	79.42 ± 12.00			
Pre test DBS	12	52.50 ± 10.01	-3.099	11	0.010*
Post test DBS	12	60.83 ± 9.45			
Pre test RL-DBS	12	33.92 ± 13.08	-2.766	11	0.018*
Post test RL-DBS	12	47.00 ± 12.02			
Pre test SI-DBS	12	33.25 ± 16.74	-2.307	11	0.042*
Post test SI-DBS	12	41.92 ± 12.26			
Pre test HP-DBS	12	76.50 ± 9.71	0.985	11	0.346
Post test HP-DBS	12	71.42 ± 15.02			
Pre test VP-DBS	12	71.92 ± 15.50	-0.592	11	0.566
Post test VP-DBS	12	74.50 ± 13.92			
Pre test C-DBS	12	48.50 ± 14.24	-3.561	11	0.004*
Post test C-DBS	12	63.00 ± 7.29			
Pre test OC-DBS	12	47.25 ± 13.94	-4.891	11	0.000*
Post test OC-DBS	12	61.67 ± 16.03			
Pre test GBS	12	635.42 ± 94.28	-1.377	11	0.196
Post test GBS	12	665.91 ± 97.44			

Values are expressed as means ± standard deviations. SBS = static balance score, DBS = dynamic balance score, RL-DBS = right-left dynamic balance score, SI-DBS = superior-inferior dynamic balance score, HP-DBS = horizontal plane dynamic balance score, VP-DBS = vertical plane dynamic balance score, C-DBS = clockwise dynamic balance score, OC-DBS = opposite clockwise dynamic balance score, GBS = general balance score, * $p < 0.05$

necessary for sustaining almost all movements [26]. In addition, balance skill was one of the necessary factors for correct posture through proprioceptors [27]. The ability to control posture and maintain balance during a movement forms the basis of physical activities [28]. Balance skill can be shaped according to the physical activity performed [29]. As can be seen, while balance skill affects performing physical activities, it can be said that physical activities have an effect on balance. In addition, it was an undeniable fact that balance was an important factor in the development of movement and the application of motor skills in children aged 7-10 years. For this reason, it was necessary to ensure the development of balance skills in children and to direct children to physical activity. It was important that the physical activities to be performed were activities that will support balance development. Especially the age group of 7-10 years was defined as the general transition phase in the period of sportive movements, in this phase, children should be directed to activities with rich content that will increase their motor skills [30]. When the literature studies were examined, it was determined that the implementation of the basic gymnastics program in preschool children positively affected balance development [31]. Tan and Çolak [32], determined that core exercises increased balance levels in children aged 8-10 years. In another study, the effect of swimming and theraband exercises on balance was examined and it was concluded that balance development was significantly increased in the group performing the two exercises [33]. In this study, the effect of regular basketball training on balance was examined. As a result of the study, after 8 weeks of basketball training, dynamic balance scores, dynamic balance scores in right and left movements, up and down movements, clockwise movements, and general balance scores increased in the exercise group. Since basketball training consists of movement patterns such as movement on one leg, shooting, sudden change of direction, etc., balance parameters may have improved positively [34, 35]. Erkmen et al. [36] examined the balance levels of athletes subjected to basketball, gymnastics, and soccer branches and found that the balance of basketball players was low compared to the other two branches. In future studies, we suggest that the effects of basketball training as well as other sportive branch training on balance should be examined.

When the control group was considered, it was determined that there was a significant increase in dynamic balance scores in dynamic balance scores, right and left movements, up and down movements, clockwise movements and opposite clockwise movements. In addition, it was determined that there was a statistical decrease in the static balance score ($p<0.05$). It was seen that similar results were obtained in terms of dynamic balance level and development of dynamic balance parameters in the exercise group and control group, but the exercise group showed better development within the scope of general balance score. The fact that the general balance scores of the exercise group increased significantly clearly showed that basketball training provides balanced development in children of this age group. The increase in dynamic balance levels in the control group may be due to the fact that the children in this group were village children living in rural areas. It was an undeniable fact that village children living in rural areas have more active living conditions than children residing in non-rural areas. The fact that children in rural areas have more playgrounds, the level of danger in their living spaces was low, and they spend more time with their friends leads these children to a more physically active life level, although they have fewer opportunities to participate in regular physical activity. When the literature was examined, Liu et al. [37], reported that physical inactivity was higher in children living in urban areas compared to those living in rural areas. In another study, it was found that inactivity level was lower in children aged 2-11 years living in rural areas compared to those living in urban areas [38]. This may be due to the fact that television time and the use of video games are more common in children living in non-rural areas [39, 40]. This may have favorably supported the development of dynamic balance parameters in the control group of the study. However, the physical activity levels of the participants were not measured within the scope of the study. This constitutes the deficiency of the study. In order to obtain a more homogeneous participant group, we suggest that the physical activity levels of the participants should also be examined in similar studies held in future.

In terms of static balance score, there was a decrease in both groups, but a statistically significant decrease was observed in the control group. In children, muscles and tendons try to adapt to the bone with disproportionate growth in the body limbs that occur as a result of growth spurts, and this process may lead to a temporary decrease in motor skills such as balance [41]. This situation may have led to a decrease in static balance levels of the participant children with the increase in height and limb length with growth. With this result of the study, it can be said that basketball training slows down the decrease in static balance level that may occur with growth.

Conclusions

In conclusion, exercise was very important for children's overall health and development. It helps to promote a lifestyle that contributes to their physical, cognitive and emotional well-being. Therefore, parents and educators should encourage and provide opportunities for children to engage in regular physical activity. In this study, the effects of basketball training on static and dynamic balance, which were important for motor development in children, were investigated and the necessity of directing children aged 7-10 years to basketball in the field for balance development was discussed. In addition, children living in rural areas were included in the study as a control group. Within the scope of the study, it was determined that 8-week basketball training provided improvement in dynamic balance levels in children aged 7-10 years. As a result of the study, it was observed that there was an improvement in dynamic balance and its sub-parameters in the control group. This result may have emerged due to the selection of the control group among children living in rural areas. The fact that children living in rural areas have more playgrounds and non-hazardous areas, the current living and environmental conditions are active in rural areas, and at the same time, even if children growing up in these conditions do not have the opportunities to participate in a regular physical activity, the fact that they have more physical motivation reasons in these living conditions suggests that their movement capacity is higher. This situation leads to an increase in the physical activity levels of children living in rural areas and, accordingly, to the development of dynamic balance. However, the physical activity levels of the participants were not revealed within the scope of the study, which is among the limitations of this study. We recommend that the physical activity levels of the participant children should be determined in similar studies to be conducted in the future and examined with the results. In addition, it was concluded that static balance level tends to decrease in children aged 7-10 years and it was thought that this may be due to growth spurts in children. It was determined that basketball training slowed down the decrease in static balance. In conclusion, basketball training offers a versatile approach to balance training in children, targeting both static and dynamic balance. It supports the development of basic physical skills, promotes injury prevention and can lead to better performance in other aspects of life. Therefore, introducing children to basketball at a young age can be highly beneficial for their long-term physical development. We suggest that future studies should examine and compare the effects of basketball training as well as regular training in other sports for balance development. Thus, it can be determined which type of physical activity children should be directed to for balance development.

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ORIGINAL ARTICLE

Characteristics of specific training in elite handball players specialized in goalkeeper position

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Abstract

Background and Study Aim Elite handball goalkeepers undergo intensive training for reflexes and advanced techniques. They develop mental toughness to handle the pressure and responsibility at key moments of the game. Thus, they protect the goal of the team. This study aims to investigate and highlight the specific training characteristics of elite handball players specialized in the goalkeeper position.

Material and Methods The best 4 goalkeepers specialized in elite handball in Romania, aged between 22 and 33 years, were selected. Specific motor tests were used: Test 1 - Jumps 15 seconds; Test 2 – Reaction speed to visual stimulus; Test 3 – Execution speed. Technical tests were used: Test specific to goalkeeper, Triangle moving, The Ten Jump, Ball throwing, Standing long jump, Passes to a fixed point; The Cooper test. To improve specific training, there were applied strategies for training optimization which include stretching for mobility, segmental muscle strength, goalkeeping specific exercises and plyometrics. The nonparametric Spearman's correlation coefficient was used to evaluate the relationship between technical training and motor skills parameters. The statistical significance level was set at $p<0.05$.

Results The performance of elite handball players specializing in goalkeeper position highlighted significant improvements in the Jumps 15 sec test. Contact time decreased by 0.13 seconds while the jump height increased by 0.55 cm, showing improved efficiency and power. In the Reaction speed to visual stimulus test, waiting time and reaction time decreased considerably, while the foot rising height increased. In the right and left leg Execution speed test, the differences observed reveal individual adaptations. The overall time is low in the right foot and there is a significant increase in the left foot. The nonparametric Spearman correlation analysis showed the relationship between the indices of technical fitness tests and the strength and speed motor skills. During Test 1 - Jumps 15 sec - 49 correlations were identified, of which 5.36% were statistically significant, highlighting strong connections between certain parameters. The analysis of Test 2 showed 56 correlations, but the lack of statistical significance reveals the absence of connections between the technical tests and the parameters of reaction speed manifestation. Regarding Test 3, a number of 28 correlations were identified. The lack of statistical significance suggests the absence of significant correlations between the technical tests and the execution speed.

Conclusions The performances of elite handball goalkeepers show significant improvements in motor and technical skills, highlighting the effectiveness of specific training and its adaptability. The progress in jumping and reaction speed indicates essential improvements for goalkeeping success, emphasizing the necessity for personalized and holistic training.

Keywords: elite athletes, tests, physical fitness, performances, correlation analysis, training strategies

Introduction

Success in competitive sports is influenced by a wide range of factors, including constitutional, conditional, coordinative, technical, psychological and tactical ones. These factors are specific to each position in team handball and are particularly important in the dynamics of the game [1]. The evolution of elite handball led to significant

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improvements in the speed and complexity of the game. The goalkeeper is less used in the attack phase; the outstanding performances result from the close collaboration between attacking and defending actions. To reach an elite level in handball requires extraordinary physical and psychological characteristics [2, 3, 4].

Sports training becomes crucial in the evolution of modern handball. The training is adapted to the diversity and complexity of the game. In order to study the various aspects of ball handling, the goalkeeper must benefit from systematic training sessions. The increased requirements of the game lead to the necessity of a specific training meant to improve performance. Training recommendations include strength and power, coordination and endurance exercises adapted to the specifics of elite handball. Goalkeeper training should focus on developing the playing position specific skills to cope with the various demands of the game [5, 6, 7, 8].

Handball is characterized by frequent changes of intensities and by different complex movements during games. Physical performance is often tested predominantly, using standardized general tests. Determining the relationship between specific and general physical performance and also between specific aerobic capacity and agility is relevant to the specialists in strength and conditioning. In the context of the handball game, general motor training, for goalkeeper inclusively, is essential in sports performance. It is subordinated to other individual aspects such as specific training, attitude and behavior. The training and development of the general motor capacity of the goalkeeper is a fundamental objective in preparation and competition. Specialized programs, including plyometric exercises for explosive power, reaction speed and dexterity, contribute to the improvement of players' performance. These programs have a significant impact on the dynamics of handball game at national and international level [9].

The complexity of handball actions, characterized by fast and demanding executions at muscular level, requires a general and specific physical training able to improve the playing strength. These exercises help to improve the performance in the game. They facilitate the body rapid adaptation to game requirements, while protecting the joints and muscle structures [9].

Handball, a fast and dynamic sport, foregrounds the essential role of the goalkeeper, but scientific research pays little attention to the development of this one. The efficiency of each player during a match is very important for victory. The goalkeeper has a vital role in the team defense. For understanding the interactions between goalkeeper and opposing players, a proper analysis is required. The development and training of goalkeepers in elite handball is a priority. It must be addressed with special attention in order to ensure superior results for the team in competition [1, 10, 11].

According to Rizescu, the main task of handball goalkeeper is to prevent the ball from entering his own goal. This requires conscious activity based on clear tactical rules, developed through observation and analysis and supported by experience and tactical intuition, on the part of the athlete and the coach as well [16].

In handball, the training of the players specialized in goalkeeper position usually starts at the age of 10 - 12 years. It involves the accumulation of technical-tactical skills useful for both field players and goalkeepers. Coaches face difficulties in selecting and training goalkeepers as most debutants want to play in attacking positions. Advanced players focus on diversifying the shots towards the goal and anticipating the movements of the opponents. Goalkeepers must understand the intentions of the opposing players and adapt the defense technique according to the type of shot. In the advanced stages, goalkeepers must have thorough knowledge of the game and be able to influence the final result of the game. The coach has a key role in the development of goalkeepers, tailoring the training to the individual needs of these ones [1, 10, 17].

In elite handball, the need to increase strength and speed in the technical-tactical executions entails the rapid adaptation of the training to the requirements of each body segment involved in playing. This aspect is one of the training priorities for the specialized goalkeepers. The use of specific exercises for general and special physical training can generate significant improvements in their motor skills. A training aiming at the development of the specific motor capacity, focused on the strength-speed ratio, can have a major impact on the goalkeeper's performance in all levels of elite handball [10, 18].

Purpose of the Study. The study purpose was the investigation and highlighting of the specific training characteristics in elite handball goalkeepers.

Materials and Methods

Participants

The best 4 players (P) of the Romanian elite handball specialized in goalkeeper position participated in this experiment. The subjects are: P1 (33 years old), player at the Saint Raphael Club, France – member of the Romanian National Team; P2 (24 years old), player at the Tatabanya Club, Hungary –University World Champion; P3 (22 years old), player in H.C. Minaur Baia Mare, Romania - member of the Romanian National Team and P4 (26 years old), player at HC Vaslui, Romania - member of the Romanian National Team. The consent of the subjects was required and signed before starting the research according to the Declaration of Helsinki.

It was approved by the Ethics Committee of the Doctoral School of Sport Science and Physical Education (ID: 07/24.07.2023), University of Pitesti, Romania.

Research Design

The longitudinal experiment was conducted along the 2017-2018 competitive year at the Romanian National Handball Team level, with players specialized in goalkeeper position(n=4).

The fitness tests selected for the assessment of specific motor ability were also validated by the national team coaches. Some of these tests are also used as means of specific training. These fitness tests were passed by the research subjects during the centralized training stage in Cluj Napoca. They were also passed within the Human Performance Research Center of the Doctoral School of Physical Education and Sport Science, University of Pitești.

Due to the small sample of subjects, it was agreed to choose the study of case as research method. In our opinion, this method will be able to create a representative database. This one could be used for other players specialized in goalkeeper position of equivalent or even lower performance levels.

Tests specific to the evaluation of motor skills:

Test 1: Jumps 15 seconds. It consisted in the continuous execution, for 15 seconds, of vertical jumps on both legs. The starting and returning position was a semi-flexion at the knee joint level. The following parameters were measured for each jump: contact time (TCont. [s]); flight time (TFlight. [s]); jump height (Height [cm]; power (Power [W/Kg]); pace (Pace [step/s]); reactive strength index (RSI [m/s]).

Test 2: *Reaction speed to visual stimulus*. It was measured using the Opto Jump Next optical system. It consisted in the measurement of the following parameters expressed in seconds and centimeters: Twait [s] – waiting time between signals; TReac. [s] –reaction time; TFlight [s] – flight time (time when the subject is not in contact with the ground); Height [cm] – the height at which the foot (sole) rises from the ground. The visual stimulus was represented by the color change of a graphic element that could be viewed on the computer monitor. When the color changed (from red to green), the subject had to lift his foot off the ground as quickly as possible. The system measured simultaneously the parameters mentioned above.

Test 3: Execution speed. It was measured by means of Witty timing electronic system. The test involved the execution during 10 sec of successive entero-lateral flexion movements of the thigh on the trunk, specific to goalkeepers. The movements were performed so that the knee of the swinging leg passed in front of the Witty system. This one measured the number of passes and the time in which they were done.

Fitness tests for technical training:

1) *Test specific to goalkeeper* (PS, sec). The goalkeeper is in basic position in point 1 of the triangle. He takes side steps to points 2, 3 and returns to point 1. Then he sprints sideways 3 m from point 1 and picks up one ball in the sequence a; b; c; d. He throws the ball into the opponent's goal without going beyond the semicircle of 6 m. After each throw, the triangle is repeated starting from point 1. The same is done until all 4 balls are thrown. The period elapsed between the departure from point 1 up to the dropping of the last ball is timed.

2) *Triangle moving* (DT, sec). A triangle is drawn whose base is the 3 m straight line of the 6 m semicircle. From the middle of the base, a perpendicular of 3 m rises up to the dotted semicircle. This will be the height of the isosceles triangle. The sides of the triangle are marked by joining the 3 points thus obtained. A 30 cm diameter circle is drawn at the top of each of the 3 angles and tangent to them. The athlete is initially facing the top of the triangle. His left foot is placed in the center of the circle to the left of the triangle base. When the test starts, the athlete moves with side steps to the right, forwards, backwards and to the left. He must touch successively all the circles, in a complete route there and back formed of the triangle sides. The test entails covering this route 3 times, without stopping. The moving technique with side steps, forwards and backwards, specific to defense playing in handball, is constantly used.

3) *The Ten jump* (DS, m). It consists of taking 10 jumping steps, from standing position, one foot placed on the ground, behind the starting line. The subject is allowed a single take-off and the jumps must be performed without interruptions – 10 jumps in a row. It is forbidden to stop and stand between jumps. The distance will be measured from the starting line up to the last mark left by the athlete's heel when landing.

4) *Throwing the ball at a long distance, with 3 step run-up* (AMH, m). The throw shall be performed from behind a line drawn on the ground. This line cannot be touched or crossed before the ball has gone beyond the hand of the thrower. The run-up can use the technique of crossed step, side step or leap step.

5) *Standing long jump* (SLL, cm). It is executed from behind a line drawn at the center of the court. The distance is measured between the tip of the shoes at jumping moment and their heel at the landing moment.

6) *Passes to a fixed point* (PPF, no. of reps). The goalkeeper is in the center of the goal, in basic position. At the signal, he picks up a ball and throws it towards a fixed point (a 200cm x 150 cm mat) placed vertically in the center of the court. The number of passes to a fixed point from 10 attempts is counted.

7) *The Cooper test* (TC, m): a 12 minute run test. The covered distance is measured.

Strategies to optimize the training:

1) Stretching exercises meant to improve coordination, balance, mobility and flexibility of joints, strength of different muscle groups; exercises to improve dexterity; exercises with rubber bands.

2) Exercises for the development of segmental muscle strength:

- exercises for abdominal and thigh muscles with 10 kg dumbbell on shoulders;

- exercises consisting of jumping on and over small obstacles of 40 cm;

- low-weight exercises to improve strength-speed ability for the upper body muscles;

- exercises for the physical training of strength-speed ability for abdominal and back muscles;

3) Exercises specific to goalkeeper's playing in the handball goal. The purpose is to improve the movements in goal area and to complete the basic positions of the goalkeeper play. Exercises used: quick left-right movements with side steps across the handball goal width; standing in the center of the goal; alternately moving the leg to the left and to the right etc.

4) Plyometric exercises (single leg exercises: jumping from one cube to another from standing on one leg; alternate jumping from one foot to the other over 7 cubes 40 cm high placed at a distance of 50 cm one from another; standing on one leg, the hands put on the gym bench – jumping from one foot to the other in a limited area; standing in the middle of the handball goal, with balls suspended left and right side, at 1 m from the goalkeeper. Alternate swings are performed with the leg on the same side, accompanied with arm movements up and down).

Statistical Analysis

The statistical indicators were calculated using the KyPlot 6.0 (©1997-2020, KyensLab Inc) program, in terms of Median, Standard Deviation (SD), Coefficient of Variation (CV%), Confidence Level of Mean (0.95) and Confidence Limit of Mean. The nonparametric Spearman's correlation coefficient was applied to evaluate the relationship between technical training and motor skills parameters in the elite handball goalkeepers. Statistical significance was set at $p < 0.05$.

Results

The specific training particularities in the elite handball players specialized in goalkeeper position were highlighted. This was done by evaluation and comparative analysis of the manifestation characteristics of strength and speed combined motor skills and their technical training level.

The results of the research are shown in tables 1, 2, 3 and 4.

The results of test 1 (Jumps 15 sec, table 1) reveal the improvement in performances of the measured parameters. Thus, the median increased by 2 jumps and the Confidence Level of Mean (0.95) (CLM) decreased by 0.47. There is a decrease by 0.33 in Confidence Limit of Mean Lower & Upper (CLM-L&U) of the size of intervals between tests. TCont. (sec) decreases by 0.13 sec between tests and both

Table 1. The results of lower limbs power in Jumps 15 seconds testing of elite handball players specialized in goalkeeper position, n=4

Variables		Median ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
					Lower	Upper
No. of jumps	Initial	12.00 ±2.48	21.44	1.05	10.53	12.63
	Final	14.00 ±1.38	10.29	0.58	12.79	13.96
TCont. (sec)	Initial	0.61 ±0.09	14.15	0.07	0.58	0.71
	Final	0.59 ±0.08	12.44	0.05	0.54	0.65
TFlight (sec)	Initial	0.47 ±0.02	3.82	0.01	0.45	0.48
	Final	0.47 ±0.02	4.72	0.01	0.46	0.48
Height (cm)	Initial	27.01 ±1.99	7.49	1.29	25.36	27.94
	Final	27.56 ±2.44	9.14	1.45	25.84	28.74
Power (w/kg)	Initial	19.89 ±1.46	7.50	1.01	18.46	20.47
	Final	20.49 ±1.84	9.19	1.14	19.49	21.76
Pace (step/s)	Initial	0.92 ±0.07	7.53	0.05	0.86	0.95
	Final	0.95 ±0.05	6.01	0.03	0.91	0.98
RSI (m/s)	Initial	0.44 ±0.06	14.78	0.04	0.38	0.47
	Final	0.46; ±0.07	15.79	0.04	0.43	0.52

Values are expressed as Median ± Standard Deviations (SD), CV – coefficient of variation; RSI – reactive strength index.

Table 2. Results of left and right foot speed of reaction to visual stimulus in the elite handball players specialized in goalkeeper position, n=4

Variables			Median ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
						Lower	Upper
Right foot	TWait (sec)	Initial	4.43 ±0.75	16.72	0.48	4.02	4.97
		Final	4.32 ±0.84	18.69	0.53	3.97	5.04
	TReac. (sec)	Initial	0.45 ±0.04	9.98	0.03	0.42	0.48
		Final	0.42 ±0.04	9.80	0.03	0.41	0.46
	TFlight (sec)	Initial	0.19 ±0.05	24.39	0.03	0.17	0.23
		Final	0.21 ±0.07	36.9	0.04	0.14	0.23
	Height (cm)	Initial	4.50 ±2.36	47.26	1.49	3.49	6.49
		Final	5.70 ±2.83	56.56	1.79	3.21	6.81
Left foot	TWait (sec)	Initial	4.86 ±0.74	15.61	0.47	4.26	5.20
		Final	4.79 ±0.67	14.58	0.43	4.21	5.07
	TReac. (sec)	Initial	0.44 ±0.02	5.43	0.01	0.43	0.46
		Final	0.43 ±0.02	5.28	0.01	0.42	0.45
	TFlight (sec)	Initial	0.20 ±0.07	34.01	0.20	0.17	0.26
		Final	0.22 ±0.07	33.11	0.05	0.17	0.27
	Height (cm)	Initial	5.15 ±4.09	63.43	2.59	3.85	9.05
		Final	5.75 ±4.41	67.17	2.80	3.76	9.37

Values are expressed as Median ± Standard Deviations (SD), CV – coefficient of variation.

Table 3. Results of execution speed of the right and left foot in the handball players specialized in the goalkeeper position, n=4

Variables			Median ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
						Lower	Upper
Right foot	No. of reps	Initial	13.5 ±3.11	23.03	4.95	8.55	18.45
		Final	13.5 ±2.94	21.03	4.68	9.31	18.68
	Time (sec)	Initial	9.75 ±0.29	3.01	0.46	9.20	10.13
		Final	9.74 ±0.17	1.76	0.27	9.47	10.01
Left foot	No. of reps	Initial	14.5 ±1.71	11.98	2.72	11.53	16.97
		Final	15.00 ±1.91	13.20	3.05	11.45	17.55
	Time (sec)	Initial	9.48 ±0.35	3.69	0.56	8.95	10.07
		Final	9.67 ±0.41	4.28	0.65	8.97	10.28

Values are expressed as Median ± Standard Deviations (SD), CV – coefficient of variation

CLM and CLM-L&U have a decrease by 0.02 sec. TFlight (sec) keeps the value of 0.47 sec; CLM and CLM-L&U decrease by 0.01 sec. Height (cm) increases the median by 0.55 cm, CLM increases by 0.16 cm and CLM-L&U by 0.32 cm. Power (w/kg): it increases the median by 0.6 w/kg; CLM increases by 0.13 w/kg and CLM-L&U increases by 0.26 w/kg. Pace (step/s) increases by 0.03 step/s, CLM and CLM-L&U decrease by 0.02 step/s. RSI (m/s) increases by 0.02 m/s; CLM has the same value of 0.04 m/s and CLM-L&U has 0.09 m/s. All these differences between tests in the analyzed parameters highlight the characteristics of lower limbs power in a short time. This is considered a specific particularity of the elite handball players specialized in goalkeeper position.

The results of test 2 (left and right foot speed of reaction to visual stimulus) of elite handball goalkeepers are shown in table 2. The analysis of the differences in the measured parameters reveals the following values:

- *right foot* – Twait (sec): the wait time decreases by 0.11 sec, CLM increases by 0.05 sec and CLM-L&U increases by 0.12 sec the size of intervals between tests. TReact. (sec): the reaction time decreases by 0.03 sec, CLM has the value of 0.03 sec and CLM-L&U has 0.02 sec. TFlight (sec): the flight time increases by 0.02 sec, CLM increases by 0.01 sec and CLM-L&U increases by 0.03 sec. Height (cm): the height of sole rising increases by 1.2 cm, CLM increases by 0.3 cm and CLM-L&U by 0.6 cm.

Table 4. Results of technical training of elite handball players specialized in goalkeeper position, n=4

Variables		Median ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
					Lower	Upper
PS (sec)	Initial	32.01 ±2.17	6.72	3.45	28.87	35.79
	Final	28.82 ±1.43	4.71	2.27	28.07	32.61
DT (sec)	Initial	15.17 ±0.58	3.83	0.93	14.31	16.17
	Final	14.45 ±0.35	2.39	0.55	13.98	15.08
DS (m)	Initial	29.00 ±1.11	3.83	1.77	27.23	30.77
	Final	29.8 ±1.21	4.05	1.92	27.83	31.67
AMH (m)	Initial	47.75 ±2.90	5.95	4.62	44.13	53.37
	Final	49.75 ±2.96	5.83	4.71	46.04	55.45
SLL (cm)	Initial	252.5 ±12.5	4.93	19.89	233.86	273.64
	Final	265.0 ±8.16	3.08	12.99	252.01	277.99
PPF	Initial	6.50 ±1.29	19.86	2.05	4.44	8.55
(no. of passes)	Final	8.00 0.82	10.21	1.29	6.70	9.29
TC (m)	Initial	2825 ±64.55	2.28	102.71	2722.28	2927.71
	Final	2925 ±47.87	1.63	76.17	2861.33	3013.67

Values are expressed as Median ± Standard Deviations (SD), CV – coefficient of variation.

All differences between the measured parameters in tests highlight the characteristics of left and right foot reaction speed to visual stimulus.

- *left foot* - TWait (sec): wait time decreases by 0.07 sec, CLM decreases by 0.04 sec and CLM-L&U increases by 0.08 sec in the size of intervals between tests. TReact. (sec): the time of reaction decreases by 0.01 sec, CLM maintains the value of 0.01 sec and CLM-L&U has 0.03 sec. TFlight (sec): the flight time increases by 0.02 sec, CLM decreases by 0.21 sec and CLM-L&U increases by 0.01 sec. Height (cm): height of sole rising increases by 0.6 cm, CLM increases by 0.21 cm and CLM-L&U by 0.41 cm.

The results of test 3 (execution speed of right foot and left foot, 10 sec) of elite handball goalkeepers are presented in table 3. The analysis of the differences in the measured parameters highlights, for the right foot, the following values: the same number of reps (13.5) between tests, a decrease of CLM by 0.27 reps and a decrease by 0.53 reps of CLM-L&U in the size of intervals between tests. The execution time decreases by 0.01 sec, CLM decreases by 0.19 sec and CLM-L&U decreases by 0.54 sec. Regarding the left foot, the number of reps increases by 0.5 executions. CLM increases by 0.33 reps and CLM-L&U by 0.66 reps. The execution time increases by 0.19 sec, CLM increases by 0.09 sec and CLM-L&U by 0.19 sec. These differences in the measured parameters show the characteristics of the execution speed between segments (right and left foot) in the elite handball players specialized in goalkeeper position.

The results of technical training in the elite handball players specialized in goalkeeper position are listed in table 4. The comparative analysis reveals differences in the fitness tests as follows: in the case of PS (sec) – specific test - the median value decreases by 3.18 sec, CLM decreases by 1.18 sec and CLM-L&U decreases by 2.38 sec in the size of intervals between tests. As for DT(sec) – triangle moving – it decreases by 0.72 sec, CLM decreases by 0.38 sec while the size of the intervals between tests at CLM-L&U decreases by 0.76 sec. In DS (m), ten-jump test increases by 0.8 m, CLM increases by 0.15 m while the size of the intervals between tests at CLM-L&U increases by 0.3 m. In terms of AMH (m), throw of the handball – it increases by 2.0 m, CLM increases by 0.09 m and CLM-L&U increases by 0.17 m in the size of the intervals between tests. In SLL (cm) - standing long jump – it increases by 12.5 cm, CLM decreases by 6.9 cm while the size of the intervals between tests at CLM-L&U decreases by 13.8 cm. Regarding PPF (no. of passes)- passes to a fixed point – it increases by 1.5 passes, CLM decreases by 0.76 passes while CLM-L&U decreases by 1.52 passes in the size of the intervals between tests. TC (m) - the Cooper test – increases the distance by 100 m, CLM decreases by 26.54 m and the size of the intervals between tests at CLM-L&U decreases by 53.09 m.

The relationship between the indices of the technical tests and the strength-speed motor skills was determined through the nonparametric Spearman's correlation analysis. The results of the analysis are presented in Figures 1, 2 and 3.

The analysis of the technical tests' indices with the parameters of manifestation of lower limbs power in test 1 - Jumps 15 sec (fig. 1) – reveals 49 correlations (65.3% negative and 42.8% positive). In terms of statistical significance of correlations, one can observe 5.36% strong connections at $p<0.05$ ($r=1.00$) between PS with TWait (left foot) and DS with TFlight, Height (right foot) and TWait (left

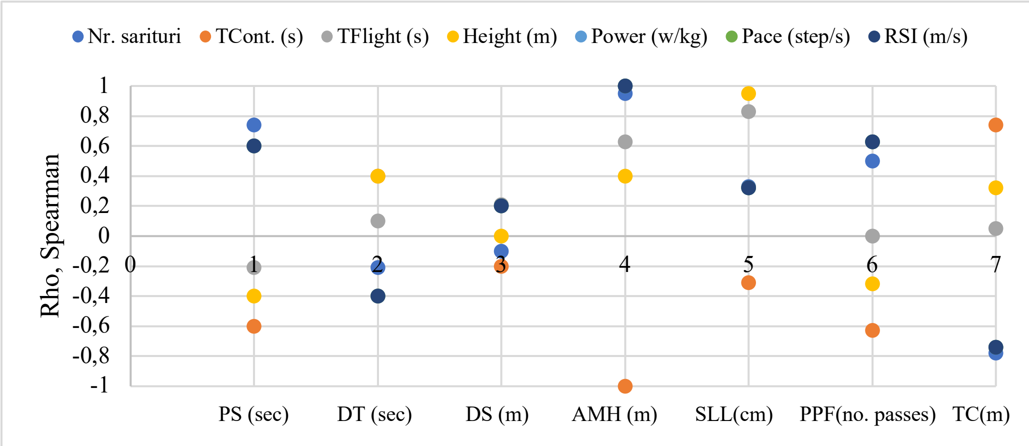


Figure 1. Relationship between technical training indices and parameters of the Test no 1, Jumps 15 sec, in the elite handball players specialized in goalkeeper position

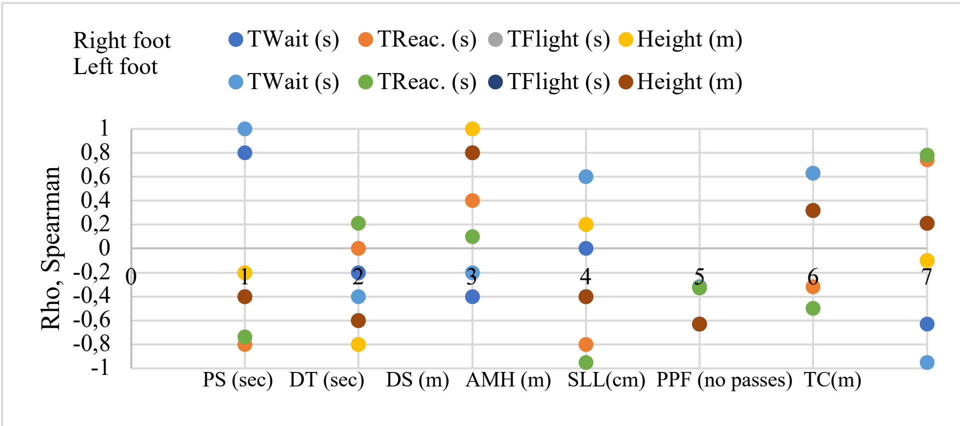
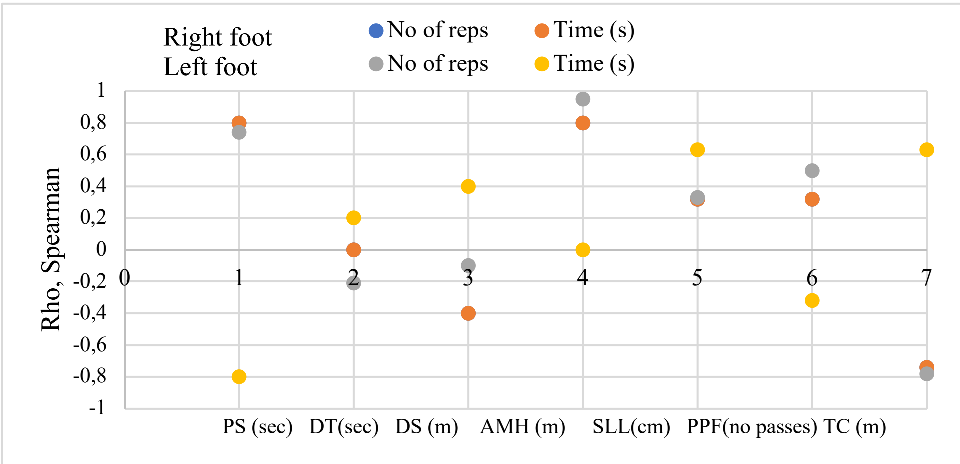


Figure 2. Relationship between the technical training indices and the test parameters of the reaction speed to visual stimulus in the case of the elite handball players specialized in goalkeeper position



Figbre 3. Relationship between the indices of technical training with the parameters of execution speed test in the elite handball players specialized in goalkeeper position

foot). The statistical insignificant correlations at p>0.05 (r=>0.75) have 4.08% strong connections and 32.6% (r=>0.5<0.75) moderate connections.

The analysis of the technical tests' indices with the manifestation parameters of the reaction speed of the left and right foot to visual stimulus in test 2 (fig. 2) shows 56 correlations (57.2% positive and 34.7% negative). As for the statistical significance, there is a lack of correlations. The statistically insignificant correlations at p>0.05 (r=>0.75) are 16.07% strong connections and 23.2% (r=>0.5<0.75) moderate connections.

The analysis of the technical tests' indices with the manifestation parameters of the execution speed with the right foot and left foot - test 3 (fig.

3) – highlights 28 correlations (71.4% positive and 28.6% negative). Regarding the degree of statistical significance, one can observe the absence of correlations. In terms of statistically insignificant correlations at p>0.05 (r=>0.75) there are 25% strong connections and 21.4% (r=>0.5<0.75) moderate connections.

All these correlation relationships express the degree of connection between the measured variables. They can be considered characteristics of the specific training of elite handball players specialized in goalkeeper position.

Discussion

The characteristics of the specific training of elite handball goalkeepers were highlighted through the comparative analysis of the motor tests parameters and the applied technical tests. The fitness tests are recommended by the specialists in the field [11]. These tests were part of those imposed by the Romanian Handball Federation for participation in the National Championships. Each test had minimal performance scales.

Regarding the characteristics of motor tests evaluation, a significant improvement in the performance of elite handball goalkeepers is noticed in the Jumps 15 sec Test. The Contact time (TCont.) decreased by 0.13 seconds, suggesting better ground contact efficiency during jumps. Flight time (TFlight) remained constant at 0.47 seconds, which proves that stability is maintained during flight. Jump height (Height) recorded an important increase of the median by 0.55 cm, while (Power) increased by 0.6 w/kg, indicating an improvement in the ability to generate power during jumps. Also, the reactive strength index (RSI) increased by 0.02 m/s, highlighting an improvement in the rate of power generation during jumps. These results reveal a positive evolution of short-term characteristics of lower limbs strength in these players specialized in goalkeeper position. Studies point out the similarity of performance abilities between the positions of elite handball players. It is suggested that one-foot horizontal jump distance may be an index of sprinting ability [19]. Anthropometric and strength level analysis shows that the position in team is influenced by these characteristics. High-intensity interval system is preferred for performance improvement due to greater specificity of the game [20]. In Test 2 – Reaction speed to visual stimulus, a significant improvement in waiting time and reaction time at both legs was observed in the elite handball goalkeepers. This improvement reveals specific adaptations and adjustments in the process of reaction and execution of the jump. Also, the height of sole rising (both feet) recorded significant increases that point out an improvement in jumping performance. In Test 3 – Execution speed on right and left leg, important differences were noticed between the right and left leg in terms of number and time of repetitions. They indicated individual adaptations and changes in the execution technique at the level of each leg. These results highlight the specific characteristics of the reaction and execution speed of each leg. The results also reflect the individual adaptations of the elite handball goalkeepers in the context of evaluation tests. Studies analyze morphologic characteristics and motor skills according to the playing position in handball game. Notable differences were revealed between positions in terms of physical characteristics and motor performance. The results provide coaches with essential information that enable them to design efficient training programs for success in handball [21, 22, 23, 24].

Elite handball goalkeepers had significant improvements in fitness tests, namely a decreased time in the specific tests, such as PS and DT, showing greater efficiency and agility. Additionally, the increase in distance in the DS and AMH tests demonstrate an improvement in power and accuracy. The increased height in the SLL test proves better jumping ability. Furthermore, the increase in the number of passes in the PPF test suggests an improvement in the accuracy and efficiency of the passes. The increase of the distance in the Cooper Test indicates better endurance and running ability. This progress highlights the sustained efforts and the dedication of the players in developing the skills needed to reach high performance in handball game.

The training of handball goalkeeper is essential and should be varied for mobilizing the entire energy potential of the body. There were applied strategies for training optimization that led to better results. The training is meant to build the technique elements; excellent physical fitness and constant commitment are required for this purpose [25]. Some specialists studied the elite handball goalkeepers' actions during shots. They concluded that the shots from all positions should be taken into consideration in order to increase the area of saves [26]. To improve the sports performance of all handball players (including goalkeepers), individualized training programs are highly important. These ones focus on specific physical and technical requirements on the playing field, aiming to develop techniques and tactical activities. These programs are adapted to the dynamics of the game and the particularities of the playing positions [27, 28]. The importance of adequate rotations of the players for keeping an optimal level of physical performance in elite men's handball was also analyzed [29].

The Spearman's nonparametric correlation analysis for elite handball players specialized in goalkeeper position reveals the following findings. Test 1 - *Jumps 15 sec* - shows notable correlations between the specific tests and the waiting time for left leg. Significant correlations were identified between the Ten jump and the flight time, the height for the right leg and the waiting time for the left leg. But there were found out statistically insignificant correlations as well. As for Test 2 – *Reaction speed to visual stimulus* - the lack of significant correlations indicates the absence of connections between technical tests and parameters of reaction speed manifestation. Similarly, in Test 3 – *Execution speed* – the lack of statistical significance highlights the absence of significant correlations between technical tests and the parameters of execution speed manifestation. These correlation relationships suggest a changing degree of connection between the variables measured in technical tests and the strength and speed motor skills. A relevant insight is provided into how technical skills may or may not relate to motor characteristics. The detailed analysis of these correlations contributes to a deeper understanding of the specific training of elite handball goalkeepers.

Recent studies point out significant statistical relationships in elite handball that can influence the selection of players, the training and match strategies. Almeida et al. found that the efficiency of wings and the blocking were key variables that changed over several editions. The top teams had taller players, with international experience and higher efficiency in the actions from 9 meters and wing. They blocked more defense throws [30]. The study of Horníková et al. focused on the relationship between reactive agility and other performance components in handball players. Significant connections were identified between Y-shaped agility and the 20 m sprint running. Also, important connections were found between reactive agility and force-time ratio but not with reaction speed [31]. Regarding the study of Hatzimanouil et al., there were analyzed statistics about goalkeepers' playing and their relevance to the team final ranking in the European Men's Handball Championship 2020. The importance of saves and the efficiency from 9 m proved to be significant for the success of the team [32]. Other specialists) compared the anthropometric data and physical performance characteristics between different playing positions in professional team handball. Close correlations were found between these aspects, providing useful information for talent identification and assessment. The information provided was also used for the development and optimization of the necessary training programs specific to the playing position [33, 34].

Several studies addressed the concerns regarding the training and performances of handball goalkeepers. Pori et al. examined the connections between motors skills and performance in goalkeepers. The authors suggested that other characteristics, like perceptual skills or experience, could influence competitive effectiveness more than the analyzed motor skills [35]. Santos and Menezes investigated the ages recommended for the specialization of handball players. They also offered helpful information about the planning of the training and the long-term specialization in handball [36]. Justin et al. focused on the impact of height and body mass on the performance of goalkeepers. The specialists concluded that tall goalkeepers are preferred, but other aspects such as perceptual-motor skills must be also considered [37]. The study of Mohoric et al. revealed the differences in morphological and performance characteristics of elite handball players according to playing positions and age categories. Valuable data are provided for the development of talent identification and training programs [38]. Massuca et al. demonstrated the influence of aerobic capacity on handball players' performance depending on the playing positions [39]. Hansen et al. identified a significant relationship between the statistics of the saves made by goalkeepers' and the final ranking of teams. They identified the importance of individual performance in the success of the team [40]. Le Menn et al. analyzed how an expert handball goalkeeper manages incertitude during competitions. They offered a more thorough understanding of the performances of an expert in sport [4]. Michalsik et al. highlighted the physical requirements that elite handball players must meet, with an emphasis on the position-specific training and on the anaerobic and strength training [41]. Bøgild et al. examined anthropometric and physiological characteristics of performance in national handball teams, revealing differences between playing positions [42].

The comprehensive training program aims to optimize handball goalkeeping performance. It addresses physical fitness and skill development through various exercises. These include stretching exercises, segmental muscle strength exercises, goalkeeper-specific drills, and plyometric exercises. This well-rounded approach ensures success in the position. [43].

These studies contribute to the complex understanding of the training and performance of handball goalkeepers, providing essential information for coaches and sport researchers.

Conclusions

Performances of elite handball players specialized in the goalkeeper position had important improvements in Jumps 15 sec test. Thus, the number of jumps increased, the contact time decreased, the height and strength increased, showing an improved efficiency and stability during jumps. It was also found out a better rate of strength development.

The reaction speed to visual stimulus test recorded significant decreases in waiting time and reaction time in both legs. The flight time increased slightly. The height of sole rising of both legs recorded increased. So, the manifestation characteristics of speed reaction of both legs to visual stimulus were revealed.

Regarding the test on Execution speed of the right and left leg, the number of repetitions remained constant in the right leg. The total time in which the repetitions were performed decreased. As for the left leg, the number of repetitions increased significantly and the total time of the reps had also a serious increase. This fact highlighted the execution speed characteristics of the right and left foot in the elite handball goalkeepers.

The results of technical training in the elite handball goalkeepers show important improvements in several fitness tests, reflecting progress in their technical skills. These differences indicate the progress made in the technical training of the elite handball players specialized in goalkeeper position. They reflect the players' efforts and dedication in developing the skills necessary for higher performance in the game.

The conclusion of the correlation analysis suggests that the connection between technical skills and motor characteristics may vary depending on the test type. So, a notable insight into the specific training of elite handball goalkeepers is provided.

Limitations of the research

• Insufficient research papers on the individualized training at the level of elite handball teams.

• Lack of easily accessible specialized equipment for the evaluation of performance capacity, with a high degree of applicability in increasing the handball players' performance.

• Lack of specialized coaches for the individualized training of handball players specialized in the goalkeeper position.

Considering these limitations is essential for the correct interpretation of the results and for the formulation of relevant and valid conclusions within the research on the specific training of the elite handball goalkeepers.

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Conflict of interest

There are no conflicts of interest to declare.

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