

ISSN 2664-9837

PEDAGOGY

of Physical Culture
and Sports

№04/2023



Key title: Pedagogy of Physical Culture and Sports (Abbreviated key-title: Pedagogy phys. cult. sports; ISSN 2664-9837).

Founders: Iermakov Sergii Sidorovich (Ukraine); (doctor of pedagogical sciences, professor).

Certificate to registration: KB 24393-14233IIP 13.03.2020.

Previous title «Pedagogics, psychology, medical-biological problems of physical training and sports» (e-ISSN 2308-7269; p-ISSN 1818-9172; ISSN-L 2308-7269).

Frequency – 6 numbers in a year.

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<https://www.sportpedagogy.org.ua>

INDEXING

Web of Science Core Collection - [Emerging Sources Citation Index (ESCI)] - http://mjl.clarivate.com/cgi-bin/jrnlst/jlresults.cgi?PC=MASTER&ISSN=*2664-9837

Scopus - <https://www.scopus.com/sourceid/21101040604>

DOAJ (Directory of Open Access Journals) - <https://doaj.org/toc/2664-9837>

ERIH PLUS (The European Reference Index for the Humanities and the Social Sciences) - <https://dbh.nsd.uib.no/publiseringskanaler/erihplus/periodical/info?id=497967>

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Dimensions - https://app.dimensions.ai/discover/publication?search_text=10.15561%2F26649837.&search_type=kws&search_field=doi

Crossref - <https://search.crossref.org/?q=2664-9837>

Open Ukrainian Citation Index (OUCI) - <https://ouci.dntb.gov.ua/en/editions/E1DygdjZ/>

MIAR - <http://miar.ub.edu/issn/2664-9837>

ResearchGate - https://www.researchgate.net/journal/2664-9837_Pedagogy_of_Physical_Culture_and_Sports

Hinari Access to Research for Health - http://extranet.who.int/hinari/en/journal_keyword_search.php?query=Pedagogy+of+Physical+Culture+and+Sports

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The motor competency level of elderly people measured by Functional Movement Screen-protocol

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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 aim of the study is to determine the level of fundamental skills which consist of motor competence such as balance, mobility, and stability.

Material and Methods The study has been conducted with people living in the elderly home “Jetimat e Ballkanit” who are representative of these people’s category living in Kosovo. 10 women and 10 men aged 50-65 were included in the study on a voluntary basis. The height, body mass, and all body composition, such as Body mass index, Body fat percentage, Body water, Muscle mass, Bones, Kilocalories, and Visceral Fat, were measured with medical scales (Tanita BC 545 N Innerscan Segmental Personal Body Analysis). Functional Movement Screen is composed of the Deep Squat, Hurdle Step, Incline Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability Push-Up, Rotary Stability, were applied. The SPSS 26 packet was used in the data analysis. Categorization of the participants with pain, low, average, and high ability were made by using frequency statistics. Differences between genders and right/left extremities were made by using Independent-Samples T-Test. Also, a regression Linear model and the Backward Elimination method were applied.

Results Gender and right/left dominancy analysis of the Functional Movement Screen scores has shown that no statistical differences appear in the data analyzed in the study ($p > 0.05$). The frequency analysis has shown that 11.1-22.2% of the people living in the elderly home have pain while applying the movements. 24.06% of them have shown low ability in the Functional Movement Screen protocol, 30.39% seem to have a normal level of functionality. There are just 37.01% of them who resulted to be in good condition based on the Functional Movement Screen protocol.

Conclusions The analysis of the study concludes that the lacking of functionality in the motor competency level of elderly people may occur from their nutrition. That, is reflected in motor competency level through decreases in muscle mass, bone density, and increases in fat percentage, body mass index, and body weight

Keywords: movement deficiency, limitations, asymmetry, body composition, motor skills, Functional Movement Screen

Introduction

As motor competence can be defined as a person’s ability to execute a wide range of motor acts in a proficient manner. Coordination of fine and gross motor skills that are necessary to manage everyday tasks, such as walking, running, jumping, catching, throwing, etc [1, 2, 3, 4], are crucial for the elderly people. They help them have an optimal level of the skills which carry out the motor competency such as balance, mobility, stability, coordination, etc. Each person wants to be able to perform fundamental movements without pain and limitations, whether one is an employee, a constructor, a competitive athlete, or a recreational. To detect abnormal movement patterns, range of motion (ROM) limitations, limb asymmetries, pain, proprioceptive deficits, strength, power, core stabilization, and postural control were designed functions of assessments [5]. Particularly in an aging population,

but also in any other age group, the results of screenings can be used to counsel participants about functional limitations. Individualized corrective exercise programs that reduce the risk of injury even during work, recreation, and during sports activity can be created [6]. For that, the founders of Functional Movement Screen (FMS) had the intent to provide a better system for sports medicine, strength, fitness, and conditioning professionals. Their aim is to identify movement dysfunction as well as improve communication between the professions [7]. It has been found by the researcher that the FMS was a reliable assessment for elderly people over 50 years old [8]. So, it should be used in conjunction with other quantitative assessments for assessing the functional abilities of the elder.

Based on the statistic, populations throughout the world are aging, and people over 65 years old very soon are expected to outnumber children under five years old [9]. And people in older age, are more likely to suffer from diseases or ill health, including

chronic disease [10]. The development of chronic diseases are as a consequence of physical inactivity [11], so based on the literature regular physical activity is so important for older adults' quality of life and for their health.

In our country, the Republic of Kosovo, there is a lack of data for the FMS test with the elderly, for this reason, we hope that this research will give us data for this category of the elderly regarding their testing through the FMS test protocol.

After the literature review, and examination of the situation of the old people who live in elderly homes in Kosovo, it has been detected lack of activity. As a result, it is caused low motor competency which is accompanied by a lack of balance, mobility, and stability as the basic skills that are necessary to manage everyday tasks. Many times, these movements are accompanied by back pain or an inability to do the movement. So, in order to improve the health and motor competency of these people, studies like this can be beneficial for creating a new approach to the elderly's health which will always be welcomed.

Based on the previous requirements, the aim of the study is the determination of the level of fundamental skills which consist of motor competence such as balance, mobility, and stability. In order to carry out the study aim, the Functional Movement Screen (FMS) protocol was used. In addition to the purpose of the study, it is intended to create new data on FMS protocol which in the future may be the base of norming of FMS tests for this category of people.

Materials and Methods

To determine the level of motor competency, the existing situation review model, and in order to classify and norm the new data on the FMS protocol, a causal relational research model was used.

Participants

10 women and 10 men aged 50-65 were included in the study on a voluntary basis. The permission for the study has been taken by the directorate of the elderly home "Jetimat e Ballkanit" (Kosovo). All members of the elderly home were informed about the aim of the study's benefits, and risks (even if there is no risk), and information about the test protocol has been given in the presence of the physiotherapist of the elderly home. Based on the physiotherapist criteria and two doctors of sport and movement science, people who have at least minimal ability to move by themselves, and people whose health is not a threat because of the execution of FMS protocol could be part of the study. All participants were allowed to leave the study even without having to explain their reasons for leaving. The study was made according to the Helsinki Declaration which protects the privacy

of the volunteers. The study also was approved by the ethics committee of "UBT College" (approval number: 13668/45).

Research Design

Test protocol (FMS tests)

The height of each participant was measured with a stadiometer, and the data was read with an accuracy of 0.1 cm, body mass (kg) and all body composition, such as Body mass index (kg/m^2), Body fat percentage (%), Body water (%), Muscle mass (kg), Bones (kg), Kilocalories, Ages prediction, Visceral Fat (Level), were measured with medical scales (Tanita BC 545 N Innerscan Segmental Personal Body Analysis). During the measurements, participants were instructed to remove their shoes and stand in light clothes. Functional Movement Screen FMS consists of the Deep Squat (DS), Hurdle Step (HS), Incline Lunge (IL), Shoulder Mobility (SHM), Active Straight-Leg Raise (AS-LR), Trunk Stability Push-Up (TS-PU), Rotary Stability (RS). The results were scored on a scale from 0 to 3. (0=pain felt when attempting the movement; 1=unable to complete accurately; 2=completed with compensation; 3=perfect) [7].

Statistical analysis

The SPSS 26 packet was used in the data analysis. A description of the sample was made by using descriptive statistics. Categorization of the participants with pain, low, average, and high ability were made by using frequency statistics. Differences between genders and right/left extremities were made by using Independent-Samples T-Test. The effects of the changes in body composition on the functional movement screen (FMS) variables have been analyzed by using the Regression Linear model, and the Backward Elimination method applied.

Results

Based on the results of table 1 Gender and right/left dominancy analysis of the FMS scores has shown that no statistical differences appear in the data analyzed in the study ($p>0.05$). Based on the similarity of the data the analyses of the study have been without any separation in gender.

In table 2 the descriptive statistics of the body composition tests have been given the percentage values.

In table 3 the descriptive statistics of the functional movement screen (FMS) protocol tests have been given the percentage values.

The frequency analysis has shown that 11.1-22.2% of the people living in the elderly home have pain while applying the movements which are necessary and have a direct impact on daily life such as the deep squat, hurdle steep, and inline lunge (Table 4). Also, 24.06% of them have shown low ability in the FMS protocol, 30.39% seem to have

Table 1. Gender and right/left dominancy analysis of the FMS scores

Variables	R/L	M ± SD	
		Women	Men
Deep Squat (Score)	-	1.30±.823	1.89±1.054
Hurdle Step	R	1.90±.994	2.22±.972
	L	2.10±.738	2.22±.972
Inline Lunge	R	1.10±.568	1.67±1.323
	L	1.10±.568	1.67±1.323
Shoulder Mobility	R	2.50±.707	2.22±.972
	L	2.40±.843	2.22±.667
Active Straight Leg Raise	R	2.40±.699	2.44±.726
	L	2.30±.823	2.33±.707
Trunk Stability Pushup (Score)*	-	1.10±.316	2.00±.707
Rotary Stability*	R	0.80±.422	1.56±.726
	L	0.80±.422	1.56±.726
FMS general score	-	19.80±4.54	24.00±8.12

*Differences between genders ($p<0.05$), Differences between right and left side and extremities (** $p<0.05$), R/L: Right Leg / Left Leg

Table 2. Descriptive statistics of the body composition

	Variables	N	R/L	Range	Min	Max	Mean	SD
Body Composition	Height (cm)	20	-	34.0	146.0	180.0	162.0	10.1
	Weight (kg)			49.4	48.6	98.0	75.43	14.1
	Body mass index (kg/m ²)			25.0	21.3	46.3	29.82	5.8
	Body fat percentage (%)			29.3	16.3	45.6	32.41	9.5
	Body water (%)			20.4	39.8	60.2	49.23	5.9
	Muscle mass (kg)			30.2	35.4	65.6	47.40	9.4
	Bones (kg)			32.1	1.9	34.0	4.22	7.2
	Kilocalories			873	1096	1969	1495.7	271.8
	Ages prediction			42.0	42.0	84.0	66.3	10.8
	Visceral Fat (Level)			14.0	5.0	19.0	12.6	3.7

R/L: Right Leg / Left Leg

Table 3. Descriptive statistics of the functional movement screen (FMS) protocol

	Variables	N	R/L	Range	Min	Max	Mean	SD
FMS	Deep Squat (Score)	20	-	3	0	3	1.58	.961
	Hurdle Step (Score)		R	3	0	3	2.05	.970
			L	3	0	3	2.16	.834
	Inline Lunge (Score)		R	3	0	3	1.37	1.01
			L	3	0	3	1.37	1.01
	Shoulder Mobility (Score)		R	2	1	3	2.37	.831
			L	2	1	3	2.32	.749
	Active Straight Leg Raise (Score)		R	2	1	3	2.42	.692
			L	2	1	3	2.32	.749
	Trunk Stability Pushup (Score)		-	2	1	3	1.53	.697
Rotary Stability (Score)	R	3	0	3	1.16	.688		
	L	3	0	3	1.16	.688		
FMS_General_Score	-	23.0	12.0	35.0	21.7	6.6		

R/L: Right Leg / Left Leg

a normal level of functionality, and just 37.01% of them resulted to be in good condition based on the FMS protocol.

The results of table 5 carry out the significant effects of the differences in body composition on the FMS scores ($p < 0.05$). So, for the people whose W, BMI, BF%, MM, B, and KCAL level has been low, the FMS score resulted to be low also and counter wise.

These effects' variance has been explained at a level of 59%.

The variables in the previous table 6 have been excluded by the backward method because they did not fit the model. Thus, the regression model has given more accurate effect ratios of dependent variables on dependent ones.

Table 4. Frequency analysis of the FMS scores based on the participants' performance level

Level	DS		HS		IL		SHM		AS-LR		TS-PU		RS		\bar{X}
	-	R	L	R	L	R	L	R	L	-	R	L			
Pain	11.1	11.1	11.1	22.2	22.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	6.47*
Low	22.2	00.0	00.0	33.3	33.3	33.3	11.1	11.1	11.1	22.2	55.6	55.6	24.06		
Average	33.3	44.4	44.4	00.0	00.0	11.1	55.6	33.3	44.4	55.6	33.3	33.3	32.39		
High	33.3	44.4	44.4	44.4	44.4	55.6	33.3	55.6	44.4	22.2	11.1	11.1	37.01		

DS: Deep squat, HS: Hurdle steep, IL: Inline Lunge, SHM: Shoulder Mobility, AS-LR: Active Straight Leg Raise, TS-PU: Trunk Stability Push-up, RS: Rotary Stability, *15.54% with pain in DS, HS, and IL. L: Left leg, R: Right leg

Table 5. The effects of the differences in the body composition on the FMS scores

Model	Variables	ANOVA	F	R square	B	Sig.
4	W: Weight (kg)				-3.129	.010
	BMI: Body mass index (kg/m ²)				-1.089	.037
	BF%: Body fat percentage (%)	0.077 ^e	2.647	.591	1.779	.013
	MM: Muscle mass (kg)				-7.992	.005
	B: Bones (kg)				-.634	.019
	KCAL: Kilocalories				.438	.005

^a Dependent Variable: FMS: General Score

^b Predictors: (Constant), Visceral Fat (Level), Body fat percentage (%), Bones (kg), Body mass index (kg/m²), Muscle mass (kg), Ages prediction, Body water (%), Weight (kg), Kilocalories (KCAL);

^c Predictors: (Constant), Body fat percentage (%), Bones (kg), Body mass index (kg/m²), Muscle mass (kg), Ages prediction, Body water (%), Weight (kg), Kilocalories (KCAL);

^d Predictors: (Constant), Body fat percentage (%), Bones (kg), Body mass index (kg/m²), Muscle mass (kg), Body water (%), Weight (kg), Kilocalories (KCAL);

^e Predictors: (Constant), Body fat percentage (%), Bones (kg), Body mass index (kg/m²), Muscle mass (kg), Weight (kg), Kilocalories (KCAL).

Table 6. Excluded variables on the regression analysis backward elimination model

Model	Variables	Sig.
2	Visceral Fat (Level)	.975
3	Visceral Fat (Level)	.757
	Ages prediction	.720
4	Visceral Fat (Level)	.974
	Ages prediction	.882
	Body water (%)	.676

^a Dependent Variable: FMS: General Score

^b Predictors in the Model: (Constant), Body fat percentage (%), Bones (kg), Body mass index (kg/m²), Muscle mass (kg), Ages prediction, Body water (%), Weight (kg), Kilocalories (KCAL)

^c Predictors in the Model: (Constant), Body fat percentage (%), Bones (kg), Body mass index (kg/m²), Muscle mass (kg), Body water (%), Weight (kg), Kilocalories (KCAL)

^d Predictors in the Model: (Constant), Body fat percentage (%), Bones (kg), Body mass index (kg/m²), Muscle mass (kg), Weight (kg), Kilocalories (KCAL).

Discussion

Results of the study have shown that besides the 24% of people who have low motor competency level which is under the requirements of the daily need in physical perspective, 15% of them have very low ability to move and movements are accompanied by pain in the certain body part. Unfortunately, the elderly home “Jetimat e Ballkanit” is one of the only four houses in the country, which means the lacking of functionality of people in this category is existent in all elderly homes in Kosovo. Based on the research of Martin, higher DS (Deep squat) scores are associated with higher physical fitness scores, and also people who passed the Back-Leg Strength Dynamometer (LB-MCS) have shown better physical fitness scores [12].

For more details, the findings of the study determine that body composition features such as body mass index, weight, fat percentage, muscle mass, bones, and kilocalories are significantly correlated and effects the motor competency level of elderly people. People who have a higher BMI were found to be more common among those with greater limitations in performing activities on daily living [13]. Many studies have reported a negative association between BMI and performance on the FMSTM in children [14], and adults. Adults who have BMI >30 had a mean composite FMSTM score that was 2 points less than adults who have a BMI <30 [15]. Based on the variance explained in the data analysis, the competency level of the elderly people measured by using functional movement screen (FMS) protocol which includes tests such as, is explained around 59% by the body composition status. Fawcett [8] in her research, after the application of Pearson correlations, found a significant negative relationship between age, BMI, body fat percentage (BF), and the total FMS scores. Based on this, when a person was older, he or she had a higher BMI value, or a higher BF percentage, as a consequence the total FMS score for either trial was lower [8].

Davison et al. also found that higher BMI and higher body fat percentage values were associated with greater functional limitations [16]. So, positive changes in body composition features may be the reason for the improvements in motor competency levels, respectively increasing the quality of life in elderly people. Based on the research of Nicolozakes et al. which examined the relationship between FMS scores and BMI and body fat percentage of American football players. They found a negative correlation between body fat percentage and FMS composite score [17].

Our study claims that the improvements in the motor competency level seem to be affected more by the muscle mass and kilocalories accompanied by the fat percentage, bone density and then body

weight and body mass index. Based on other studies, older adults are enabled to control and accomplish successfully various physical fitness tests if they increased lower body motor [18, 19]. Similar findings, also have supported other studies which have found an association between various physical tests and muscular strength in older adults [20, 21, 22].

When analyzing the chain of effect and correlation, seems that good nutrition builds muscles and bones [23]. A high level of muscle mass and bones do not let increase the fat percentage and body mass index, and as a result, motor competency level needed for everyday life in elderly people such force, mobility, stability, endurance, etc., increases.

Not surprisingly, visceral fat level and age prediction measured by the digital scale (Tanita BC 545 N Innerscan Segmental Personal Body Analysis) resulted to be no significance in body composition or motor competency level. The reason for this may be considered that the age prediction is an estimation variable based on the body composition and visceral fat may be a complicated and not very reliable measurement in the body. However, while we estimated that the body water percentage may be correlated to the motor competency level and body composition the result of the study proved differently. So, the visceral fat, age prediction, and body water percentage have been categorized as the variables which do not fit the model and eliminated by the backward elimination method of regression analysis.

Conclusions

The analysis of the study concludes that the lacking of functionality in the motor competency level, may occur from their nutrition which is reflected in motor competency levels through decreases in muscle mass, bone density, and increases in fat percentage, body mass index, and body weight.

This study also was undertaken to describe and confirm the feasibility of performing the FMS in older adults, and to evaluate the relationship between functional movement ability, age, physical activity levels, and body composition.

Conclusion of the study the need arises to check and increase the quality of nutrition in the elderly houses in Kosovo.

In order to see the effects of nutrition and physical activities on health and motor competency levels monitoring the body composition features as well as motor skills is an immediate need.

Besides qualitative nutrition and systematic monitoring of the body composition and motor competency level, the physical activities applied in the elderly houses need an update and need to be applied by experts of movement science instead of physiotherapists or experts who are not specialists in movement science.

Conflicts of Interest

There is not declared conflict of interest by the authors.

Acknowledgments

We really acknowledge the head of the elderly house “Jetimat e Ballkanit” Mr. Halil Kastrati, for making this study possible and helping in every step of data analysis with all his and the house’s resources.

We thank the physiotherapist of the house “Jetimat e Ballkanit” Mr. Musedin Nebiu for his professional support in data collection and evaluation of the elderly people’s body composition and moto competency level.

Also, we thank a lot our students Alberina Shabani and Ismail Shabani, for their help in the data collection of the study.

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Cite this article as:

Thaqi A, Berisha M, Shaqiri K. The motor competency level of elderly people measured by Functional Movement Screen protocol. *Pedagogy of Physical Culture and Sports*, 2023;27(4):267–273. <https://doi.org/10.15561/26649837.2023.0401>

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Received: 28.04.2023

Accepted: 09.06.2023; Published: 30.08.2023

Comparison the acute effect of moderate-intensity treadmill exercise and arm crank exercise on autonomic cardiac functions in adult males

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Abstract

Background and Study Aim Cardiovascular parameters testing can be used by various modalities ranging from ground running to sophisticated computerized treadmills. The purpose of this study was to compare the acute effect of treadmill moderate-intensity exercise with arm crank exercise on autonomic cardiac function among adult males.

Material and Methods One hundred-twenty male participants participated in this study. They were randomly allocated to a treadmill exercise group with sixty participants and the other sixty participants allocated into an arm crank exercise group. Both groups performed exercises for forty minutes. Autonomic cardiac functions (heart rate variability - HRV), heartbeats, and arterial blood pressure) were determined with the help of Phillips DigiTrak XT Holter heart rate monitor, Polar® Grit X watch, and automatic sphygmomanometer. An independent t-test was used to compare the anthropometric data between both groups. Repeated measure analysis of variance and one way analysis of variance (ANOVA) were used to determine the differences between treadmill exercise and arm crank for autonomic cardiac functions among adult males.

Results The HRV decreased significantly during treadmill exercise and arm crank exercise. Mean values of heartbeats (HR), systolic blood pressure (SBP), and rate pressure product (RPP) increased significantly during both exercises. In comparison, mean values of HRV parameters were reduced more significantly during treadmill exercise than arm crank. Mean values of the HR, SBP, and RPP increased significantly during arm crank than treadmill exercises.

Conclusions The study's findings suggest that treadmill exercises are responsible for a greater significant reduction in HRV. The HR, SBP, PP, and RPP significantly increased during arm crank than treadmill exercises. This study suggests that when recommending exercise to adult male individuals, the intensity and mode of exercise are crucial.

Keywords: arm crank, treadmill, leg exercise, acute exercise, moderate-intensity, physiological responses.

Introduction

Exercise is essential in preventing and maintaining health in all age groups [1, 2]. Exercise promotes controlling body weight, reducing body fat, reducing the risk of cardiac diseases, managing blood sugar and insulin levels, and improving cardiorespiratory fitness [3]. Despite the benefits of regular exercises in preventing and treating different types of patients during the rehabilitation process or training purposes, if it is not prescribed and supervised properly, it might raise the relative risk of musculoskeletal injury or cardiovascular events [4]. As a result, attention should be taken

while performing exercise for rehabilitation purposes. Due to the above purpose, a trainer or a physical therapist should better understand the biological individuality through tests to measure physical capacity. The prescription and supervision are appropriate for a safe workout [5].

Several studies have shown that repeated intermittent treadmill exercise is an effective therapeutic strategy [6]. Treadmill exercise provides a significant benefit over other types of exercise. The volume of external work done can be easily determined, and exercise intensity and duration can be regulated [7]. Observational studies conducted in the 1980s and early 1990s determined the treadmill exercise test for prognostic importance. Treadmill exercises were used to determine the maximal exercise capacity, whether evaluated by exercise

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doi:10.15561/26649837.2023.0402

time or workload accomplished. Treadmill exercise test data have confirmed that heart rate recovery is a marker of physical fitness and exercise capacity, irregular heart rate recovery is a major predictor of mortality in the cardiac patient [8], asymptomatic individuals [9], and exercise training improves heart rate recovery in cardiac patients [10].

Arguments have been made in the past that the specificity of the testing procedure affects the performance of parameters during testing. Different protocols have investigated the physiological differences between arm and leg exercises. Arm crank is a useful substitute to a treadmill for exercise [11]. The exercise protocol is graded in the same way as a treadmill protocol is, with two-minute increments in effort until exhaustion. Peak heart rate is 90 to 95 percent of what is expected on the treadmill, and peak systolic blood pressure is 80 to 85 percent of what is expected. As a result, the double product is often high enough to reveal ischemia alterations [12]. Apart from the importance of tests of upper body exercise capacity in athletes who use the upper body, such as swimmers and boaters, it is also an important measure for people who are unable to perform lower body exercises and can be a useful exercise tool for people with vascular diseases, orthopaedics and neurosurgery [13].

The treadmill is commonly used to improve cardiopulmonary fitness [14]. Arm crank is also used to improve health status for individuals who cannot use a leg bicycle or treadmill [15]. As a result, the location and size of the involved active muscle during treadmill and arm crank exercise are different. They may have various cardiovascular effects that need to be investigated [16]. The interaction of the sympathetic and parasympathetic over the heart during exercise is worthy of being investigated, and it has been an interesting research point [17, 18]. Most of the previous studies have focused on evaluating the cardiovascular effect upon upper or lower limb exercise [16]. There is no available data that compared the effect of the treadmill and arm crank exercise on autonomic cardiac functions, except one study compared the effect of arm crank with leg cycle ergometer in middle-aged individuals [15]. Therefore, the aim was to compare the acute effect of treadmill moderate-intensity exercise with arm crank on autonomic cardiac function in the normal adult. It was null hypothesized that there is no significant difference between treadmill moderate-intensity and acute arm crank exercise on autonomic cardiac function in normal adults.

Materials & Methods

Participants

One hundred-twenty adult males' participants participated in this study. Sixty participants were randomly assigned to the treadmill exercise group

and sixty to the arm crank exercise group.

Inclusion criteria: non-obese male volunteers with body mass index $< 30 \text{ kg/m}^2$, aged from 25-36 years. All participants were asymptomatic for cardiovascular and respiratory diseases. They currently do not receive any medical prescriptions.

Exclusion criteria: Any participant with a history of cardiovascular or pulmonary diseases or has taken any medicine that may affect their performance during the test [15].

Ethical approval. This study was approved by the Ethics Research Committee of the Institutional Review Board of Imam Abdulrahman Bin Faisal University (IRB-2015-03-159). Before participating in this study, each participant signed a consent form and was informed that collected data would only be used for research purposes.

Study Design

Comparative cross-sectional design was selected to conduct this study.

Assessment procedure: Every participant was asked to avoid strenuous exercise, caffeine beverages, and have enough rest for two days before the test session to avoid any carry-over effect of stimulants or depressants on autonomic function [15, 18]. Every participant underwent the following assessment.

Bodyweight and body mass index were measured with auto calibrated stadiometer scale.

Heart rate variation was measured using the Philips DigiTrak XT-Holter heart rate monitor, a highly validated method for detecting HRV measures [19]. The electrodes were attached to each participant's chest to detect HRV recordings before and during the exercise session. The recorded data of time domains were transferred to a computer for further analysis.

Arterial blood pressure: Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured by using an electronic sphygmomanometer (Geratherm, Germany) [20]. Mean arterial blood pressure (MABP) is the perfusion pressure of the body organs; normally, it ranges from 65 to 110 mmHg [20]. It was calculated as $[\text{DBP} + 1/3 \text{ pulse pressure}]$ [20]. Pulse pressure (pp) = $\text{SBP} - \text{DBP}$. The rate pressure product (RPP) is an indirect method that easily measurable the index of myocardial oxygen consumption. It was calculated by multiplying SBP in mm Hg x HR in beats/min $\times 10^{-2}$ [20, 21, 22].

Exercise program: Before exposing the pre-intervention measures, every participant relaxed in a sitting position for 30 minutes to achieve hemodynamic stability. The heart rate monitor recorded continuous heartbeats at rest for 40 minutes and during exercise sessions for 40 minutes. The exercise intensity was determined in advance for every participant from 64 -74% of the

maximal heart rate (HR-max) [18, 22, 23]. The HR-max was calculated using the Karvonen equation ($HR_{max} = 220 - age$) as it showed good correlations with the measured HR-max [24]. The recorded data were transferred from the device to the computer for further analysis.

Treadmill Group: Each participant performed exercise for 40 minutes on a computerized treadmill machine [15, 18]. Participant began at the lowest speed for 5 minutes at zero inclination as a warmup; then the speed was gradually increased to achieve the pre-determined individualized moderate intensity for 30 minutes, then exercise was continued to the slowest speed for 5 minutes for a cool-down exercise. The HR and blood pressure were recorded pre, during, and immediately after exercise.

Arm-crank Group: Each participant performed an arm crank exercise for 40 minutes with the Hudson machine from the sitting position. Seat's height and distance were adjusted to achieve full extension of participant arms at the horizontal (shoulder-level) position. For Warmup, each participant equally peddled with both arms on arm crank at the lowest speed for 5 minutes. The exercise intensity gradually increased to achieve individualized moderate intensity for 30 minutes. Each participant continued arm exercise at the slowest speed for 5 minutes for a cool-down exercise [15, 18]. The HR and blood pressure were recorded pre, during, and immediately after exercise.

Statistical analysis

The collected data were statistically analyzed using SPSS (Version 23.0) for descriptive and inferential analysis. The missing data, outliers, and normality was checked and found that data were normally distributed. Parametric tests were used to analyze data. An independent t-test was used to compare the demographic data of both groups. The repeated measure analysis and one way analysis of variance (ANOVA) were used to determine the differences between treadmill and arm crank exercise for cardiac autonomic functions. Statistical significance was determined at p -value < 0.05 and confidence interval at 95%.

Results

Demographic data of participants

The mean values of age, body mass index, maximal HR and HRV maximal HR were (25.09 ± 2.12 , 24.94 ± 2.32), (30.53 ± 4.93 , 30.67 ± 5.41), (63.22 ± 13.87 , 63.69 ± 13.29), and (189.52 ± 4.96 , 189.33 ± 5.40) of treadmill and arm crank groups respectively. Independent t-test showed non-significant differences between both groups p -value > 0.05.

On comparison of arm crank with treadmill exercises the mean values of both SDANN, SDNN and RMSSD of HRV showed significant differences (F-values = 8.568, 6.831 & 6.230) p -value = (0.004, 0.010 & 0.014) respectively with more reductions in HRV during treadmill than during arm crank exercises.

The one-way ANOVA (Table 1) showed significant reductions in mean values of the HRV (SDANN, SDNN, RMSSD) during both treadmill and arm crank exercises at 0.05 level of significance.

The repeated measure analysis (Table 2) showed significant increases in mean values of the SBP, HR and RPP during both treadmill and arm crank exercises in regarding baseline values p -value < 0.05, whereas the SBP, HR and RPP reduced significantly after both arm crank and treadmill exercises in regarding its values during exercise p -value < 0.05.

The repeated measure analysis (Table 3) showed significant differences between pre, during, and postconditions for pulse pressure, mean blood pressure, and heart rate recovery after one minute of the treadmill and arm crank exercises. Whereas an insignificant difference between pre, during, and post-test of mean blood pressure for treadmill exercise.

On comparison, there were significant differences in mean values of SBP between arm crank and treadmill both during exercise and after exercise (F-statistic = 88.543, 14.608, p -value < 0.001) respectively. Also, there were significant differences in mean values of the HR both during and after both arm crank and treadmill exercises (F-statistic = 42.510, 26.048, 8.822 and p -value < 0.001, < 0.001)

Table 1. The heart rate variability measures pre-and during treadmill and arm crank exercises.

Variables	Mean ± SD		95%CI	F-statistic	p-value	
	Pre	During				
Treadmill	SDANN	62.07 ± 13.15	41.61 ± 18.37	40.41-65.26	49.165	< 0.001
	SDNN	64.24 ± 13.59	44.11 ± 18.38	42.74-67.61	46.545	< 0.001
	RMSSD	46.86 ± 16.96	26.69 ± 13.43	23.46-50.08	52.181	< 0.001
Arm crank	SDANN	62.18 ± 13.15	51.02 ± 16.79	50.70-65.49	16.422	< 0.001
	SDNN	64.40 ± 13.69	52.08 ± 18.02	50.53-68.66	15.761	< 0.001
	RMSSD	46.94 ± 17.00	32.94 ± 14.04	30.36-49.02	24.167	< 0.001

SDANN: the standard deviation of the average normal-to-normal intervals. SDNN: the standard deviation of normal-to-normal intervals. RMSSD: the root means square of successive differences.

Table 2. Mean values of systolic blood pressure, heart rate, and rate pressure product pre, during, and post treadmill and arm crank exercises.

Variables		Mean \pm SD	95% CI	F-value	p-value
1-Systolic blood pressure					
Treadmill	Pre	123.27 \pm 13.05	119.89-126.64	21.952	< 0.001
	During	132.17 \pm 2.83	131.44-132.89		
	Post	124.98 \pm 1.95	124.43-125.54		
Arm crank	Pre	121.53 \pm 14.20	117.86-125.20	67.766	< 0.001
	During	139.70 \pm 5.52	138.27-141.13		
	Post	126.35 \pm 1.65	125.89-126.81		
2-Heart rate					
Treadmill	Pre	78.57 \pm 5.41	77.17-79.96	1206.847	< 0.001
	During	125.17 \pm 2.37	124.55-125.78		
	Post	108.58 \pm 6.95	106.79-110.37		
Arm crank	Pre	77.68 \pm 6.71	75.95-79.42	1434.390	< 0.001
	During	130.15 \pm 5.43	128.75-131.55		
	Post	113.88 \pm 3.99	112.83-110.56		
3-Rate pressure product					
Treadmill	Pre	10.06 \pm 1.83	9.59-10.53	393.900	< 0.001
	During	16.66 \pm 0.88	16.43-16.88		
	Post	13.43 \pm 2.99	13.33-13.81		
Arm crank	Pre	9.91 \pm 1.95	9.41-10.42	542.349	< 0.001
	During	17.69 \pm 1.0	17.43-17.95		
	Post	14.38 \pm 0.55	14.52-14.50		

Table 3. Mean values of pulse pressure and mean arterial pressure at pre, during and post treadmill and arm crank exercises.

Variables		Mean \pm SD	95% CI	F-value	p-value
1-Pulse pressure					
Treadmill	Pre	41.08 \pm 9.61	38.6-43.57	13.591	< 0.001
	During	49.85 \pm 9.28	46.69-51.18		
	Post	41.75 \pm 9.09	39.40-44.10		
Arm crank	Pre	40.6 \pm 9.95	38.03-43.17	35.034	< 0.001
	During	56.13 \pm 9.76	53.61-58.66		
	Post	44.92 \pm 11.66	41.90-47.93		
2-Mean blood pressure					
Treadmill	Pre	95.09 \pm 8.86	92.80-97.38	5.912	0.003
	During	99.85 \pm 6.13	97.96-101.13		
	Post	97.15 \pm 5.91	95.62-98.68		
Arm crank	Pre	94.47 \pm 9.17	92.90 - 96.84	16.136	< 0.001
	During	96.41 \pm 9.97	94.34 - 98.46		
	Post	102.28 \pm 6.06	100.71 -103.84		
3-Heart rate recovery after one minute					
Treadmill		75.47 \pm 9.91	73.94-76.99	15.433	< 0.001
Arm crank		80.93 \pm 9.01	78.60-83.26		

respectively. In addition, there were significant differences in mean values of the RPP & PP only during both arm crank and treadmill exercises (F-statistic=36.219,18.186, p-value=<0.001). There was a significant difference in the mean values of the heart rate recovery between arm crank and treadmill exercise table 3.

Discussion

Evaluation of cardiac autonomic function in response to exercise is a promising area in exercise physiology. This study was conducted to determine the differences between treadmill or arm crank exercise in response to autonomic cardiac functions. The findings showed significantly reduced HRV time domains during the treadmill and arm crank exercise. While comparing, the result showed that reduction of time domains was greater in favour of arm crank than treadmill exercise. The current result was supported with previous studies of Forjaz et al. [25], Segan et al. [26] and Ahmadian et al. [15]. Arm crank exercise is associated with a significant reduction of time domains in parallel with the significant increase in SBP, RPP, PP and HR [25, 26]. Ahmadian et al. [15] found a significant reduction in HRV measures during acute arm crank and leg cycle ergometer. They explained this reduction by increasing sympathetic modulation to accelerate heart rate and cardiac output to increase blood supply to active muscles [15]. Ahmadian et al. [15] also found that this significant reduction in HRV measures remains higher during arm crank than during leg cycle ergometer. This is parallel with existing findings, which show that the reduction in time domains is bigger during treadmill activity than with arm crank exercise. They referred to greater respiratory-induced sinus arrhythmia as changes in respiration, particularly the respiratory rate can modify HRV [18].

The current result contradicts the studies of Cottin et al. [27], Princi et al. [28], Weippert et al. [20] and Faria and Faria [29] found that time domains and frequency measures of HRV were greater during judo or sailing exercise than cycling exercise at a similar heart rate. They suggest a different sympathovagal modulation on cardiac function. Weippert et al. [20] found that dynamic isometric exercise accompanied a significant reduction in HRV time domains in parallel with a significant increase in SBP, HR, MABP and RPP. The current results also contradict the results of Faria and Faria [29], who found insignificant changes in cardiorespiratory response to either acute upper or lower body exercise. They compared arm rowing with leg extension exercise in which they used different modes of exercise than that used in the current study [29].

The current results proved significant increases in the HR, SBP and RPP during treadmill and arm crank exercise to provide adequate blood supply

to active skeletal muscles. Myers supported these responses, who reported that the SBP increases progressively to achieve the highest value at maximal workload with a minor change in DBP [30]. Tulppo et al. found that arm crank is associated with higher HR than leg cycling exercise at equal maximal oxygen consumption (VO_{2max}). This may be due to rapid withdrawal vagal outflow during arm crank exercise [31].

The underlying physiological mechanisms may be due to increases in cardiovascular variables, sympathetic discharge, sympathovagal modulation of cardiac function [20,28], as well as an increase in sympathetic cardiac stimulation, adrenal glands and blood vessels [32]. The degree of vagal withdrawal and sympathetic stimulation depends mainly on applied exercise's mode and intensity [20, 28, 32]. Also, Di Blasio et al. found that movement of the upper body and breathing during arm crank exercise compete to recruit small muscle masses of the upper body and shoulder muscles [33]. The parasympathetic to sympathetic influence on the HR is 4:1 at rest, while during maximal intensity exercise, it reverses to approximately 1:4 [34]. The rate pressure product is the response of coronary circulation to myocardial metabolic demands, and it is the product of heart rate in systolic blood pressure. It is an easily measurable index that correlates with myocardial oxygen demand [35]. The presence of a statistically significant correlation between RPP, PP and spectral measures of short-term HRV supports a simplistic approach to autonomic assessment, in that easily measurable BP indices could be used as surrogates of HRV when it is not feasible to determine HRV indices directly [36].

The current result was expected during and after treadmill and arm crank exercise because participants had a well-functioning autonomic cardiac system. This result was supported with previous studies of De Almeida et al. [37], Robergs and Roberts [38], Ilias et al. [39], Forjaz et al. [25], Segan et al. [26], Toner et al. [40], Louhevaara et al. [41]. De Almeida et al. proved that arm and leg exercise is associated with significant increases in SBP, HR and RPP [37]. Robergs and Roberts proved that upper-limb exercise results in a greater cardiovascular strain, including greater HR and intra-arterial blood pressure for a given level of sub-maximal workload than lower-limb exercise [38]. Also, arm ergometers have been prone to subsequent cardiac events as arm exercise may not be sufficient to unmask a compromised cardiorespiratory system [39]. Toner et al. found that arm crank exercise significantly increases HR, SBP and RPP compared to lower limb exercises [40]. This elicits greater strain on the cardiovascular system during arm crank than during lower limb exercise. Thus, they suggested engagement of lower limb exercise to attenuate the strain placed on the cardiovascular system in cases

of the arm crank exercise [25, 26]. Toner et al. & Louhevaara et al. reported that as a result of reduced workload during arm-crank than during leg cycle ergometer exercise by 44% [40, 41], arm exercise makes more stress on the cardiorespiratory system than leg cycling exercise [42]. This may be explained by differences in physiological muscle mass and its properties. Lower and upper limb muscular mass represent 32% & 7.6% of total body muscle mass, respectively [43]. The absence of a muscular leg pump during arm crank exercise reduced venous return to the heart, leading to reduced ventricular filling and stroke volume. This will increase the production of catecholamine that accelerates both heart and respiratory rate in arm exercise compared with the combined arm and leg exercise [42]. The current results disagree with Coplan et al. study [21]. They found exercise at 85% of the predicted HR is associated with significant increases in the HR, SBP, VO_2 max and RPP during treadmill than during arm-crank exercise. The current results also showed reductions in HR, SBP, RPP and MABP after stopping exercise. This may be due to the shift of autonomic control from sympathetic to parasympathetic control [44].

The current study's limitations include the lack of mixed gender, cohort, follow-up, intervention, and athletes or patients, all of which reduce the generalization of the study. In order to determine the comprehensive impact of treadmill and arm-crank exercise, future research should utilize

intermittent follow-up, longitudinal effect, mix-gender, age categories, prospective effect, and athletes or patient-specific population.

Conclusions

Findings from the study suggest that treadmill exercise is more responsible for a greater significant reduction in mean values of HRV. This suggests that participants' parasympathetic withdrawal was less during treadmill exercises than arm crank exercises. The HR, SBP, PP, MABP and RPP significantly increased during arm crank than treadmill exercises. According to this study, there is higher sympathetic modulation during arm crank exercise than treadmill exercise. This study suggests that when recommending exercise to adult male individuals, the intensity and mode of exercise are crucial.

Conflicts of interest

The authors did not report any conflicts.

Source of Funding

It is non-funded research (IRB-2015-03-159).

Acknowledgments

I gratefully gratitude the volunteers involved in this study. I also gratitude laboratory team Mohammad Alalaw, Belal Elsayed Shanb, Hassan Alameer, Naji Alkhuder, Mahdi Almakhamil, Rawda Alsayed Shanb, Yaseen Aleid for their patience and cooperation.

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Cite this article as:

Shanb AA, Youssef EF, Ahsan M, Ahmed RM, Shanab ME, Abdelkhalikk MY. Comparison the acute effect of moderate-intensity treadmill exercise and arm crank exercise on autonomic cardiac functions in adult males. *Pedagogy of Physical Culture and Sports*, 2023;27(4):274–281. <https://doi.org/10.15561/26649837.2023.0402>

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Received: 28.04.2023

Accepted: 09.06.2023; Published: 30.08.2023

Circuit training based physical condition training model to increase speed, agility, arm power, and limb muscle power of basketball athletes

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Abstract

Background and Study Aim Basketball involves skills that must be applied dynamically, explosively and repeatedly. Players must be able to speed up and slow down with control, especially when dribbling, shooting or bouncing the ball. The purpose of the study was to test a circuit training-based physical condition training model to increase speed, agility, arm power, and leg muscle power for basketball athletes.

Material and Methods This type of research is an experiment with two groups, namely the experimental group (n = 28) and the control group (n = 28). The samples were male athletes aged 15-18 years. Subjects had participated in competitions and all players were healthy with no history of illness or injury reported in the previous 3 months. The instruments were 20-meter running test speed, agility (Illinois Test with Dribbling the Ball), arm power (MEDBALL), and leg power (Counter Movement Jump Test). The data analysis technique was a t-test.

Results The results of the study can be concluded that the circuit training-based physical condition training model consisting of 6 posts, is effective for increasing speed ($0.017 < 0.05$), agility ($0.000 < 0.05$), arm power ($0.000 < 0.05$), and leg muscle power ($0.036 < 0.05$) of basketball athletes. We recommend that basketball coaches consider incorporating a circuit training-based physical condition training model in training, as a simple and practical model to improve athletes' physical condition.

Conclusions We recommend that basketball coaches consider including a circuit training-based physical condition training model in training, as a simple and practical model for improving athletes' physical condition. For researchers who intend to continue or replicate this study, it is recommended to conduct tighter control in the entire series of experiments.

Keywords: training model, circuit training, physical condition, basketball

Introduction

Basketball is a game played by two teams, each of which consists of five players, each team tries to put the ball into the opponent's ring, and prevent the opponent from scoring. Basketball has several basic playing techniques, including shooting, dribbling, defense, pivot and others [1]. The way to get points in a basketball game is by putting the ball into the ring. Mostly to get points players have to jump to do lay ups and jump shoots. This shows that players must have good jumping skills, so as to produce maximum performance. Basketball games have complex movements, meaning that the movements consist of a combination of elements of motion that are neatly coordinated. In addition, it involves skills that must be applied dynamically, explosively, and repeatedly. Basketball players must be able to speed up and slow down with control, especially when dribbling, shooting or bouncing the ball [2].

In addition to technique, the physical components that must be possessed by basketball players are such as agility, strength, endurance, coordination,

balance, speed and explosive power [3]. Movement when dribbling a basketball is constantly changing, generally it can be done slowly or very quickly depending on the goals or conditions that occur when the player dribbles. The movement of a good basketball player is characterized by fast and agile movement when making attacks with dribbling the ball. Therefore, speed and agility are needed in basketball games, especially when carrying the ball to pass opposing players [4]. Good agility can prevent painful injuries.

The importance of arm power and leg muscle explosiveness in basketball is that shooting is a complex movement involving various components of physical conditions that support each other. Shooting requires synchronization between the legs, waist, shoulders, wrist strength and fingers which are interrelated and support each other. Basketball sports in jump shoot techniques, leg muscle power functions to make sudden movements and require full exertion, to get hard and directed jump shots to support the achievement of maximum shots. Leg muscles affect the ability or results of repulsion [5]. The higher a person's jump the closer to the ring, and the easier it is to enter the ball in doing lay ups.

The function of the leg muscles is to support the body and to provide an initial energy boost. Players to produce the right jump shoot need contributions from leg muscle explosiveness and balance which are expected to produce good and accurate shots [6].

Efforts to improve the achievements of basketball players, one of which is by training. Exercise is one of the factors that is very decisive in achieving sports achievements. The form of exercise chosen will also be very decisive in achieving the desired training target. Physical exercise that is done properly, measured and regularly and with adequate nutritional intake will improve fitness that can be seen or observed. Preparation of an exercise program, there needs to be an assessment of muscle contraction, exercise dosage which includes training load, number of sets, rhythm, repetitions, and recovery [7]. Basketball players rely on attributes related to speed, agility, arm power, and leg muscle power to perform key movements during on-court performances. However, the effectiveness of exercise-related training models in basketball has not been fully identified, implemented, and evaluated. One training method that can be used is circuit training.

Circuit training is an exercise program combined from several exercise items whose purpose in doing an exercise will not be boring and more efficient. Circuit training is an exercise program consisting of several stations and at each station an athlete performs a predetermined type of exercise. One circuit training is said to be complete, when an athlete has completed training at all stations in accordance with the predetermined dosage [8, 9]. Each station consists of an exercise performed for 45 seconds, and exercise repetitions between 15-20 times, rest time in one station before moving to the next station is 1 minute or less [10]. Circuit training has elements of physical condition [11]. Circuit training with aerobic and anaerobic training has synergistic effects on cardiovascular and strength [11, 12]. Circuit training can also shape the character of an athlete. Weight training can be included in the circuit training program to maximize training [13, 14]. Through circuit training the athlete's condition can be maximally formed by combining elements and other aspects of the sport. Circuit training includes exercises for speed, agility, arm power, and leg muscle power.

In our opinion, the advantages of circuit training are training heart strength and lowering blood pressure, increasing various components of physical condition simultaneously in a relatively short time, muscle power will be trained and adaptability increased, does not require expensive gym equipment, can be adjusted in various areas or training places, saves time and can be done by many people at once. Based on the background that has been stated above, the researchers are interested in conducting research on circuit training-based

physical condition training models to increase the speed, agility, arm power, and leg muscle power of basketball athletes. The results of the study are expected to increase knowledge and existing training methods to be used as exercises to increase the speed, agility, arm power, and leg muscle power of basketball athletes.

Materials and Methods

Participants

This study has two groups: the experimental group (n = 28) - given a circuit training-based physical condition training mode; the control group (n = 28) - taken based on random sampling. Pretest measurements were taken. Pretest data was used to determine groups based on ordinal pairing techniques, so that the initial abilities of the experimental group and control group were not different. The samples were male athletes aged 15-18 years in basketball clubs in the Special Region of Yogyakarta, Indonesia. Subjects had participated in competitions and all players were healthy with no history of illness or injury reported in the previous 3 months.

Informed Consent: Before the study commenced, all participants and their legal guardians were provided with detailed information regarding the purpose, procedures, potential risks, and benefits of the experiment. Informed consent was obtained from both the participants and their legal guardians, ensuring that they had a comprehensive understanding of the study and voluntarily agreed to participate. The consent forms were written in a language easily understood by the participants and their legal guardians.

Ethics Committee Approval: The research protocol, including the study design, participant recruitment, and data collection procedures, was submitted to and approved by the ethics committee of university.

Research Design

This type of research is experimental. This experimental research is a study in which at least one manipulation variable will be found to study cause-and-effect relationships. Therefore, experimental research will definitely be closely related to the activity of testing a hypothesis. This is done to look for influences, relationships, and differences in changes to the group or variable being studied. The instrument to measure the pretest and posttest is a 20 meter running speed test [15], agility using the illinois test with dribbling the ball [16], arm power using seated medicine ball toss (MEDBALL) [17], and leg power using counter movement jump test [15]. Then given treatment for 18 meetings, with reps and sets increasing at each meeting. The circuit training-based physical condition training model to increase speed, agility, arm power, and leg muscle power for basketball athletes in Figure 1.



Figure 1. Circuit training-based physical condition training model.

Statistical Analysis

The statistical analysis for this study utilized the t-test as the primary statistical method. Two types of t-tests were employed: the paired sample t-test and the independent sample t-test. The significance level (alpha) was set at 0.05. Statistical techniques such as Shapiro-Wilk tests were applied to assess normality, while tests like Levene’s test were used to evaluate homogeneity. The statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) software, specifically version 21. SPSS.

Results

The results of the pretest and posttest of speed, agility, arm power, and leg muscle power of basketball athletes are presented in Table 1.

Normality Test

A test for normality is a method of determining whether the distribution of data in a sample can reasonably be attributed to a particular population with a normal distribution. Calculate this normality test with Shapiro-Wilk. Normality test results are shown in the table 2.

Based on the statistical analysis of the normality test performed using the Shapiro-Wilk test in Table 2 the results of the normality test with a value of $p > 0.05$ show that the data follows a normal distribution.

Homogeneity Test

Homogeneity test is used to test the homogeneity

of a homogeneous or non-uniform sample of a population. Homogeneity test using the Levene test. A test is considered homogeneous if the $p\text{-value} > 0.05$. The results of the homogeneity test are shown in the table 3.

Based on the analysis in Table 3 using Levenes test $p \geq 0.05$ values were found. These results indicate that the population is equally diverse or homogeneous because there is a similar diversity in the data set.

Hypothesis Test Results

The hypothesis test of this study was analyzed with t test which is an independent paired sample test using SPSS version 21 software for hypothesis analysis. The results of hypothesis testing are explained below:

Based on the analysis results in Table 4, it can be explained that (1) the speed data obtained the t value 2.464 and $p\text{-value} 0.017 < 0.05$, these results indicate there is a significant difference between the experimental group and the control group. The speed of the experimental group given the circuit training-based physical condition training model is better than the control group with a difference of 0.36 seconds. (2) agility data obtained t value 6.648 and $p\text{-value} 0.000 < 0.05$, these results indicate there is a significant difference between the experimental group and the control group. The agility of the experimental group given the circuit training-based physical condition training model is better than

Table 1. Pretest and posttest of speed, agility, arm power, and leg muscle power.

Data	Experimental Group (n=28)				Control Group (n=28)			
	Pretest		Posttest		Pretest		Posttest	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Speed (s)	3.79	0.62	3.41	0.57	3.78	0.53	3.78	0.54
Agility (s)	25.64	0.48	24.46	0.81	25.64	0.47	25.63	0.46
Arm Power (m)	8.59	0.35	9.60	0.62	8.60	0.33	8.81	0.49
Limb Muscle Power (cm)	41.54	3.57	44.25	3.72	41.57	3.35	42.14	3.63

Table 2. Normality test results.

Data	Experimental Group (n=28)		Control Group (n=28)	
	Pretest	Posttest	Pretest	Posttest
Speed	0.228	0.140	0.206	0.094
Agility	0.116	0.543	0.120	0.102
Arm Power	0.128	0.410	0.132	0.220
Limb Muscle Power	0.112	0.208	0.109	0.088

Table 3. Homogeneity test results.

Data	Levene Statistic	Sig.
Pretest-Posttest Speed	0.357	0.552
Pretest-Posttest Agility	0.578	0.241
Pretest-Posttest Arm Power	1.734	0.193
Pretest-Posttest Limb Muscle Power	0.035	0.853

Table 4. Independent sample test experiment group and control group.

Independent Samples Test			
Data	t-test for Equality of Means		
	t	Sig. (2- tailed)	Difference
Speed	2.464	0.017	0.36 (s)
Agility	6.648	0.000	1.17 (s)
Arm Power	5.305	0.000	0.79 (m)
Limb Muscle Power	2.146	0.036	2.11 (cm)

the control group with a difference of 1.17 seconds. (3) arm power data obtained t value 5.305 and p-value of 0.000 <0.05, these results indicate there is a significant difference between the experimental group and the control group. The arm power of the experimental group given the circuit training-based physical condition training model is better than the control group with a difference of 0.79 meters. (4) leg power data obtained t value 2.146 and p-value of 0.036 <0.05, these results indicate there is a significant difference between the experimental group and the control group. The experimental group's limb power given a circuit training-based physical condition training model is better than the control group with a difference of 2.11 centimeters.

Discussion

The results showed that the circuit training-based physical condition training model consisting of 6

posts was effective in increasing the speed, agility, arm power, and leg muscle power of basketball athletes. The training is carried out for 8 weeks, each athlete first warms up, core exercises for each post, and cools down. The circuit training program increased the muscle strength, agility, anaerobic capacity, and cardiovascular endurance of the study subjects. To choose a set of activities to increase physical fitness, use this program as a guidance [17, 18]. In a single training session, circuit training is one of the most effective workouts for enhancing physical capabilities such as strength, aerobic and anaerobic endurance, flexibility, and coordination [20]. Strength and endurance can be developed using the circuit training technique [21]. The benefits of circuit training on speed, leg, arm, and agility are tremendous. An effective way to increase running speed, agility, and strength in the upper and lower body is through circuit training [22].

Circuit training with speed, agility, and speed training produces higher results for agility than circuit training with jumping training [23]. During the six-week training period for circuit training coupled with speed agility speed up combination training and circuit training with jump rope training, upper body long-term muscular endurance performance was greatly enhanced [24]. For the 12-week training period, the circuit strength training group had significant interaction effects and meaningful effect sizes, and the mean effect size for the CT was noticeably higher [25]. Wijaya [26] researched that six posts make up the circuit training activity that will be performed: post 1 is a sit-up, post 2 is a push-up, post 3 is a jumping jack, post 4 is a run, post 5 is a shuttle run, and post 6 is a squat jump. According to the findings, on the first and second days after receiving isotonic fluids, participants' systolic blood pressure and heart rates significantly decreased as a result of body adaptation, however on the third to fifth days, there was no drop. Participants who were administered mineral water saw a substantial rise in their systolic blood pressure and heart rate. Diastolic blood pressure is unaffected by the administration of isotonic fluids or minerals. However, a rise was seen in blood sodium levels.

Muñoz-Martínez [27] shows that the goal of this systematic review and meta-analysis was to assess published research that looked at the effects of resistance circuit-based training on maximum oxygen absorption and one-repetition upper-body strength in healthy individuals. The meta-analysis revealed that resistance circuit-based training is effective in raising maximum oxygen uptake and one-repetition maximum bench press in healthy people, regardless of the study design. Karuppasamy [28] determined how certain physical and physiological factors in male volleyball players responded to plyometric training and circuit training. 24 male volleyball players between the ages of 18 and 25 were chosen at random. According to the findings, plyometric and circuit training dramatically increased anaerobic and aerobic capacity as well as muscular endurance, flexibility, agility, and explosive strength.

Sobrero [29] studied the differences existence in health and performance measures in women participating in High intensity functional training (HIFT) or traditional circuit training (TCT) after a six-week training program. The results both groups increased body mass, and improved muscular endurance, upper body strength, lower body power, and agility. In addition, the HIFT group decreased body fat, while the TCT group increased body fat. Marcos-Pardo [30] found out how resistance circuit training at a moderate to high intensity affected senior citizens' body composition, functional independence, muscular strength, and quality of

life was the goal. There was a randomised controlled study. Both sexes showed significantly greater values of physical strength and a considerable improvement in functional autonomy. However, there were no differences in these groups' quality of life that could be seen. The other variables showed no signs of change. When groups were compared, similar findings were established. Resistance training at a moderate-to-high intensity increased both men's and women's upper and lower body strength significantly while also increasing their overall lean body mass and functional capacity. This research differs from our own study. Our research focuses on circuit training-based models for improving the physical conditioning of basketball athletes, with the goal of enhancing speed, agility, arm power, and leg muscle strength. The circuit training program in our study consists of six stations. Station 1 includes exercises such as jumping rope, push-ups, ickey shuffle, and shuttle runs. Station 2 comprises jump squats, x-drills, triangle drills, and tricep dips. Station 3 involves lateral squats, biceps curls, four corner drills, and high knee runs. Station 4 incorporates lunges, tricep curls, m-drills, and high knees. Station 5 features band lateral walks, Hindu push-ups, zig-zag runs, and heel kicks. Lastly, station 6 consists of hurdle hops, tricep resistance band exercises, hexagon drills, and kicking.

Conclusions

Based on the results of the study, it can be concluded that the circuit training-based physical condition training model consisting of 6 posts is effective in increasing the speed, agility, arm power, and leg muscle power of basketball athletes. These results are indicated by speed data ($0.017 < 0.05$), agility ($0.000 < 0.05$), arm power ($0.000 < 0.05$), and leg muscle power ($0.036 < 0.05$). The results of the study can be used as material for consideration for coaches in making appropriate training programs to increase the speed, agility, arm power, and leg muscle power of basketball athletes. Thus the exercise will be effective and get results in accordance with what is expected. Based on our results, we recommend that basketball coaches consider including a circuit training-based physical condition training model in training, as a simple and practical model for improving athletes' physical condition. For researchers who intend to continue or replicate this study, it is recommended to conduct tighter control in the entire series of experiments.

Acknowledgement

The author appreciates the cooperation of all the enthusiastic subjects. The research was funded by the author.

Conflict of interest

We know of no conflicts of interest associated with this publication, and there has been no significant financial support for this work that could

have influenced its outcome. As the corresponding author, I confirm that the manuscript has been read and approved for submission by all the named authors.

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Cite this article as:

Annasai F, Sumaryanti, Nugroho S, Hartanto A, Arianto AC. Circuit training based physical condition training model to increase speed, agility, arm power, and limb muscle power of basketball athletes. *Pedagogy of Physical Culture and Sports*, 2023;27(4):282–288. <https://doi.org/10.15561/26649837.2023.0403>

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Received: 16.05.2023

Accepted: 17.06.2023; Published: 30.08.2023

Predictors of Filipino physical education teachers' intentions in the use of exercise as punishment

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Abstract

Background and Study Aim Studies on exercise as punishment (EAP) have focused on students and coaches, but less attention has been given to the perspectives of physical education (PE) teachers. This study examined the factors that influence Filipino PE teachers' intentions to use EAP. Specifically, the study examined the role of socio-demographic characteristics, attitudes, and subjective norms in predicting intentions to use EAP in PE classes.

Material and Methods A cross-sectional study was conducted to collect data from 397 PE teachers from all 16 regions of the Philippines. A researcher-made questionnaire was used to collect data on the participants' socio-demographic characteristics, attitudes, subjective norms, and intention to use EAP in their classes. Descriptive statistics and regression analysis were used to analyze the data.

Results The results showed that attitude was the strongest predictor, followed by gender (male), subjective norms, and age (over 45 years). This analysis suggests that the intention to use EAP is more prevalent among males and those over 45 years. It also shows that attitudes significantly predict these intentions. This suggests that teachers who perceive exercise as a tool for improving physical fitness and enforcing adherence to rules in a PE setting are more likely to have such intentions. In addition, respondents with higher social pressure in employing exercise as a disciplinary measure in PE classes showed greater intentions to use EAP.

Conclusions The intention to use EAP is more prevalent among male PE teachers, those who are older, and those with positive attitudes towards disciplining students using physical exercises. Additionally, teachers who feel more social pressure to use exercise as a disciplinary measure are also more likely to use EAP. These findings can be used to inform the development of PE teacher training programs and policies that promote the use of positive reinforcement and other non-punitive methods of discipline in PE classes.

Keywords: attitude, exercise as punishment, health, physical education, subjective norm, teachers

Introduction

Physical exercise is an essential aspect of maintaining a healthy lifestyle. It is defined as any physical activity that involves the contraction of muscles and the expenditure of energy, including activities such as walking, running, swimming, and weightlifting. Regular physical exercise offers numerous benefits, such as improved cognitive function in children [1] and reduced anxiety in adults [2]. It also improves muscle strength and endurance [3] circulation and blood flow [4], lung and heart function [5], and overall physical fitness [6]. However, there are some instances where exercise can be used as punishment, leading to various negative consequences.

Exercise as punishment (EAP) has been used in various settings, such as schools [7, 8]. One reason for using EAP is the belief that it helps individuals build discipline and self-control [7]. Requiring individuals to perform physical activities for their

misbehavior can prompt them to follow the rules and take responsibility for their actions [9]. Additionally, exercise can promote physical fitness and health, benefiting sedentary and inactive individuals [10, 11]. On the contrary, potential drawbacks to using EAP have been observed. One of the main concerns is the negative association with physical activity. Some studies suggest that EAP can contribute to negative attitudes toward physical activity and a lack of engagement with exercise [12, 13]. Additionally, it could result in physical harm and overexertion, jeopardizing health and safety. For example, a child who is forced to run laps as punishment may become dehydrated or injured. These effects show that EAP can be counterproductive to promoting physical fitness and health, as individuals may be less likely to exercise voluntarily in the future.

In the fields of physical education (PE) and sports, using EAP is a prevalent practice. Richardson et al. [13] reported that many youth had experienced being forced to exercise as a form of punishment, which appears to be embedded in PE and sports

culture. Coaches and trainers often use exercise to modify behaviors that negatively impact performance [9, 13]. This can manifest in various ways, including running, push-ups, jumping jacks, and even suspension from practice. Nonetheless, studies have indicated that physical exercise as a discipline or behavior management technique can foster unfavorable attitudes toward exercise that persist into adulthood [14, 13]. EAP is considered inappropriate in 29 states and a form of corporal punishment by the National Association for Sport and Physical Education [15, 16]. Despite the well-documented negative effects of EAP on attitudes and behaviors toward exercise, it is noteworthy that this approach remains prevalent in various countries, such as the Philippines.

In the Philippines, EAP has recently been the subject of much attention as a pressing issue, particularly in light of several incidents in which government officials have used excessive exercise to correct behaviors. For example, a Filipino man who violated quarantine rules was forced to do 300 squats by the police as punishment, ultimately resulting in his death [17]. The incident sparked widespread public outcry and led to an inquiry into the use of excessive exercise as a disciplinary measure. Multiple reports also surfaced of teachers directing students to kneel for extended periods of time as punishment for misbehavior [18, 19, 20]. It is of paramount importance to note that the issue of physical inactivity among Filipinos has been a major concern in the country. Recent surveillance data have reported a concerning prevalence of insufficient physical activity among young Filipinos [21, 22]. Despite the Philippine government's initiatives to encourage physical activity through sports, PE, and healthy lifestyles [23, 24, 25, 26], current data indicates that the country still needs to tackle the issue of physical inactivity effectively. While there are a number of factors that may have contributed to the issue of physical inactivity, the use of EAP may have played a role, as some people may have a positive attitude towards or feel socially pressured to use it.

The attitudes and subjective norms of individuals may influence their use of EAP. The Theory of Reasoned Action (TRA) provides insight into how a person's behavior is influenced by their attitude towards a specific behavior and the perceived social pressure (subjective norms) to engage in that behavior [27]. TRA is a cognitive theory that can help predict various health behaviors, including EAP. It consists of two components: attitudes and subjective norms. Attitudes refer to an individual's beliefs about a specific behavior, while subjective norms refer to their beliefs about what their significant others think about that behavior. Previous research has applied the principles of TRA to examine the intentions of PE majors toward using EAP [14]. Results showed that the constructs of TRA

explained almost 70% of the variance in participants' intentions to use EAP. Another study was conducted with sports coaches, citing their beliefs on EAP as a form of performance motivation and team cohesion [7]. Existing studies have explored the reasons for using EAP from the point of view of students and coaches, and more is needed from the perspective of PE teachers. They may feel that exercise is a way to teach students discipline and respect, or feel compelled to do it because it is a common practice. Furthermore, although existing studies on EAP are scarce, they have primarily been conducted in Western countries. Therefore, further investigation is needed to understand the underlying reasons for EAP in the Philippines, where it is prevalent. This is particularly important given the unique cultural and social factors that may contribute to using EAP in the Philippines.

Another possible factor behind the use of EAP in schools is the socio-demographic characteristics of teachers. Although there is limited research to support this claim, some have argued that younger, less experienced teachers may be more likely to use EAP because they may be less skilled and experienced in managing students and using alternative methods of discipline. Zhukova [28] noted that the first few years of teaching are often the most difficult and demanding for new teachers. This is because teaching is a complex skill that takes time and experience to master. Zafer et al. [29] found that younger teachers are less effective in teaching and classroom management than older teachers. On the contrary, older teachers, who typically have more teaching experience, tend to use corporal punishment to discipline students. One reason for this is that corporal punishment is "what they have known all along" [30], or it is deeply ingrained in their way of thinking and behaving that it has become a common and acceptable practice [31]. The study by Yousuf et al. [32] also noted that older teachers were the ones who frequently use corporal punishments for disciplining students.

Furthermore, gender may also be a contributory factor in using EAP. Studies found that male teachers are three times more likely than female teachers to inflict severe corporal punishment on students [33, 34]. In recent years, the studies by Matofari [35] and Anwar et al. [36] found the same results, citing that male teachers have affirming attitudes toward corporal punishment. It is important to note that the socio-demographic characteristics of teachers are just some of the possible factors that may contribute to the use of EAP in schools. More research is needed to fully understand this complex issue.

Purpose of the Study. The study's purpose was to examine the predictors of Filipino PE teachers' intentions in using EAP. More specifically, it aims to answer the following questions:

1. Do PE teachers' socio-demographic characteristics (gender, age, education, years of experience) affect their intentions toward using EAP in their classes?
2. Do PE teachers' attitudes and subjective norms affect their intentions toward using EAP in their classes?

Materials and Methods

Participants

The respondents were 397 public school teachers across the 16 regions of the Philippines. This number is above the 377 computed minimum sample size by Raosoft® software for an unknown population. The study employed convenience sampling because data collection was conducted via online platforms. This approach allowed for widespread questionnaire dissemination during the pandemic when direct contact and social interaction were limited. Table 1 shows the socio-demographic profile of the respondents. In terms of gender, the number of males was comparable to that of females. Most of them were under 45 years old (55.2%), had a postgraduate degree as their highest educational attainment (73.8%), and had more than ten years of teaching experience (88.7%).

Table 1. Socio-demographic profile of respondents (n = 397)

Socio-demographic Variables	Frequency	Percent
Gender		
Male	198	49.9
Female	199	50.1
Years of Service		
Less than 10 years	45	11.3
More than 10 years	352	88.7
Highest Educational Attainment		
Undergraduate	104	26.2
Postgraduate	293	73.8
Age		
Under 45 years old	219	55.2
Above 45 years old	178	44.8

Research Design

A cross-sectional study design was employed in this study. This design allowed the researchers to collect data from a group of PE teachers at a single point in time, which enabled them to gain a better understanding of the factors that influence these teachers' decisions to use EAP. Data were collected between January and March 2023, three years after COVID-19 had been declared a pandemic.

Data Gathering

The data-gathering procedure followed five phases: Phase 1: development of a questionnaire

that measures the variables of the study; Phase 2: content validation of the questionnaire guided by three experts (one expert in the English language and two experts in PE); Phase 3: pilot testing of a questionnaire for internal reliability consistency testing; Phase 4: distribution of the questionnaire via social media groups and institutional websites; and Phase 5: screening of the gathered data to determine the completeness and accuracy of the data set.

In Phase 1, the study used a researcher-made questionnaire to ask the PE teachers' socio-demographic characteristics, attitudes, subjective norms, and intention to use EAP in their classes. The development of the questionnaire was guided by the theoretical recommendations for constructing Theory of Planned Behavior measures [37, 38]. The attitude dimension comprised four questions regarding a person's general feeling of EAP's benefits, such as: "Exercise, as a consequence, can improve students' physical fitness". The subjective norms dimension comprised four questions regarding a person's belief of what their significant others think about EAP. "I tend to follow other PE teachers who use exercise as a punishment". The intention dimension comprised four questions regarding a person's likelihood of doing EAP in their classes. "I intend to use exercise to penalize students who fail to follow the rules and instructions in my PE classes". We employ a four-point scale for the response rate, where 1 represents "strongly disagree" and 4 indicates "strongly agree".

In Phase 2, the questionnaire underwent a series of reviews by three education experts to ensure each item aligned with the study's variables. One expert in the English language reviewed and corrected some items with grammatical and sentence structure issues. Two PE experts ensured that the items were within the context of PE. In Phase 3, the pilot testing of the questionnaire yielded a Cronbach's alpha rating ranging from 0.717 to 0.743 after the deletion of 5 items. The questionnaire has acceptable internal reliability consistency. In Phase 4, the prospective respondents answered the questionnaires distributed online via social media groups and institutional websites. In the instructions, the respondents have read the directions for answering the questionnaire and the ethical protocol statements. In Phase 5, the gathered data was screened by excluding responders who were not regular public school teachers at the basic education level and those with incomplete answers.

Statistical Analysis

We utilized SPSS software version 26 (SPSS 26.0 IBM Corporation, Armonk, New York, USA) to conduct our data analysis, encompassing descriptive statistics and regression analysis. The data for age, gender, years of experience, and educational level

were analyzed using descriptive statistics, such as mean, frequency, and percentage. For assessing the assumption of normality, we examined skewness (± 3) and kurtosis (± 10) indices, following the method suggested by [39]. We calculated Pearson's r correlation coefficients to investigate the relationships between all the variables in the study at a bivariate level. To check for multicollinearity, we evaluated both tolerance and the variance inflation factor (VIF). A linear multiple regression analysis was subsequently performed, with the dependent variable being the intention to use EAP. We set the significance level at $p < 0.05$. The proportion of variance in the intentions to use EAP was communicated via changes in the R-squared value. Within this study, we classified age, gender, years of experience, and educational level as dummy variables to ensure accurate results.

Results

We conducted a Pearson's r correlation coefficient analysis to explore potential significant correlations between socio-demographic variables, attitudes, subjective norms, and the intention to use EAP. As indicated in Table 2, the analysis results suggested significant correlations between the intention to use EAP and several variables, including gender (male), experience (< 10 years), age (< 45 years), attitudes, and subjective norms. Specifically, the most significant

correlation with intentions to use EAP was attitudes ($r = 0.818, p < 0.01$), followed by subjective norms ($r = 0.767, p < 0.01$), gender ($r = 0.747, p < 0.01$), experience ($r = 0.296, p < 0.01$), and age ($r = -0.183, p < 0.01$). Subsequently, we carried out a multiple linear regression with the intention to use EAP as the dependent variable, and the factors of gender (male), experience (< 10 years), age (< 45 years), attitudes, and subjective norms were designated as the predictors. Prior to conducting the multiple regression analysis, we ensured that the four key assumptions of multiple regression - homoscedasticity, linearity, multicollinearity, and normality - were tested. Table 2 illustrates that the values of skewness and kurtosis were within the acceptable ranges according to Brown [39]. As the tolerance value exceeded 0.1 and the variance inflation factor (VIF) remained below 10, we established that multicollinearity was not a concern in our research variables [40]. Consequently, the multiple regression analysis was executed once all assumptions were satisfactorily met.

A linear multiple regression analysis was carried out to ascertain which variables were influential in the intentions to use EAP. The outcome revealed a high R^2 value of 0.728, accounting for 72.8% of the variance in the intentions to use EAP. As detailed in Table 3, the attitude ($\beta = 0.404, p = 0.000$) was identified as the strongest significant predictor of these intentions. Following this, gender (male) ($\beta =$

Table 2. The results of Pearson correlation

No	Variables	1	2	3	4	5	6	7
1	Gender (Male)	1						
2	Experience (< 10 years)	-.357**	1					
3	Education (Undergraduate)	0.082	.438**	1				
4	Age (< 45 years)	-.418**	.322**	-0.108*	1			
5	Attitude	.762**	-.336**	-.214**	-.220**	1		
6	Subjective Norms	.696**	-.395**	-.294**	-.231**	.833**	1	
7	Intentions	.747**	-.295**	-0.068	-.183**	.818**	.767**	1
	Skewness	0.01	2.45	1.09	-0.21	-0.41	-0.37	-0.25
	Kurtosis	-2.01	4.02	-0.82	-1.97	-1.47	-1.11	-1.36

Note: ** $p < 0.01$; * $P < 0.05$

Table 3. Predictors of intentions to use exercise for punishment

Dependent Variable	Predictors	B	T	p	R ²	F	p	TOL	VIF
Intentions to use exercise for punishment	Gender (Male)	0.316	7.024	0.000	0.728	209.242	0.000	0.345	2.901
	Experience	0.019	0.642	0.521				0.786	1.272
	Age (< 45 years old)	0.087	2.863	0.004				0.761	1.314
	Attitude	0.404	7.453	0.000				0.237	4.226
	Subjective Norms	0.239	4.832	0.000				0.285	3.505

0.316, $p = 0.000$), Subjective Norms ($\beta = 0.239$, $p = 0.000$), and age (< 45 years old) ($\beta = 0.087$, $p = 0.004$) were established as additional influential factors. Education (undergraduate level) was found not to be a significant predictor.

Discussion

This study aimed to examine the predictors of Filipino PE teachers' intentions in using EAP. More specifically, it examined if socio-demographic characteristics (gender, age, education, years of experience), attitudes, and subjective norms affect the intentions toward using EAP in classes.

A linear multiple regression analysis was conducted to ascertain which variables influenced the intention to use EAP. The results showed that attitude was the strongest predictor, followed by gender (male), subjective norms, and age (over 45 years). This analysis suggests that the intention to use EAP is more prevalent among males and those over 45 years. It also shows that attitudes significantly predict these intentions, suggesting that those who perceive exercise as both a tool for improving physical fitness and enforcing adherence to rules in a PE setting are more likely to have such intentions. In addition, respondents with higher social pressure in employing exercise as a disciplinary measure in PE classes showed greater intentions to use EAP. This study supports previous research that shows people's attitudes and subjective norms influence the use of EAP. In particular, Burak et al. [14] found that 70% of the variance in participants' intentions to use EAP was explained by their affirming attitude about it and the social pressure they perceived from their peers or leaders. Additionally, Kerr et al. [7] found that sports coaches use EAP because they believe it can motivate athletes to perform better and improve team cohesion.

Furthermore, our findings support the notion that older teachers tend to use corporal punishment to discipline students [32]. Contrary to the notion that younger teachers are less expert or effective in teaching and classroom management than older teachers [29, 28], older teachers tend to use corporal punishment to discipline students because that is how they were taught [30] and it is a common and acceptable practice in their place [31]. On the other hand, the study supports the notion that gender is a contributory factor in using EAP. Studies found that male teachers are three times more likely than female teachers to inflict severe corporal punishment on students [33, 34]. In recent years, the studies by Matofari [35] and Anwar et al. [36] found the same results, citing that male teachers have affirming attitudes toward corporal punishment.

The findings imply that EAP has been used in school settings [7, 8], particularly in PE classes. Many Filipino PE teachers see EAP as a common and acceptable practice to discipline students, but

they need to be aware of the potential drawbacks of this approach. It has been noted that many people believe that exercise can help individuals improve their physical fitness and health [10, 11], develop self-control and a sense of responsibility, and manage misbehavior [9, 7]. However, there is also evidence that EAP can lead to negative attitudes toward physical activity, a lack of engagement with exercise, and physical harm [12, 13]. EAP has also been noted to impact performance negatively [9, 13]. PE teachers should be aware of the potential drawback of using EAP, especially in its impact on individuals being less likely to exercise in the future.

It is crucial to note that the problem of physical inactivity among Filipinos has been a major concern in the country [21, 22]. Despite the Philippine government's initiatives to encourage physical activity through sports, PE, and healthy lifestyles [23, 24, 25, 26], current data shows that the country still needs to address the issue of physical inactivity effectively. While there are many factors that may have contributed to physical inactivity, EAP may have played a role in this problem.

Our study adds to the existing knowledge about EAP by examining the topic from the perspective of PE teachers. Previous studies have focused on the perspectives of students and coaches, but less attention has been given to the perspectives of PE teachers. This is important because PE teachers are often the ones who implement classroom policies and procedures. Moreover, this investigation provides significant input in understanding the underlying reasons for the prevalent use of EAP in the Philippines.

Conclusions

This study determined a number of relevant contributions to the limited knowledge on PE teachers' intentions in the use of EAP in their classes. In particular, the intention to use EAP is more prevalent among male PE teachers, those who are older, and those with positive attitudes towards disciplining students using physical exercises. Additionally, teachers who feel more social pressure to use exercise as a disciplinary measure are also more likely to use EAP.

Recommendation

The study's findings have important recommendations for PE teachers and policymakers. First, it is important for PE teachers to be aware of their own attitudes towards exercising and disciplining misbehavior, as these attitudes may influence their intentions to use EAP. Second, policymakers should consider the potential risks of using EAP, such as the negative impact on student motivation and self-esteem, and should develop policies that discourage the use of EAP in PE schools. Lastly, the findings can be used to inform the development of PE teacher

training programs and policies that promote the use of positive reinforcement and other non-punitive methods of discipline in PE classes.

Conflict of interest

We hereby declare that there is no conflict of interest in this research

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Cite this article as:

Tanucan JCM, Wider W, Sofyan D. Predictors of Filipino physical education teachers' intentions in the use of exercise as punishment. *Pedagogy of Physical Culture and Sports*, 2023;27(4):289–296.
<https://doi.org/10.15561/26649837.2023.0404>

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Received: 22.05.2023

Accepted: 21.06.2023; Published: 30.08.2023

Aging, personality, and teaching aptitude in school grade physical education teachers

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Abstract

Background and Study Aim The primary objectives of the research were to examine the impact of aging on teaching aptitude, explore the association between personality traits and teaching effectiveness, and identify potential interactions between age, personality, and teaching aptitude.

Material and Methods Data were collected through standardized measures assessing teaching aptitude, personality traits, and demographic information. An intentional sampling with a survey group size of 283 physical education teachers (28.6% Female) including Trained Graduate Teachers (26.5%) and Post Graduate Teachers (73.5%) respectively. One-way analysis of variance, Pearson correlation coefficient, Hierarchical Regression, and mediation methods were used to analyze the obtained data.

Results Teaching aptitude was negatively related to chronological age (male, $r = -.296$, female, $r = -.43$), teaching experience (male, $r = -.343$, Female, $r = -.326$), and neuroticism (male, $r = -.408$, female, $r = -.399$). Extraversion, Openness, Agreeableness, and Conscientiousness were positively related to teaching aptitude. Hierarchical Regression shows that gender has not explained significant variation among teaching aptitude after controlling the effects of personality traits and age (R^2 square changes = .004). However, personality has partial mediating effects on the direct relationship between age and teaching aptitude.

Conclusions Teaching aptitude decreases with age in both genders. The decreasing teaching aptitude with age has significant implications on the education system. However, the personality traits of the teachers also changed with age. Teachers gained more neuroticism as aged. It is essential to identify the factors contributing to this phenomenon and develop strategies to mitigate its effects.

Keywords: teaching aptitude, Big-five personality, age, teaching effectiveness.

Introduction

Teaching aptitude refers to a person's natural ability to effectively teach and facilitate learning [1]. It encompasses a range of skills, including communication, organization, patience, empathy, adaptability, and subject matter expertise. A person with a strong teaching aptitude is able to convey information clearly, motivate and engage students, and create a positive learning environment [2]. A teacher is a role model for every student their personality, aptitude, and attitude mold the child as desired [3]. Teachers' aptitude for teaching decides a teacher's success as a professional and learners' development as a whole. Teachers' aptitude for teaching might be innate ability but it can be manifested with appropriate and adequate practices such as behavioral grooming apt for the profession. There are many behavioral issues that make a person unfit for the teaching profession, aggression is one of them [4, 5].

Research suggests that certain personality traits are particularly important for effective teaching. For example, the "Big Five" personality traits (openness, conscientiousness, extraversion, agreeableness, and neuroticism) have been found to be associated with

teaching effectiveness. Specifically, openness to experience, conscientiousness, and agreeableness have been positively correlated with teaching effectiveness, while neuroticism has been negatively correlated [2, 6]. However, it's important to note that personality traits are only one factor that can influence teaching effectiveness and that effective teaching also involves a range of skills, knowledge, and experience. Additionally, a person's teaching style and approach may vary depending on the context, subject matter, and student population they are working with.

Some studies reported a significant relationship between teachers' salaries and teaching aptitude [7]. the relationship between average pay and teacher aptitude was positive [8, 9]. However, the present study does not pertain to teachers' salaries. The salaries of the teachers should not be a factor of generalization and may be affected by different socio and economic aspects. Another important study explored the impact of demographic characteristics such as age, gender, qualifications, experience, and marital status on teaching aptitude [10]. A study conducted in the Gurugram and Mewat districts of Haryana reported average teaching aptitude in teacher trainees, and no significant difference was observed between age and teaching aptitude

[11]. After the covid-19 pandemic, comprehensive variations were revealed in teaching methods and technologies used for online and offline teaching. In this context, teachers’ self-innovativeness plays a crucial role in teaching effectiveness [12]. Therefore, the aged teacher may find it difficult to manage with the latest pedagogical technologies.

Earlier studies have evident the lack of assessment of teaching aptitude in the physical education domain. The relationship between, teaching aptitude, personality traits, and demographical variables such as age, sex, region, etc. is still not clear. Finally, there is a need for more research on how teaching aptitude relates to different psychological and chronological factors. With this point of view, the present study has been designed to explore the potential relationship between teaching aptitude, self-efficacy, personality, and age as a chronological factor.

Material and Methods

Participants

Participants were 283 Physical Education teachers including 202 males (71.4%) and 81 females (28.6%) working in government and private schools located in rural and urban regions of Haryana province. A Total of 150 schools from six administrative divisions of Haryana were selected through cluster random sampling. The mean age of the male teachers was 38.06 years and female teachers was 33.48 years. To identify the protentional factors affecting teaching effectiveness subjects were further categorized into age groups, gender, grade, nature of the job, school type, and school location respectively. The detailed demographic information of the subjects was depicted in Table 1.

Study Design

Teaching effectiveness was assessed through Teaching Aptitude Test (TAT) developed and standardized by S. C.-Gakhar and Rajnish [13]. The following test contains 35 statements in respect of teaching aptitude where four alternative answers have been given for each statement and only one answer was correct. The teaching aptitude test was developed on 400 prospective school teachers and the reliability and validity were found to be 0.78 and 0.68 as well. The normative reference values were provided by the authors in the manual to find out the status of Teaching Aptitude. The obtained score ranged from 0 to 35 and indicated seven categories of Teaching Aptitude i.e., < 12 = very low teaching aptitude, 13 – 16 = low teaching aptitude, 17 – 20 = below average teaching aptitude, 21 – 24 = average teaching aptitude, 28 – 25 = above average teaching aptitude, 29 – 32 = high teaching aptitude, 33 < very high teaching aptitude.

The NEO-FFI (NEO = Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness, FFI = Five-factor inventory) consists of 60 items designed to assess the Big Five personality traits. It is the most widely used and robust measure of personality traits with sound psychometric properties established by previous researchers [14]. In the present study, the Cronbach alpha values for each subscale’s internal consistency were as follows: .84 (neuroticism), .74 (extraversion), .68 (openness), .74 (agreeableness), and .83 (conscientiousness).

The inventory developed by Schwarzer and Jerusalem in 1995 [15] was used to assess the general self-efficacy of the participants. The inventory consists of 10 statements in the context of general

Table 1. Demographic Profile and mean difference among potential factors affecting teaching aptitude of Physical Education Teachers

Factors	Groups	N	Mean	Df	t/F	Sig. (Two-Tailed)
Age	20 – 29 Y	76	17.24	3 (279)	19.390	.000
	30 – 39 Y	93	13.62			
	40 – 49 Y	98	9.37			
	50 – 59 Y	16	15.75			
Gender	Male	202	12.97	281	.946	.345
	Female	81	13.91			
Grade/Level	TGT*	75	15.92	281	3.646	.000
	PGT*	208	12.27			
Job Status	Regular	139	12.71	281	1.151	.251
	Temporary	144	13.75			
School Type	Govt.	121	11.93	281	2.528	.012
	Private	162	14.22			
School Location	Rural	207	12.89	281	1.288	.199
	Urban	76	14.20			

TGT* - Trained Graduate Teacher; PGT* - Post Graduate Teacher

self-efficacy. General self-efficacy is related to emotion, optimism, and work satisfaction. Negative coefficients were found for depression, stress, health complaints, burnout and anxiety. The statements were scored in a 4-point Likert scale ranging, “Not at all – 1, Hardly true – 2, Moderately True – 3, Exactly True – 4”. The total score was calculated by finding the sum of all items. For the GSE (General Self-efficacy) the total score ranged between 10 to 40. A higher score indicates more self-efficacy.

Statistical analysis

All statistical calculations were carried out using the IBM SPSS 26 (IBM, Armonk, NY, USA) statistical package. The arithmetic mean was used as descriptive statistics. Independent sample t-test and one-way analysis of variance (ANOVA) were used to calculate significant mean differences among the selected groups. Karl Pearson’s correlation coefficient was calculated to find out the relationship between variables. Further, multiple regression was performed to explain the variation in the dependent variable (Teaching Aptitude) by independent variables. Hierarchical regression was used to examine the unique contribution of each predictor variable to the dependent variable, after controlling for the effects of all other predictor variables in the model.

Mediating effects (indirect relationship) of personality factors were analyzed through path analysis using Analysis of Moment Structures (AMOS) and a model has been prepared including the dependent variable (Teaching aptitude), independent variable (age), and mediator (personality traits). The level of significance was 0.05 respectively.

Results

One-way analysis of variance was used to compare the mean score of teaching aptitude among different age groups (See Table 1). Results revealed significant differences [$F(3, 279) = 19.390, p < 0.05$]

between the age groups in their teaching aptitude. The mean values indicate a high score of teaching aptitude in the 20 – 29 years age group. Teaching aptitude is decreasing with age. In reference to the 20 – 29 year of age group, a higher mean difference (MD = 8.27) was reported in 40 – 49 years of age group.

In the case of different grades of the school teachers i.e., TGT (Trained Graduate Teacher) and PGT (Post Graduate Teacher), a higher mean ($t = 3.346, df = 281, p < 0.05$) was observed in TGT grade teachers. Teachers who were working in private schools reported higher teaching aptitude ($t = 2.528, df = 281, p < 0.05$) than their government schools’ counterparts. No significant difference was observed between male vs. female Teachers, regular vs. temporary teachers, and teachers working in rural and urban school locations.

Table 2 and Table 3 explore the correlation matrix of both genders among teaching aptitude, age, teaching experience, General Self-Efficacy, and Big-five personality factors. Correlation analysis indicates a number of significant relationships. Specifically, consistent with our hypothetical model and predictions, age was negatively correlated (male, $r = -.296$, female, $r = -.431$) with teaching aptitude. Teaching experience is also negatively (male, $r = -.343$, Female, $r = -.326$) correlated with teaching aptitude. Teaching aptitude is positively correlated with Extraversion, openness, agreeableness, and conscientiousness. Neuroticism was negatively (male, $r = -.408$, female, $r = -.399$) correlated with teaching aptitude.

We first examine the extent to which the Big Five personality traits predicted teaching aptitude (Table 4). The Big Five personality traits collectively explained 42.8% of the variance in teaching aptitude. Agreeableness solely explained 30% variance in teaching aptitude. Neuroticism explained 7.4% variance. Conscientiousness and Extraversion explained 4.3% and 1.2% variance as well. Openness was significantly correlated with teaching aptitude

Table 2. Correlation Matrix Male

Variables	TAT	Age	Ex.	GSC	E	N	O	A	C
TAT	1	-.296**	-.343**	.077	.268**	-.408**	.213**	.567**	.479**
Age	-.296**	1	.889**	-.043	-.109	.131	-.007	-.138	-.168*
Ex.	-.343**	.889**	1	-.043	-.136	.148*	.006	-.141*	-.161*
GSC	.077	-.043	-.043	1	.254**	-.081	.142*	-.006	.206**
E	.268**	-.109	-.136	.254**	1	-.117	.268**	.135	.257**
N	-.408**	.131	.148*	-.081	-.117	1	-.147*	-.251**	-.193**
O	.213**	-.007	.006	.142*	.268**	-.147*	1	.252**	.313**
A	.567**	-.138	-.141*	-.006	.135	-.251**	.252**	1	.502**
C	.479**	-.168*	-.161*	.206**	.257**	-.193**	.313**	.502**	1

TAT - Teaching Aptitude Test, Ex. - Teaching Experience, GSC - General Self-Efficacy, E - Extraversion, N - Neuroticism, O - Openness, A - Agreeableness, C - Conscientiousness; * $p < 0.05$; ** $p < 0.01$

(Table 2 and Table 3) but did not predict variance in regression analysis and was removed from the model.

In Table 5 hierarchical regression was used to examine the unique contribution of each predictor variable to the dependent variable, after controlling for the effects of all other predictor variables in the model. After controlling the effects of personality traits, the obtained value of R^2 was .429 respectively. In the second block, the age explains 2.6% ($R^2 = .454$) additional variance (see R square changed in Table 5) and it was significant at 0.05 level of significance. In the 3rd block, variance by gender as a predictor was analyzed. The values of R square change (.004) did not explain significant additional variance in the dependent variable after controlling the other predictors.

To obtain a deeper understanding of the intricate relationship between personality traits and age as predictors of teaching aptitude, we investigated the extent to which personality traits mediate the relationship between age and teaching aptitude using Analysis of Moment Structures (AMOS). Results showed that the direct relationship (beta = -.31, $p < 0.05$) between age and teaching aptitude was statistically significant. In particular, when personality traits were included, the relationship between age and teaching aptitude was significantly reduced from -.31 to -.18 respectively (See Figure 1).

Furthermore, the changes in teaching aptitude with reference to age were illustrated in Figure 2 respectively. It was clearly depicted in Figure 2 that score of teaching aptitude was gradually decreasing with age and the lowest teaching aptitude was

Table 3. Correlation Matrix Female

Variables	TAT	Age	Ex.	GSC	E	N	O	A	C
TAT	1	-.431**	-.326**	.101	.362**	-.399**	.483**	.510**	.410**
Age	-.431**	1	.884**	-.049	-.237*	.223*	-.233*	-.333**	-.312**
Ex.	-.326**	.884**	1	.083	-.175	.238*	-.202	-.221	-.265*
GSC	.101	-.049	.083	1	.319**	-.256*	.202	-.076	.351**
E	.362**	-.237*	-.175	.319**	1	-.379**	.573**	.244*	.526**
N	-.399**	.223*	.238*	-.256*	-.379**	1	-.417**	-.275*	-.427**
O	.483**	-.233*	-.202	.202	.573**	-.417**	1	.411**	.453**
A	.510**	-.333**	-.221	-.076	.244*	-.275*	.411**	1	.248*
C	.410**	-.312**	-.265*	.351**	.526**	-.427**	.453**	.248*	1

TAT - Teaching Aptitude Test, Ex. - Teaching Experience, GSC - General Self-Efficacy, E - Extraversion, N - Neuroticism, O - Openness, A - Agreeableness, C - Conscientiousness; * $p < 0.05$; ** $p < 0.01$

Table 4. Multiple regression using the stepwise method

z	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.548 ^a	.300	.297	6.357	.300	120.322	1	281	.000
2	.612 ^b	.374	.370	6.022	.074	33.185	1	280	.000
3	.645 ^c	.417	.410	5.824	.043	20.394	1	279	.000
4	.654 ^d	.428	.420	5.776	.012	5.646	1	278	.018

^a. Predictors: (Constant), Agreeableness; ^b. Predictors: (Constant), Agreeableness, Neuroticism; ^c. Predictors: (Constant), Agreeableness, Neuroticism, Conscientiousness; ^d. Predictors: (Constant), Agreeableness, Neuroticism, Conscientiousness, Extraversion

Table 5. Hierarchical Regression

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.655 ^a	.429	.418	5.784	.429	41.577	5	277	.000
2	.674 ^b	.454	.443	5.663	.026	12.974	1	276	.000
3	.677 ^c	.459	.445	5.650	.004	2.223	1	275	.137

^a. Predictors: (Constant), Conscientiousness, Neuroticism, Extraversion, Agreeableness, Openness; ^b. Predictors: (Constant), Conscientiousness, Neuroticism, Extraversion, Agreeableness, Openness, Age; ^c. Predictors: (Constant), Conscientiousness, Neuroticism, Extraversion, Agreeableness, Openness, Age, Gender

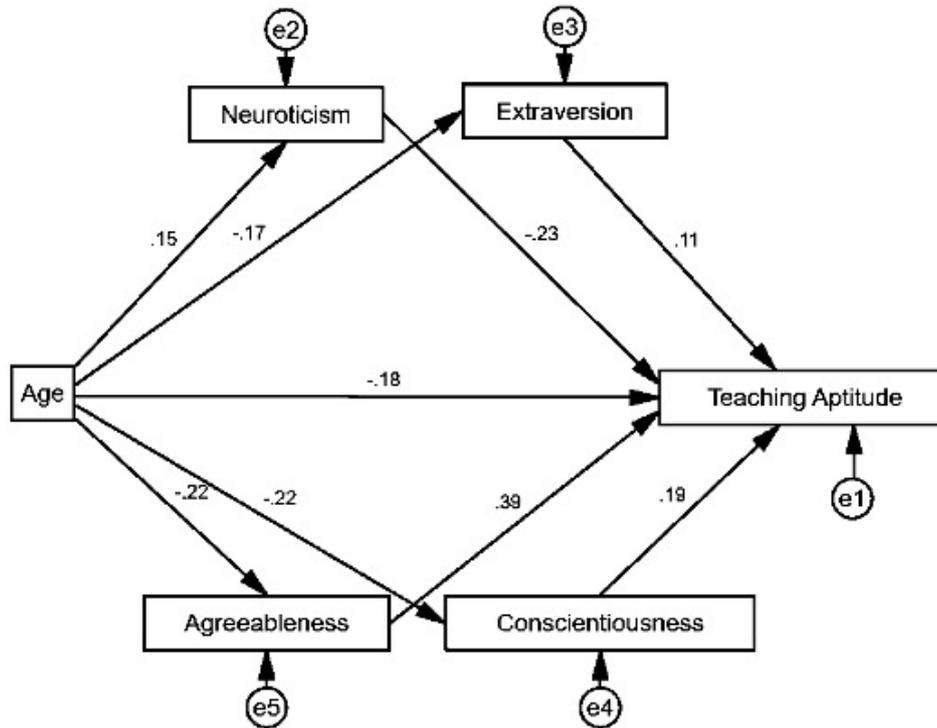


Figure 1. Age and teaching aptitude partially mediated by personality traits

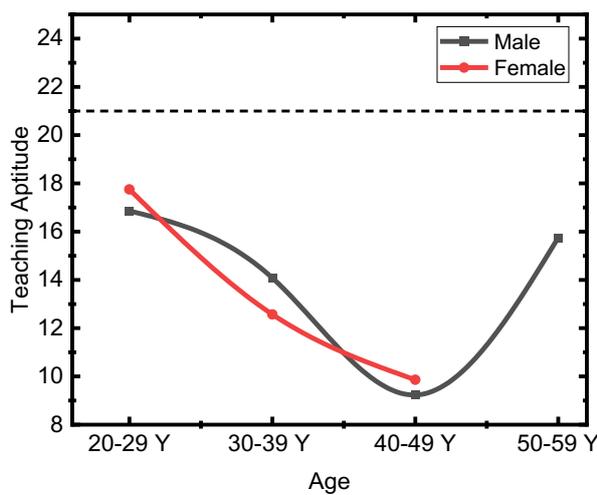


Figure 2. Line graph showing Mean values of Teaching Aptitude in each age group including the reference line (dotted line at 21) which indicates the average score of teaching aptitude given in TAT manual.

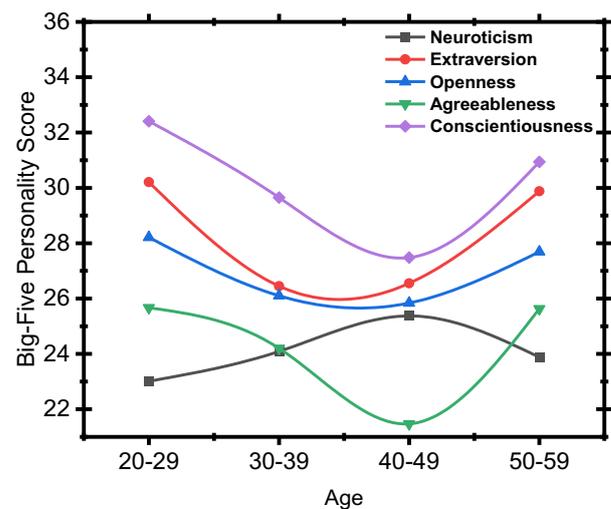


Figure 3. Dynamic changes in personality traits within age

reported at the age of 40 – 49 years, after that a slight uplift was observed at the age of 50 – 59 years as well. A similar pattern was observed in respect of personality traits with reference to the age of the school teachers. Figure 3 revealed the dynamic changes in personality traits.

Discussion

The results of this study established a number of interesting linkage between age, personality and teaching aptitude. Taken as a whole, these findings yield a number of insights with potential practical

implications on the dynamic interplay between personality and teaching aptitude, as well as on their joint influence on academic development.

First, we examine the potential factors affecting teaching aptitude i.e., age groups, gender, grade level, job status, school types and school location. Some factors were significantly associated with teaching aptitude. Interestingly, a significant difference was noticed among selected age groups in their teaching aptitude. Teaching aptitude decreased as age increased (Figure 2). Lowest teaching aptitude was reported in 40 to 49 of age

group and a significant increase was reported after age 50 as well. Several studies have been conducted to investigate the relationship between age and teaching aptitude. One such study conducted by Saravanan and Sivasubramanian [16] on a sample of 120 teachers in India revealed that teaching aptitude decreases with age. The study found that older teachers were less enthusiastic about teaching, had lower levels of self-confidence, and showed less creativity in their teaching methods.

Another study conducted [17] on a sample of 150 teachers in India found that older teachers had lower levels of job satisfaction, which was directly linked to their decreasing teaching aptitude. The study found that as teachers aged, they experienced burnout, which negatively affected their teaching aptitude. These findings are supported by other studies conducted in different countries. A study conducted by Sternberg and Williams [18] on a sample of American teachers found that older teachers had lower levels of creativity and innovation in their teaching methods. Similarly, a study conducted by Tamir [19] on a sample of Israeli teachers found that older teachers had less enthusiasm for teaching and were less likely to try new teaching methods.

No significant difference was observed between male and female school teachers in their teaching aptitude. The location of the school (rural or urban), and job status whether regular or temporary have not significant effect on the teaching aptitude of the physical education teachers.

Second, regarding the correlation between teaching aptitude and other parameters, general self-efficacy did not have a significant association with teaching aptitude. As reported earlier, age was negatively correlated with teaching aptitude. personality results have several significant implications for teachers. Perhaps most notably, our results establish that being Neuroticism is critical for teaching performance. Other personality traits such as Extraversion, Openness, Agreeableness and Conscientiousness were positively related to teaching aptitude. Thus, having these personality traits facilitate a variety of effective teaching strategies and may be especially useful traits for attaining high levels of academic achievement.

Research has shown that certain Big Five personality traits are more strongly associated with teaching aptitude than others. Here are some findings:

Openness to experience: This trait is associated with creativity, imagination, and an interest in new ideas. Teachers high in openness to experience are more likely to use innovative teaching methods and adapt to changes in the education system. Studies have found a positive correlation between openness to experience and teaching aptitude [20].

Conscientiousness: This trait is associated with responsibility, attention to detail, and goal-directed

behavior. Teachers high in conscientiousness are more likely to be organized, prepared, and reliable. Studies have found a positive correlation between conscientiousness and teaching aptitude [21].

Extraversion: This trait is associated with sociability, assertiveness, and positive emotions. Teachers high in extraversion are more likely to engage students in classroom discussions, provide feedback, and create a positive classroom environment. Studies have found a positive correlation between extraversion and teaching aptitude [22].

Agreeableness: This trait is associated with cooperation, empathy, and interpersonal harmony. Teachers high in agreeableness are more likely to create a supportive and respectful classroom environment. Studies have found a positive correlation between agreeableness and teaching aptitude [23, 24].

Neuroticism: This trait is associated with emotional instability, anxiety, and vulnerability to stress. Teachers high in neuroticism are more likely to experience burnout and have lower job satisfaction. Studies have found a negative correlation between neuroticism and teaching aptitude [25].

But, when we examined the relationship between age and personality traits, we found that Extraversion, Openness, Agreeableness, and Conscientiousness were negatively related to age, while, Neuroticism was positively related to age. All the personality traits which positively related to teaching aptitude were decreasing as age increased. The dynamic changes in personality traits in reference to the age of the school teachers were illustrated in Figure 3 respectively. Except for neuroticism, the mean score of all personality traits were decreasing lowest at 40 – 49 years of age.

Finally, the mediation analysis was performed using personality traits as mediator between age and teaching aptitude. As shown in Figure 1 the beta coefficient between age (independent variable) and teaching aptitude (dependent variables) was reduced -.31 to -.18 after mediating by personality traits. Therefore, a partially mediating effects of personality traits were observed on age and teaching aptitude. In addition, age was positively correlated to Neuroticism. While Neuroticism has a negative impact on teaching aptitude. therefore, teaching aptitude is decreasing with age.

Implications

The decreasing teaching aptitude with age has significant implications on the education system. Older teachers are often assigned to teach senior classes, which require a higher level of creativity and innovation. If these teachers lack the necessary teaching aptitude, students may become disinterested in their lessons, leading to a decline in academic performance.

Furthermore, older teachers may struggle to adapt to new teaching methods and technologies, which are essential in today's education system. As a result, they may become less effective in their teaching and fail to meet the evolving needs of their students.

Conclusion

In conclusion, teaching aptitude decreases with age, which has significant implications on the education system. It is essential to identify the factors contributing to this phenomenon and

develop strategies to mitigate its effects. This could include providing professional development opportunities for older teachers, mentoring programs, and encouraging them to incorporate new teaching methods and technologies in their lessons. By doing so, we can ensure that teachers of all ages are equipped with the necessary skills and aptitude to provide high-quality education to their students.

Conflict of Interest

No Conflict of Interest was declared among the authors.

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Cite this article as:

Bijender, Nara K, Kuma P. Aging, personality, and teaching aptitude in school grade physical education teachers. *Pedagogy of Physical Culture and Sports*, 2023;27(4):297–304. <https://doi.org/10.15561/26649837.2023.0405>

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Received: 24.05.2023

Accepted: 26.06.2023; Published: 30.08.2023

Aquatic gymnastics program to improve kinesthetic manual praxis in children with Down syndrome

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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

An alternative solution to improve the praxis function in children with Down syndrome is the application of modern therapeutic programs that take place in the aquatic environment. The article focuses on a study tracking the effects of a therapeutic program based on water gymnastics resources as an alternative technology to improve kinesthetic manual praxis in individuals with Down syndrome.

Material and Methods

Thirty children with Down syndrome (aged between 9 and 11 years) participated in the experiment and were differentiated in equal numbers into two groups: experimental (undergoing an 11-month therapeutic water gymnastics course) and control (taught using traditional technologies). The research battery for tracking the dynamics in the kinesthetic organization of manual movements included three neuropsychological probes with six items each, performed separately by the fingers of both hands. The empirical data were processed according to generally accepted methods of mathematical statistics: a Shapiro-Wilk test for the assumption of normality, descriptive statistics for the dependent variables and an independent samples t- test to verify between-group differences. SPSS 16.0 statistical package was used for statistical analysis, with a level of significance $\alpha = 0.05$.

Results

In the primary phase, the two groups were homogeneous in terms of the initial results of their performance in the area of fine motor movements. In the final phase, a statistically significant difference was identified between the experimental and control groups in the performance of all three probes: Reproduction of finger postures by the visual model ($t = 4.053, p < 0.001$); Reproduction of finger postures by the kinesthetic model ($t = 2.973, p < 0.01$); Transfer of finger postures by the kinesthetic model ($t = 2.866, p < 0.05$). A significant improvement was registered in the experimental group's performance in all components of manual praxis ($\Delta = 15.70\%$; $\Delta = 12.58\%$; $\Delta = 10.39\%$).

Conclusions

The positive dynamics in praxis function development within the studied domain serve as clear evidence. These changes in the realization of purposeful, pre-planned manual actions can be generated through a well-structured training and therapy program utilizing the benefits of water gymnastics as an intervention method. This is a sufficiently encouraging fact for children with Down syndrome, given the specific psychomotor profile determined by the genetic pathology.

Keywords: praxis function, alternative therapy, water space, Down syndrome

Introduction

Down syndrome is one of the most striking examples of a genetic pathology that determines the symptoms of permanent underdevelopment of the mental sphere. In the modern psychology of atypical development, the idea of the total (diffuse) characteristic of this type of development [1] is inspired. It predominantly affects the formation of the highest levels of all mental functions, in particular, praxis - the planning, execution and sequence of movements. The kinesthetic praxis, classified by Luria [2] as afferent, is a basic structural unit in the architectonics of praxis as a higher psychic function. Its emanation is the manual praxis, which is interpreted as the ability to perform the necessary set of movements (especially without visual control) based on kinesthetic analysis and synthesis [3]. Kinesthetic intelligence integrates the skills to

measure, differentiate and reproduce the force, temporal and spatial parameters of movement. It plays a vital role in various types of activities in the performance of precise hand movements when fine control and management of adjustable parameters are required: decrease or increase the amplitude of the movement, a change in its pace, in the amount of force. Contemporary child development researchers are united around the position of the priceless effect of the hand function on speech development [4]. The subordination between the level of development of the speech function and the degree of formation of manual movements is determined by the anatomical proximity of the disposition of the motor and speech areas in the cerebral cortex, the mutual relationship between speech and motor formation in the conditions of typical [5] and atypical development [6].

In children with Down syndrome, there is a lack of precision in the execution of movements, an inability for motor planning and control and a deficiency

in spatial representations and spatial-motor coordination [7, 8]. The degraded tactile sensitivity can lead to alterations in the kinesthetic component of movements [9, 10]. Most infants and toddlers go through the stages of early motor development more slowly and exhibit greater within-population variability than typically developing infants [11]. Specific movement disorders of the limbs, including difficulties with precise finger movements, have also been observed in 10-16-year-old children [12]. The abnormal motor patterns in individuals with Down syndrome may be of particular concern for academic functioning in school, performance in daily life, play, and other areas of professional life [13].

The awareness of the specific nature of the praxis function deficiency in Down syndrome concentrates the efforts of specialists from various fields on the search for effective therapeutic approaches [14, 15, 16]. Traditional intervention technologies follow procedures and steps that take place in the usual „dry“ environment and that assist to some degree in improving the overall functioning of the child with a chromosomal aberration. In contemporary practice, more and more attention is paid to different duration, intensity and technique therapeutic programs for people with motor, neurological and mental disorders whose physical activities are carried out in a water space [17, 18, 19, 20]: swimming, water spinning, surf yoga, aqua aerobics, aqua gymnastics.

Aqua gymnastics is a therapeutic method, the essence of which consists in performing physical exercises in a water environment under the guidance of a hydro therapist, with special equipment: belts, boards, cuffs, rubber dumbbells and swimming sticks. Researchers have defined water gymnastics as the safest and most effective way to treat and rehabilitate musculoskeletal disorders by combining suitable physical activity with the beneficial properties of water [21, 22]. From a biomechanical point of view, gymnastics includes a large variety of movements which can be used in a large range of connections and combinations [23]. Therapy through water gymnastics, due to the properties of the aquatic environment, allows: (a) Reduction

of the load on the musculoskeletal system – the lifting force of the water compensates for the force of gravity, which generates pressure on the spine and joints; (b) Strengthening the muscular corset by using the „deep“ muscles of the body to maintain balance in the water; (c) Improving overall joint mobility and flexibility with minor muscular effort; (d) Strengthening the overall physical condition, which is manifested by the presence of healthier sleep and a good emotional status; (e) Improving the functional state of the basic neural processes – excitation and inhibition. All these aspects are in favor of water gymnastics as a promising strategy to improve kinesthetic differentiation of movements considering their high-quality performance.

In the course of researching literary sources and methodological developments on a national and global scale, we found a low amount of publications related to the use of water gymnastics programs for the development of manual praxis in children with Down syndrome. The presented situation motivates the need to conduct a study. *Its purpose was* to track the effects of a therapeutic program based on the resources of water gymnastics for the development of manual praxis in children with the characteristic profile of Down syndrome.

Materials and Methods

Participants

The experimental study involved thirty Bulgarian children with Down syndrome (Table 1). The age of the respondents ranged from 9 to 11 years, which allowed for conducting an adequate study through a battery of neuropsychological probes. All children are raised in families and attend the special education support centres in the city of Stara Zagora, Republic of Bulgaria.

Research Design and Procedure

An adapted version of an experimental methodology developed by Luria [24] was used to study kinesthetic manual praxis. The methodological complex included three neuropsychological probes:

- Reproduction of finger postures by the visual

Table 1. Background informaton of the partisipants

n=30			
Category	Demographic characteristics	N	%
Types of Down syndrome	Trisomy 21	26	86.87
	Mosaicism	4	13.13
Gender	Male	17	56.67
	Female	13	43.33
Age	9	8	26.66
	10	10	33.34
	11	12	40.00

model (RFPVM). The researcher consistently demonstrates a sequence of finger configurations and stimulates the child to produce them in the same way.

- Reproduction of finger postures by the kinesthetic model (RFPKM). The probe is performed in the absence of visual control by the child. The experimenter folds the child's fingers in certain positions, returns them to the starting position and instructs the child to reproduce them.
- Transfer of finger postures by the kinesthetic model (TFPKM). The experimenter folds the child's fingers in certain positions on one hand and asks him to make the same configuration on the other hand independently. The transfer of postures is performed first from the leading hand (for left-handed children from left to right) and then vice versa. The probe is performed without the presence of visual control.

The three probes included six items each, performed by both hands separately: the „goat“ pose (stretching forward on the 2nd and 5th finger); the „scissors“ pose (stretching forward on the 2nd and 3rd finger); the „wheel“ pose (involving 1st finger in combination with each subsequent finger).

Fourth Grade Scale, which includes quantitative and qualitative indicators, was used:

0 – independent and correct performance of the task;

1 – performance of the task with a number of minor errors corrected by the child without the involvement of the experimenter;

2 – the realization of the sample is carried out after providing stimulus support;

3 – inability to complete the task.

The increase in quantitative indicators is inversely proportional to the correct execution of the probes. Tracking the dynamics of kinesthetic manual praxis development was carried out by fixing the obtained data before and after applying the therapeutic program.

Intervention

The preliminary procedure included preparing forms certifying the possibility of consent or refusal of participation in the study by the parents/guardian while respecting the requirement of the complete confidentiality of children's personal data. An 11-month structured program based on the resources of water gymnastics as a therapeutic physical activity was implemented on the children of the experimental group (Fig.1).

Before starting the therapeutic sessions, we made a study of the children's medical records in order to eliminate potential risk factors.

Statistical Analysis

The normal distribution of the variables was verified through the Shapiro-Wilk test. Descriptive

statistics were used for the dependent variables. The Student's t-criterion determined the significance of the differences in the results. SPSS 16.0 statistical package was used for data processing. For all analyses, statistical significance was set to $\alpha = 0.05$.

Results

When interpreting the results of the study, the successful performance of the tests in both groups before and after the application of the therapeutic program in water gymnastics was taken into account. In addition, the qualitative features of the mistakes made were analyzed, and the achievements of the children who were being worked with using traditional methods were compared to those who passed the therapeutic course.

First of all, it should be noted that the results of the Shapiro-Wilk test were not significant ($p > 0.05$) for both control and experimental groups, which means that the assumption of normality in both groups was met.

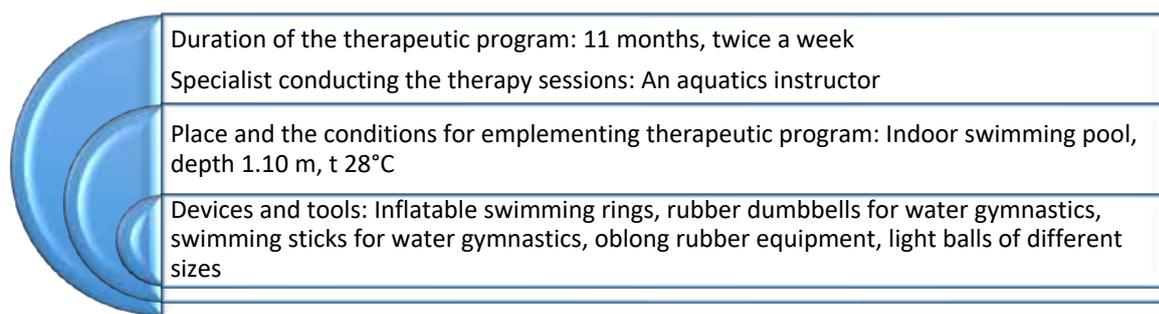
The data obtained from the first probe (RFPVM) formed the following picture (Table 2).

At the beginning of the experiment, the children demonstrated identical results, which showed no statistically significant difference between the experimental and control groups in the studied component ($p > 0.05$). The examination and evaluation of the achievements of the children of the experimental group after passing the water gymnastics course showed a statistically significant improvement of 15.70%. At the same time, a minimal change was noted in the control group, which did not have statistical significance ($\Delta = 3.76$). A comparison of the statistically valid data in both groups regarding the ability to produce finger postures according to a visual pattern showed a significant difference between them at the final stage of the study ($t_{emp} > t_p, p < 0.001$).

The results of the children in both groups at the beginning of the experiment were similar in terms of their ability to reproduce finger postures according to a kinesthetic model (Table 3), where there was also no statistically significant change ($p > 0.05$).

The therapeutic nature of the program was evident in the experimental group, which showed a statistically significant improvement of 12.58%. In contrast, the quantitative indicators of the control group were characterized by a low level of positive change in motor behavior that had no statistically significant effect ($\Delta = 6.43\%$). The comparative approach to the results in the two groups in the final phase of the experiment revealed a statistically significant difference in this domain as well ($t_{emp} > t_p, p < 0.01$).

The tendency for the approximately identical results of the two groups at the beginning of the study was also maintained when applying the third probe ($p > 0.05$). However, performance on



8-10 min

Warming-up exercises on land

- Walking (on toes, on heels, on the inside and outside of the foot, with high knees with different positions of the hands - to the side, above, with a clap behind the back) and running (regular running, high knee running, skipping running)
- General development exercises for: arms, shoulder girdle, torso, lower limbs, with general impact (squats, jumps)

23-25 min

Water exercises for upper and lower limbs

- For the hands and fingers (sample exercises: figure-of-eight movements with the wrists - with fingers together and spread and at different speeds; movements with the whole hand with and without contraction in the elbow joint - along a straight and curved trajectory, etc.)
- For the legs (sample exercises: balancing, kicking, cycling, etc.)

3-5 min

Relaxing exercises in water environment

- Walking in different directions (forward, backward, sideways)
- Jumping into the water (performed from the edge of the pool)
- Mobile games (sample games: Carousel, The Four Elements, Where's the Ball)

Figure 1. Therapeutic water gymnastics program applied in the study

Table 2. Results of the RFPVM probe

Groups	Period of the experiment	Mean	Std. Deviation	Std. Error Mean	t	p
				Final of experiment		
Control	Start	9.83	0.31	0.26	4.053	<0.001
	Finish	9.46	0.86			
Experimental	Start	9.93	0.61	0.07		
	Finish	8.37	0.25			

Table 3. Results of the RFPKM probe

Groups	Period	Mean	Std. Deviation	Std. Error Mean	t	p
				Final of experiment		
Control	Start	10.27	0.55	0.18	2.973	<0.01
	Finish	9.61	0.55			
Experimental	Start	10.33	0.49	0.06		
	Finish	9.03	0.19			

Table 4. Results of the TFPKM probe

Groups	Period	Mean	Std. Deviation	Std. Error Mean	t	p
				Final of experiment		
Control	Start	9.24	0.42	0.13	2.866	<0.05
	Finish	8.90	0.35			
Experimental	Start	9.33	0.28	0.13	2.866	<0.05
	Finish	8.36	0.35			

the probe was different after the children from the experimental group participated in the 11-month water gymnastics course (Table 4).

We identified a statistically significant positive performance – a limited error rate manifested it in this component of the manual praxis ($\Delta=10.39\%$). The low score in the control group should be noted in contrast – it showed a minor improvement of 3.68% in the studied component after applying traditional strategies for its development. Statistical analysis of the results when examining the most complex pattern of motor behavior at the end of the study revealed another significant difference between the participants in the two groups ($t_{emp} > t_p$, $p<0.05$).

Discussion

The main aim of the study was to look into the therapeutic effect of a developed water gymnastics program on the kinesthetic organization of the manual movements in children with Down syndrome aged 9-11 years.

When performing the RFPVM probe, the children who completed the therapeutic course in water gymnastics demonstrated significantly higher achievements than those trained by traditional methods. Wrong finger choices were minimized. The range of the time intervals for producing the desired manual pose has been significantly narrowed. Movement disorder symptoms were reduced. Previously observed synkinesis, localized in the area of the hands and face, gradually limited their occurrence. Distinct difficulties in visual-motor coordination also became regressive, which is in correlation with earlier research reporting successful motor performance of children with Down syndrome [12]. In the control group, we recorded isolated successful attempts to reproduce postures by a visual model using the leading (usually left) hand. Obviously, these motor patterns of behavior are related to the features of interaction between the two hemispheres in children with Down syndrome, which are the subject of active research [25, 26, 27].

Compared to the first probe, the results obtained from the RFPKM probe showed weaker performances in both groups. However, the children trained in experimental conditions had a higher success rate

than their peers in the control group, verified by the formed statistically significant difference. The difficulties found in the implementation of the probe, reflected in the lower scores in this study, are in line with the results of research that applies both to children with Down syndrome and children with other types of disorders [28]. The same authors found clear failures in the considered domain, even in children with typical development. However, the obtained data in no way diminishes the greater progress achieved in the experimental group, in which the children realized positive responses manifested by finger differentiation to represent the required postures without the presence of visual support. The typical inertia of movements was not observed, suggesting an easily achievable switch to the new posture.

Statistically significant differences between the two groups of children with Down syndrome were also identified regarding the TFPKM probe. In the initial stage of the research, the transfer of manual configurations by kinesthetic pattern was possible only in single cases. Almost all children were unable to quickly find the desired set of movements required for the corresponding hand configuration. Movements were diffuse in nature (e.g., fingers 3 or 4 were shown in parallel with fingers 2 and 5). We also recorded manifestations of echopraxia. An explanation for the specific kinesthetic behavior of the examined children could be sought in its conditioning by the existing deficits in tactile and proprioceptive sensitivity. A similar interpretation is found in the scientific works of some researchers, according to which the difficulties in the tactile system are related to the lack of integrity in the sphere of perception and the intermodal interactions with disorders of the muscle tone [29]. After applying the structured intervention scheme, a positive dynamic was reported in the experimental group when presenting the third probe. Probably, in an indirect way, opportunities are created to improve the interhemispheric regulation of motor reactions with a view to acquiring new bimanual skills and their successful use in the absence of visual control. The performance of this probe was also characterized by lower results, in general,

but the positive trend exhibited at the end of the experiment is a sufficiently encouraging fact for the application of a non-traditional therapeutic model, providing conditions for improving the potential of higher mental functions, in particular, kinesthetic manual praxis.

A conclusion related to a significant improvement of kinesthetic manual praxis in the children of the experimental group can be formulated considering the results obtained from the three probes. Proof of the positive dynamics are the demonstrated results of the t-test of Student, which exceed the limit values. The strongest positive effect of the therapeutic program in water gymnastics was evident in the development of the manual expression skill by the visual model. The children encountered difficulties in the implementation of the other two probes in which visual control was excluded. However, compared to baseline values, a significant positive change was found.

Conclusions

The undertaken research was focused on identifying the effects of the applied water therapeutic program on the development of kinesthetic manual praxis in children with Down syndrome aged 9-11 years. It showed that the type of intervention models, different from the

conventional ones, occupy a proper place in optimizing the motor behaviour of these children. The results showed that despite the imperfections in the vertical (subcortical) organization of the brain – an essential detail of the clinical picture of the syndrome, the structuring of a relevant training and therapy program can generate positive changes in the realization of purposeful, pre-planned manual actions. We should note that the conducted research, besides providing answers, also raises many questions, which requires concentrating the efforts of the specialists (specialists in Physical education and sport, specialists in Special education, neurophysiologists, etc.) on further research in this direction. Furthermore, the results of the conducted experiment could be extrapolated to the research corpus for the implementation of other intervention schemes for the development of praxis function in children from this heterogeneous population, such as Down syndrome.

Acknowledgement

First of all, we would like to sincerely thank all the parents of the children who supported this study with their active cooperation.

Conflict of interest

The authors state no conflict of interest.

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Cite this article as:

Georgieva D, Ivanova V. Aquatic gymnastics program to improve kinesthetic manual praxis in children with Down syndrome. *Pedagogy of Physical Culture and Sports*, 2023;27(4):305–311. <https://doi.org/10.15561/26649837.2023.0406>

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Received: 22.05.2023

Accepted: 21.06.2023; Published: 30.08.2023

Trends in muscular fitness performance among 9-12-year-olds: implications for monitoring and test selection

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Abstract

Background and Study Aim Long-term trends in muscular fitness show a gradual decline, which has become even more intense due to the Covid-19 pandemic. Declines in muscular fitness are associated with deteriorated health and well-being parameters. It is crucial to monitor this decline and appropriate tests need to be selected and interpreted correctly. The aim of this research was to apply muscle fitness tests and compare the development of performance between 9 and 12-year-olds and, at the same time, to compare performance differences between boys and girls.

Material and Methods 225 girls and 259 boys aged 9 to 12 years (11.1 ± 0.9) took part in the studies. Seven tests were selected to assess muscular fitness: bent-arm hang (BAH), push-ups, sit-ups, standing broad jump (SBJ), medicine ball throw (MBT), handgrip dynamometry (handgrip), and pulling back-leg dynamometry (back-leg).

Results The results showed that the development curves of muscle tests are incomparable. A linear increase was recorded for the MBT test. The handgrip, back-leg, and MBT tests have similar development although they do not test the same type of force. A very different trend (stagnation, decline) was found for the BAH and push-up tests. Girls and boys showed a comparable trend in all tests, however, boys always had higher absolute performances.

Conclusions Our data are intended to contribute to the expert discussion on the choice of muscular fitness tests. Based on these results, the selection of multiple tests may be recommended for optimal assessment of muscular fitness. In future research, it would be advisable to follow up by testing a larger cohort.

Keywords: physical fitness, strength, sex differences, dynamometry

Introduction

The secular trend in physical fitness shows that cardiorespiratory fitness and muscular fitness have undergone a gradual decline [1]. In previous decades, these reductions are up to tens of percent. At the same time, we observe a consistent increase in childhood obesity and reduced physical activity in children [2]. This situation has been exacerbated by pandemic restrictions due to the Covid-19 pandemic, leading to a worsening in body composition and muscular fitness levels in children and adolescents [3].

Recent studies have shown that the decline in physical activity in children and adolescents, along with an increase in screen time, is becoming a major concern [4, 5]. Muscular fitness plays a key role in children's physical development, as it forms the basis for physical activity, body image, and metabolic health [6, 7]. Muscular fitness decline has been associated with the development of obesity, poorer bone density, lower academic performance, and well-being deterioration. Markers of muscular fitness in childhood show an association with adiposity levels and cardio-metabolic parameters in

adulthood [6, 8]. Emphasizing strength monitoring in childhood is henceforth a logical step. Measuring the level of muscular fitness gives us information about the state of society and consequently serves as feedback for the subjects. Ultimately, this information allows us to design appropriate and effective intervention programs.

Muscular fitness is commonly measured using standardised body weight tests or hand grip strength tests. Neither the number of tests nor their choice are uniform [9, 10, 11]. As a result, we need to know as much information as possible about muscular fitness tests and their association with maturation. The choice of tests and their evaluation is essential for general recommendations regarding exercise, fitness, and leisure time.

Monitoring the development of strength tests during childhood has been part of much research. There is an increase in strength performance prior to puberty, this trend is, however, not uniform for all types of tests. A steeper curve can be seen in the progression of the Standing broad jump test in children from 6 to 12 years, compared to push-ups or bent-arm hang (BAH) [12, 13, 14]. There is also a noticeable difference between the relative strength and absolute strength tests, which is evident in the push-ups, BAH, and handgrip strength tests

respectively. Absolute strength shows a steeper trend [14, 15, 16, 17]. We also encounter a different pattern in the changes in dynamic strength in the standing broad jump and ball throw tests [12, 18].

Another characteristic feature of muscular fitness is different results between boys and girls, which they reach already during their prepubertal development. The difference in results is not just in terms of absolute values, but also of a different developmental curve. Changes in performance are closer to a linear progression in boys, while girls show a more moderate increase [12, 15, 19]. However, this trend cannot be established in absolute terms, as it varies depending on the test.

In general, commonly used tests for the assessment of dynamic, relative, and absolute strength may not show the same trend in the period before the onset of puberty. These findings are transferred to test interpretation and give us important information about changes in muscular fitness during the maturation process. The development of strength parameters is also related to the selection of age-specific tests. The authors are not aware of any study that has comprehensively monitored muscle fitness tests and analysed the development of changes. The aim of the study was to use seven muscular fitness tests and to compare the performance development of children aged 9 to 12 years old, with a simultaneous comparison of boys and girls.

Materials and Methods

Participants

A total of 6 public schools were selected at random. Children from grades 3 to 5 were involved in the study. The research sample comprised 225 girls and 259 boys who were from 9 to 12 years old (11.1 ± 0.9). All participants were of Caucasian ethnicity and met the following inclusion criteria: being between 9-12 years of age while the research was being conducted, having no objective medical conditions based on medical examination, and having parental/legal guardian consent. Only data from children who completed all tests were included in the statistical analysis, resulting in 37 children being excluded from the study.

Parents or legal guardians were informed about the research process, which took place in the second half of 2022 and was approved by the Committee for Research Ethics at the University of Hradec Králové (No. 12/2022). The study was conducted in accordance with the latest version of the Declaration of Helsinki.

Research Design

Testing

Anthropometry was measured without shoes and in light clothing. Weight was measured on an

electronic scale (HN-289, Omron, Japan). The Body Mass Index (BMI) was further calculated by dividing the body weight by the height squared (kg/m^2).

Seven tests were selected to assess muscular fitness, which was designed to measure relative, absolute, and dynamic strength and to evaluate the level of upper and lower body strength. These tests were as follows: BAH, push-ups, sit-ups, standing broad jump, medicine ball throw, handgrip dynamometry (MAP 80K1S, KERN. Kern & Sohn GmbH, Germany), and pulling back-leg dynamometry (SH5007, Saehan Dynamometer. Saehan Corporation, India).

The testing process was conducted in two days and it had been always preceded by technical drills. Participants had 2 to 3 attempts, with several minutes of sufficient rest in between. The best attempt always counted. The sequence of the tests was designed to avoid the influence of fatigue on the following testing process. Day 1 was devoted to the following movements: handgrip, SBJ, and push-ups, while day 2 was to back-leg, MBT, and BAH. At the beginning of testing, a dynamic warm-up exercise containing full-body movements was always performed.

Standing broad jump (SBJ)

The participant stands in a parallel position with both feet behind the marked line. A countermovement or arm swing could be used to jump. Participants had to land with both feet at the same time and block the jump without further advancement. A further attempt was allowed if the subject fell backward or touched the ground with another part of the body. The test was performed three times, counting the best jump. The distance was measured with tape from the starting line to the heel of the closest foot to the starting line.

Push-ups

A participant starts in the push-up position: hands and toes touching the floor, the body and legs are in a straight line, feet slightly apart, the arms at shoulder width apart and extended and at the right angle to the body. Keeping the back and knees straight, the subject lowers the body until there is a 90-degree angle at the elbows, with the upper arms parallel to the floor. The repetition is counted after the starting position is taken. The requirement was to perform the maximum number of repetitions. During the test, the subject was not allowed to change the position of his hands or toes.

Bent-arm hang (BAH)

A participant is assisted into position, the body lifted to a height so that the chin is above the level of the horizontal bar. The bar is grasped using an overhand grip, with the hands shoulder-width apart. The chin must not touch the bar. There was no requirement for the position of the lower limbs. The

timing started when the subject is released. The test was stopped when the chin was below the level of the bar.

Sit-ups

A participant lies supine on the mat, keeping the hands on the shoulders and the knee flexed at an angle of 90°. A researcher holds the subject's ankles firmly for support. The subject must come up to a position where both elbows touch the knees. When returning to the starting position, both shoulder blades must touch the mat. The participant repeats this movement as many times as possible. The number of repetitions performed in 60 seconds was considered.

Medicine ball throw (MBT)

A subject stands with his feet in a parallel position with a medicine ball (3 kg, 30 cm diameter) at chest level, both hands on the medicine ball, elbows bent. The throw was performed using both hands without trunk rotation with a countermovement. The distance was measured from the point of ball impact to the point of throw. Each participant performed three throws, and the best result among attempts was considered.

Handgrip dynamometry (handgrip)

Grip strength was measured in a standing position with the shoulder adducted and flexed elbow. Measurements were taken twice, and the higher value was recorded.

Pulling back-leg dynamometry (back-leg)

A subject stands with both feet on the device and holds the handle with both hands. The handle has been adjusted so that it is approximately at the knee level and the chain passes between the legs. This motion simulates a partial deadlift. During the pull, the handle must not rest on the thighs. Measurements were taken twice, and a higher value was recorded.

Statistical Analysis

The sample was divided into quartiles according to the date of children's birth (1st quartile: January-March 2nd quartile April-June, 3rd quartile: July-September, 4th quartile: October-December). According to the average values, trend graphs were created for muscle fitness tests and anthropometric variables. For the measured values, a test for normality of the data was performed (Shapiro-Wilks, Q-Q plot). The W value was compared at a significance level of $p=0.05$. Normality was tested for height and weight to confirm that this was a representative sample. Data analysis was performed using IBM SPSS software, version 20. A comparison of the development curves was performed using a qualitative method where there had to be an agreement between all authors.

Results

Table 1 shows the anthropometry measurements and the results of the muscular fitness tests. The table also includes the results of boys and girls. The data of height and weight showed a normal distribution. The percentage of obesity as a significant factor for the muscular fitness score was 12 %. Height and weight data showed a normal distribution ($W=0.012-0.078$), while for muscle tests normality was confirmed only for SBJ ($W=0.474$).

Figure 1 shows developmental curves of muscle tests and anthropometry. The mean values and results of girls and boys are plotted.

Anthropometric variables show a gradual and comparable increase. For BMI, we observe fluctuations between quarters, but a rising trend is evident. Fluctuations (increases and decreases) between quartiles are also evident in other measurements, most notably in the bent-arm hang.

Most measurements show gradually increasing absolute values, although fluctuations between quartiles are noticeable. No clear upward trend can be established for bent-arm hang, stable comparable values are more likely set. A negative trend in performance was measured for the push-ups where there was a gradual decline in performance.

In general, not all tests show the same trend of gradual increase. The measurements show different trends in performance progression. For the handgrip, back-leg, and MBT movements, a plateau was recorded, with a larger increase from the third quartile of 2011. For the SBJ and sit-ups, there is a gradual continuous (linear) increase. For the bent-arm hang test, we rather observe values stagnation. For the fourth quartile of 2012, we observe deviations that are not in conformity with the trend of a gradual increase of values (height, handgrip, push-ups).

Girls generally performed lower than boys in all muscular fitness tests. Despite the variation across quartiles, both groups showed a comparable trend in their scores. Comparable parameters were observed for height and weight.

Discussion

The purpose of the research was to compare muscular fitness tests in prepubertal children, to look for trends in performance, and to compare girls and boys. The results show that an increase in muscle strength parameters is not comparable between the tests. We identified a linear increase only in the SBJ test, in other cases the curve has a different shape. The results of the back-leg, handgrip, and MBT have a comparable development, although they do not test the same type of strength. A very different trend in terms of stagnation or decrease was observed for the BAH and push-ups. Girls and boys showed

Table 1. Results of anthropometry and muscular fitness tests

ALL										
Quartile	Weight (kg)	Height (cm)	BMI (kg/m²)	SBJ (cm)	MBT (m)	BAH (s)	Handgrip (kg)	Back-leg (kg)	Push-ups (reps)	Sit-ups (reps)
2012_4	37.29	147.09	17.22	133.36	3.05	5.23	19.50	55.82	17.45	17.36
2012_3	35.88	142.30	17.61	143.22	3.19	8.88	18.65	54.13	16.74	20.70
2012_2	38.64	143.99	18.47	135.40	3.11	6.71	19.63	52.98	10.19	21.02
2012_1	38.08	145.90	17.85	140.43	3.29	6.90	19.31	53.96	10.62	22.89
2011_4	38.36	146.23	17.78	146.57	3.20	10.18	20.27	57.26	9.48	24.39
2011_3	39.57	146.49	18.40	147.33	3.15	8.79	20.28	55.65	9.02	19.75
2011_2	47.70	152.25	20.26	150.33	3.99	8.13	24.22	65.30	10.73	24.35
2011_1	43.40	151.22	18.85	145.93	3.70	9.66	23.66	61.17	11.41	23.44
2010_4	48.26	155.21	19.94	153.66	4.04	7.19	25.20	68.92	11.08	26.15
2010_3	49.07	156.88	19.76	165.21	4.41	10.98	26.55	76.07	12.23	28.81
2010_2	50.07	154.77	20.53	150.85	4.12	6.62	25.46	69.44	10.02	26.78
2010_1	49.21	157.92	19.62	160.53	4.23	10.25	26.64	67.44	8.11	28.72
Girls										
2012_4	38.41	148.86	17.33	129.00	2.99	4.22	18.21	54.29	14.00	19.71
2012_3	37.36	142.08	18.42	135.00	3.01	4.93	17.56	48.50	11.92	18.55
2012_2	39.89	144.42	18.91	132.08	2.98	7.50	19.27	51.20	9.32	24.62
2012_1	37.52	144.93	17.83	134.52	3.16	8.40	18.90	51.78	9.15	25.63
2011_4	37.83	147.10	17.29	145.41	2.97	10.74	20.15	55.00	9.14	25.45
2011_3	40.10	146.00	18.88	140.52	2.98	6.21	19.72	52.33	5.19	18.86
2011_2	44.21	150.94	19.12	143.00	3.64	7.23	22.11	58.89	9.61	24.89
2011_1	44.32	154.00	18.57	135.33	3.53	8.21	24.31	61.52	11.81	25.33
2010_4	49.09	156.17	19.98	148.50	3.87	6.09	24.82	68.15	9.65	27.81
2010_3	48.67	159.00	19.23	167.20	4.13	9.16	27.34	72.87	10.13	30.33
2010_2	55.71	155.97	22.57	142.00	3.98	3.88	25.48	62.94	7.94	25.88
2010_1	50.66	158.43	20.02	150.21	3.82	10.05	26.48	61.36	6.14	28.36
Boys										
2012_4	35.33	144.00	17.02	141.00	3.18	7.00	21.75	58.50	23.50	17.67
2012_3	34.28	142.55	16.72	152.18	3.38	13.20	19.84	60.27	22.00	24.36
2012_2	36.91	143.39	17.85	140.00	3.29	5.61	20.12	55.44	11.39	21.28
2012_1	38.67	146.90	17.87	146.58	3.42	5.35	19.73	56.23	12.15	22.81
2011_4	38.85	145.44	18.24	147.63	3.42	9.67	20.37	59.33	9.79	23.42
2011_3	39.15	146.87	18.02	152.63	3.28	10.79	20.70	58.22	12.00	20.44
2011_2	50.55	153.32	21.19	156.32	4.28	8.86	25.95	70.55	11.64	23.91
2011_1	42.44	148.30	19.15	157.05	3.87	11.18	22.99	60.80	11.00	21.45
2010_4	47.60	154.45	19.91	157.73	4.17	8.05	25.50	69.52	12.21	24.85
2010_3	49.29	155.75	20.05	164.14	4.56	11.95	26.12	77.79	13.36	28.00
2010_2	46.08	153.92	19.09	157.13	4.22	8.56	25.45	74.04	11.50	27.42
2010_1	48.29	157.59	19.36	167.09	4.49	10.38	26.74	71.32	9.36	28.95

SBJ - standing broad jump; MBT – medicinbal throw; BAH – bent-arm hang; Back-leg – Pulling back-leg dynamometry

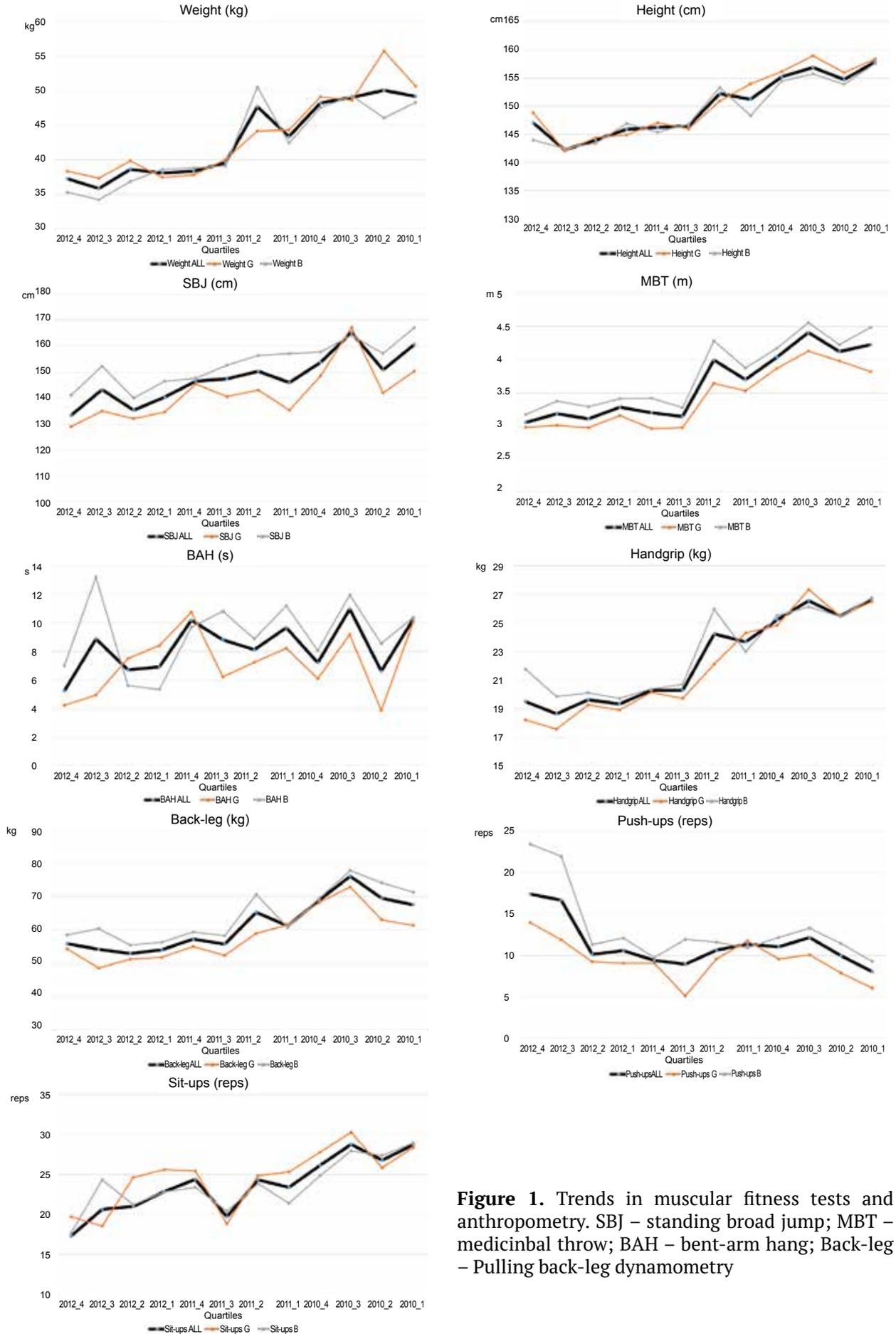


Figure 1. Trends in muscular fitness tests and anthropometry. SBJ – standing broad jump; MBT – medicinbal throw; BAH – bent-arm hang; Back-leg – Pulling back-leg dynamometry

a comparable developmental trend in all tests and boys always recorded higher absolute performances.

The results show a comparable linear increase in weight, height, BMI, and SBJ. In other cases, the curves show a different pattern. The findings of the trend for weight, BMI and SBJ are supported by other research [13, 20, 21] and this is hence a very well predicted parameter. The SBJ test, which assesses dynamic lower body strength, is thus different from other tests.

It was found that in terms of height and weight, the sample showed a normal distribution and is thus a normal population sample. Similarly, the cohort did not show a high number of obese children. For muscular tests, normality was confirmed only for the SBJ test ($W=0.474$). When displayed on a Q-Q plot for SBJ, a linear regular increase in performance with age can be observed. Only the back-leg test showed a linear-like pattern, but normality was not statistically confirmed ($W=0.03$). The results of the normality test support that a regular gradual increase in performance with age was not confirmed for most muscle tests.

A gradual linear increase in handgrip strength with a steeper ascent from the age of 11 is documented by Häger-Ross & Rösblad [19] and Butterfield et al. [15], but in Molenaar et al. [16] and Fredriksen et al. [22] the development is rather linear with no significant increase until the age 12. However, our measurements show that a steeper increase occurred in the second and in the first quartile of 2011, i.e. at years 10 of age. The dependence of the increase in absolute strength is mainly related to the degree of maturation, height and muscle mass, therefore, there are significant changes with the onset of puberty [17]. Accordingly, the handgrip developmental curve in prepubertal individuals has not been finally determined yet.

Body weight tests are widely used owing to their easy administration and their connection to natural movement patterns. Rúa-Alonso et al. [3] and Tomkinson et al. [21] report a (moderate) linear trend in progression in the BAH test, which is different from our results. A clear positive trend cannot be identified from measurements by Castro-Piñero et al. [12] or Gulías-González et al. [23], where values fluctuate between years. The trend for the push-ups test, which can be described as slightly decreasing or stagnant between some quartiles, can also be observed in the research conducted by Castro-Piñero et al. [12]. Tomkinson et al. [21] or Gulías-González et al. [23] report a very slight increase in performance for sit-ups – their data are comparable to ours. Thus, body weight tests generally do not show a consistent trend and we do not find full agreement even for every test across studies. It needs to be taken into account when setting standards and interpreting testing.

The percentiles are used to set standards [24],

however, it is essential to determine which growing trend they have. For the SBJ test, it appears that a gradual linear increase can be expected for children between the ages of 9 to 12 - a similar gradual linear increase can be expected for the handgrip [22]. The situation is different for body weight tests given by the fact that research findings are not uniform. It is probably not possible to expect a linear increase in the performance of children of age from 9 to 12. The development between even larger groups is not identical and fluctuations, plateaus, or even declines in performance can be expected. A crucial factor in this context is, among others, the influence of weight or obesity, which significantly affects strength test results [25, 26].

Handgrip dynamometry is a reliable indicator of absolute strength [19]. The back-leg test is not yet as widespread, but given the same development trend, it could represent a suitable alternative. Interestingly, we also find a similar trend for MBT test, which is designed to assess dynamic strength. It is possible that this variation of the 3 kg medicine ball throw will be strongly dependent on absolute strength. A comparable trend in values increase was also found for weight. This trend indicates a significant relationship between weight and hand grip strength that has been repeatedly demonstrated [17].

Muscular fitness assessment includes absolute strength, dynamic strength, and relative strength (muscular endurance) testing. Very often, a limited number of tests are selected to assess the level of physical fitness or muscular strength [1, 9, 21]. Test selection is important for research and testing purposes in common practice. Our data suggest that repeated measurements with longer time intervals cannot predict developmental trends unambiguously and that there may be considerable variation between tests. All indications are that it is difficult to accurately determine the level of muscular fitness from one or two tests. This also makes it more difficult to interpret the results.

Girls and boys did not reach the same level of muscular fitness, nevertheless, their development of height and weight can be described as the same. Although greater differences appear after the onset of puberty, differences can be observed earlier. Differences between the absolute handgrip performances of girls and boys (6-12 years) were found by Fredriksen et al. [22] while confirming the same trend in the development of values. This trend was also supported by Butterfield et al. [15], with significant differences between girls and boys only being evident after they reach the age of 12. However, Beunen & Thomis [27] report significant differences between girls and boys already at prepubertal age, in particular for SBJ and BAH tests. Even so, we believe that differences at this age will generally not be significant. A progressive increase in performance is also evident after the onset of

puberty, although in this case, there is already a significant differentiation between girls and boys. Boys generally show a steep increase in performance in muscular tests [28]. The situation is different for girls, as stagnation can be expected in body weight tests (push-ups, BAH, SBJ) [12, 27]. The performance sex difference is due to hormonal, morphological, and body composition changes [29].

Weight or BMI significantly affects the results of muscular tests. We observe a negative effect in body weight tests, however, no such trend is shown for the handgrip strength test [26, 30]. If the research sample is not tested comprehensively, but only certain tests are used (e.g. push-ups, sit-ups, or handgrip), misleading conclusions may be drawn. Therefore, the percentage of obese individuals must be taken into account. In our study, 12 % of children were obese, which is a standard representation in the region [31].

We see the research limitation in the unequal number of children in each quartile, the biggest problem was the fourth quartile in 2012 with a low number of subjects. This may have led to a distortion of the beginning of the development curves.

Conclusions

It is essential to monitor the muscular fitness level of children, especially in view of the observed worldwide increase in weight and obesity. Test selection and interpretation play a central role in testing children of all ages. Research has shown that there are different developmental curves for muscular fitness tests and they thus cannot be expected to have identical progression. In most cases, progression has not been linear, and stagnation or decline have also been observed. Girls and boys showed the same trend in all cases, with boys achieving higher absolute performances. These research data are intended to contribute to the discussion on the choice of physical and muscular fitness tests. However, based on these results, the selection of multiple tests can be clearly recommended. As this is original research, it would be advisable to follow up with studies with a larger sample size or a larger age range.

Conflict of interest

The authors have no conflict of interest to declare.

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Cite this article as:

Schlegel P, Křehký A, Havrdová K, Dočkalová D, Pavlíková T. Trends in muscular fitness performance among 9-12-year-olds: implications for monitoring and test selection. *Pedagogy of Physical Culture and Sports*, 2023;27(4):312–320.
<https://doi.org/10.15561/26649837.2023.0407>

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Received: 27.05.2023

Accepted: 30.06.2023; Published: 30.08.2023

Analyzing predictive approaches in martial arts research

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Authors' Contributions: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript preparation; E – Funds Collection.

Abstract

Background and Study Aim Predicting the results of martial arts competitions is an important task that attracts the attention of both sports analysts and fans of these sports. The objective of this study is to perform an analytical examination of publications on martial arts prediction, with the aim of identifying the primary research directions in this field.

Material and Methods The bibliometric analysis of PubMed database data was used to create a sample of studies at 18.05.2023. The keywords “prediction”, “martial arts” were used for the search. A total of 151 publications were found. The first publication was dated 1983. VOSviewer 1.6.19 program was used: keyword analysis method and direct citation analysis with the construction of bibliometric maps, the visualization of cluster density, weights – citations.

Results 51 journals from 21 countries were identified. The unconditional leader among the countries is the United States (16 journals). Between 1983 and May 18, 2023, 741 scientific works were found. The analysis involved 67 authors whose link strength was more than 0. Eight clusters were identified. They were characterized by the presence of 271 links with total link strength of 276. The number of items in the clusters did not have a significant difference; this can be explained by the popularity of all directions in the research. The authors of the seventh and eighth clusters had the most publications. To visualize the network 63 items (keywords) were selected. They were grouped into 4 clusters. The network includes 951 links; the total link strength is 4027. The most popular studies are highlighted. These studies include the following keywords: “humans”, “martial arts”, “female”, “male”, “athletes”, “young adult”, “middle aged”.

Conclusions The analysis of the bibliometric maps revealed the tendencies of scientific research and highlighted the priority areas. The relevance of the problem of prediction in martial arts is confirmed. An increase in the number of publications in PubMed database over the past decade has been observed. The main areas of research include martial arts, health, sports training, and humans. Most publications focus on utilizing artificial intelligence and machine learning techniques for predicting competition outcomes. Additionally, they explore the application of analytical tools to uncover patterns in data and identify critical factors that impact competition results. Modern technologies and the availability of big data open up new possibilities for predicting competitive success in martial arts.

Keywords: prediction, martial arts, VOSviewer, bibliometric mapping.

Introduction

Nowadays, martial arts are a popular sport worldwide. Every year the level of professionalism and technical skills of athletes is growing, which makes competitions more and more intense and spectacular [1, 2, 3]. Also, there is an increase in competition in the international arena, which leads to the need for further search for new pedagogical tools and methods in the system of preparation of highly qualified athletes [4, 5, 6].

One of the ways to achieve high results in sport is clear management, planning, and use of advanced training methods in the training process [7]. The successful and effective management of

sports training is impossible without a reasonable prediction. Predicting creates the prerequisites for making qualified decisions in sport [8]. Setting prospective goals always involves predicting sport performance [9].

The main primary goal of training elite athletes is successful performance at major competitions [10]. The identification of talented athletes and ways of their development is one of the most discussed and popular directions in sports science [11, 12]. Health prediction is an effective tool to determine the level of physical fitness and risk of injury in athletes and amateurs [13, 14].

Predicting the result in martial arts attracts the attention of both sports analysts and fans of these sports [15, 16]. It can have an important practical value by helping athletes and coaches. Performance

prediction allows us to determine the optimal strategy of preparation for competitions to improve the tactics of a fight (fight, battle) [17, 18]. Such prediction can be used as a tool for sports betting [19, 20].

The above data allow us to consider the chosen direction of research relevant. Several sources, constant updating of information in this area significantly complicate the analysis. The bibliometric method and in particular VOSviewer software tool can be used to analyze the literature. VOSviewer is a tool that helps create visual maps and visualize bibliographic data. Such maps can contain journal titles, authors' names, names of organizations where research was conducted, and keywords. This program is capable of systematizing and grouping key terms into specific semantic clusters reflecting interest in a particular problem over a certain period of time [21, 22].

Purpose of the Study. To analyze publications devoted to prediction in martial arts using VOSviewer software tool in PubMed database and to determine the priority scientific directions in this area.

Materials and Methods

Methodology

We used the bibliometric method to achieve the goal of the study [23]. The research tool was VOSviewer 1.6.19. VOSviewer is a software used to build and visualize bibliometric networks. These networks include journals, researchers, and individual publications. They are built on the basis of citations, bibliographic links, joint citations, or co-authorship [24].

The main method of data analysis using the VOSviewer software tool was "co-occurrence", which clusters keywords according to how often they occur together in the same paper. The keywords form thematic clusters. The clusters are marked with different colors, the size of each keyword is determined by the "total link strength" index, i.e., the link strength of a given keyword with all others, and the lines reflect the links between two individual keywords [25].

Data Extraction

When the article selection was completed, the following data were extracted for visual and bibliometric analysis: author name, article title, publication journal, keywords, organization, publication country, and citation amount.

Research Design

The bibliometric analysis of PubMed database data was used to create a sample of studies at 18.05.2023. The phrase "prediction in martial arts" was used for the search. A total of 151 publications for the period 1983-2023 were extracted. The study

period was divided into four decades (Figure 1). The number of publications by decade was as follows: 1983-1993 – 4 (2.7%), 1994-2003 – 5 (3.3%), 2004-2013 – 36 (23.8%), 2014-2023 – 106 (70.2%). It is observed a large increase in publications after 2004. This is due to the popularization of many types of martial arts in the world. All publications were published in English.

Based on the most cited references, we identified promising areas of research in this category. Distance-based bibliometric maps have been used – these are maps where the distance between two elements reflects the strength of the correlation between the elements. A smaller distance usually means a stronger connection [21].

Statistical Data

The study identified 51 journals from 21 countries. The United States stood out as the leading country with 16 journals. Between 1983 and May 18, 2023, 741 scientific works were found. The analysis involved 67 authors whose link strength was more than 0. Eight clusters were identified. They were characterized by the presence of 271 links with total link strength of 276. To visualize the network 63 items (keywords) were selected. They were grouped into 4 clusters. The network includes 951 links; the total link strength is 4027.

Results

51 journals from 21 countries were identified according to the keywords "prediction" and "martial arts". The unquestionable leader among the most productive countries is the USA (16 journals). The other major contributors are China (7 journals) and the United Kingdom (4 journals).

Bibliometric maps were created using VOSviewer 1.6.19 software tool. The analysis of these maps was aimed at identifying trends in scientific research in the field, highlighting priority areas. The results for the leading authors in this field are presented in Figure 2. 741 scientific studies were extracted between 1983 and May 18, 2023. 67 authors whose link strength was more than 0 participated in the analysis. A feature of Fig. 2 is its division into 8 clusters. They are characterized by 271 links and their total strength is 276. The first cluster includes 12 authors, the second has 11 authors, the third and fourth have 10 authors each, the fifth has 9 authors, the sixth has 6 authors, the seventh has 5 authors, and the eighth has 4 authors. Note that the authors of the seventh and eighth clusters have the most publications: Franchini Emerson (6) and Capranica Laaura (3). These clusters include the smallest number of authors. The link between seventh and eighth clusters is formed by these authors. However, this link is formed by only one document.

63 items (keywords) were selected to visualize the network (Fig. 3). They were grouped into 4

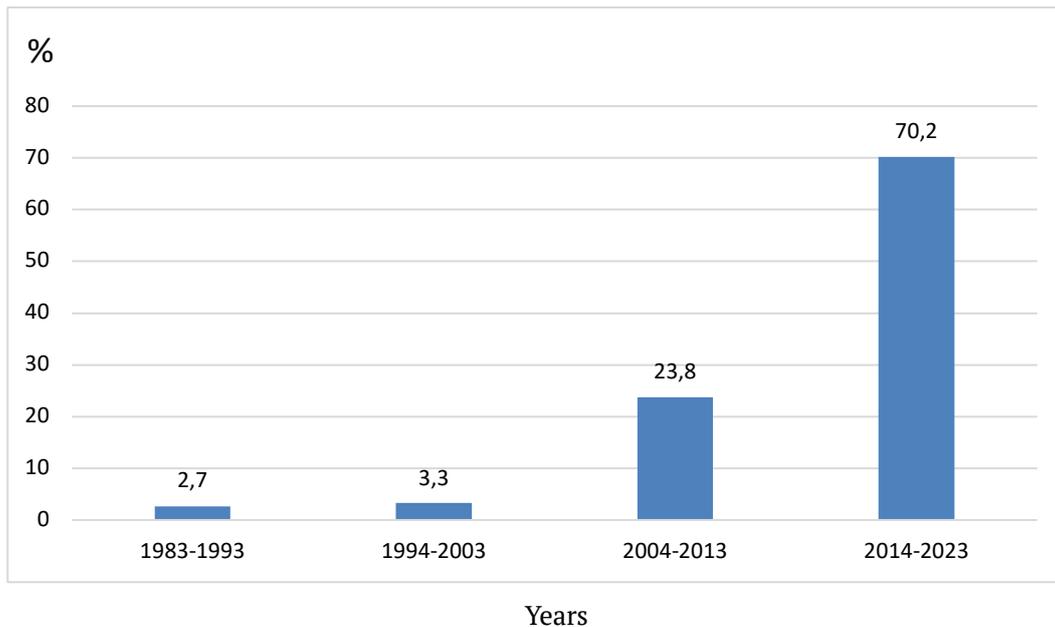


Figure 1. Dynamics of publications in the research period

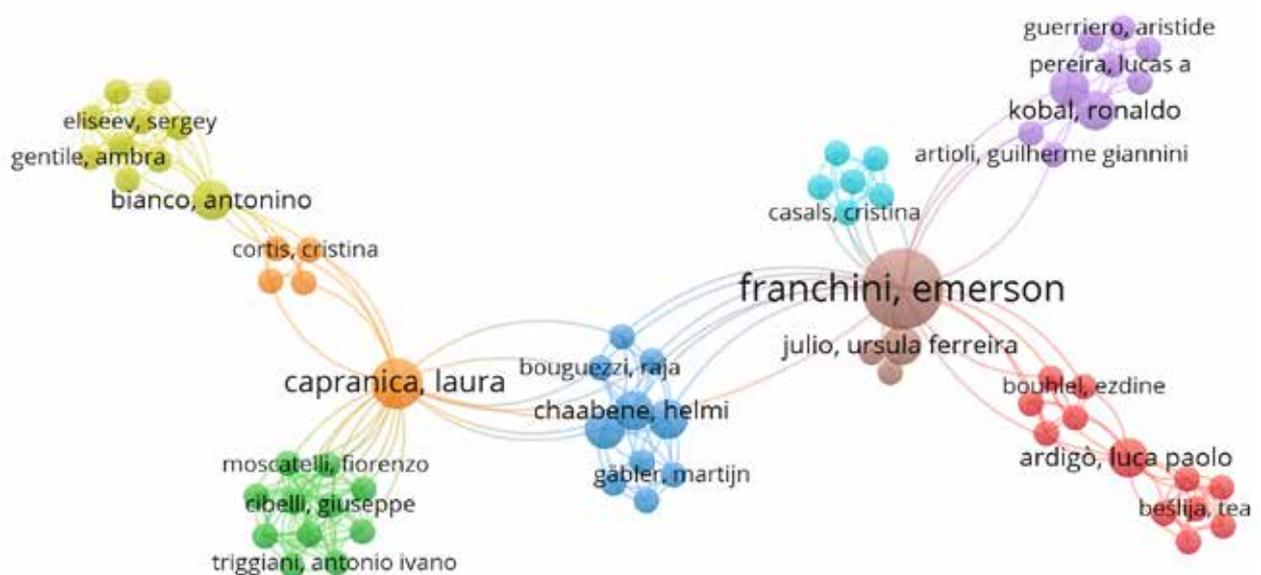


Figure 2. Bibliometric map of the top authors of publications that have studied the prediction in martial arts. Source: own study based on data obtained from PubMed and analyzed with VOSviewer (18.05.2023)

clusters. The network includes 951 links, the total link strength is 4027. Each keyword is in a circle. The larger the size of the circle, the more links have that keyword. The proximity of these circles on the map reflects the strength of the correlation between objects.

An analysis of Figure 3 makes it possible to highlight the most popular studies. These studies include the following keywords: “humans”, “martial arts”, “female”, “male”, “athletes”, “young adult”, “middle aged”. The first cluster on the map is highlighted in red. It includes 19 keywords. The cluster is conventionally called “martial arts”. It is the most significant keyword in this cluster. It occurs 97 times, has 54 links to other keywords on the map, and the total link strength (TLS) is 576.

Further, the occurrences and number of links in decreasing order are as follows: Male – occurrences 96, links 62, TLS 737; Young adult – occurrences 34, links 53, TLS 287; Adolescent – occurrences 31, links 52, TLS 256; Athletes – occurrences 31, links 47, TLS 221; Body composition – occurrences 12, links 32, TLS 92; Body weight – occurrences 9, links 32, TLS 83; Cross-sectional studies – occurrences 7, links 29, TLS 59; Combat sports – occurrences 9, links 27, TLS 68; Competitive behavior – occurrences 8, links 26, TLS 60; Mixed martial arts – occurrences 6, links 26, TLS 52; Wrestling – occurrences 6, links 26, TLS 59; Anthropometry – occurrences 8, links 25, TLS 62; Boxing – occurrences 7, links 25, TLS 64; Retrospective studies – occurrences 5, links 18, TLS 42; Absorptiometry – occurrences 5, links 16, TLS

37; Aggression – occurrences 7, links 15, TLS 41; Social perception – occurrences 5, links 14, TLS 33; Judo – occurrences 5, links 13, TLS 20. The keywords of this cluster characterize martial arts types, age groups, anthropometric and morphofunctional features, and psychological preparedness.

The second cluster also includes 19 keywords. It is marked in green on the map. Conventionally, this cluster can be called “health preservation”. The keywords of this cluster characterize physical exercise, disease prevention, recovery from injuries, and old age. The occurrence and number of links in the order of decreasing are as follows: Female – occurrences 68, links 62, TLS 564; Middle aged – occurrences 32, links 50, TLS 289; Aged – occurrences 25, links 43, TLS 236; Tai ji – occurrences 30, links 38, TLS 250; Surveys and questionnaires – occurrences 12, links 37, TLS 118; Aged, 80 and over – occurrences 8, links 32, TLS 88; Exercise – occurrences 15, links 31, TLS 116; Treatment outcome – occurrences 13, links 31, TLS 119; Risk factors – occurrences 8, links 27, TLS 71; Postural balance – occurrences 8, links 27, TLS 70; Exercise therapy – occurrences 8, links 26, TLS 7; Quality of life – occurrences 8, links 25, TLS 81; Anxiety – occurrences 5, links 24, TLS 45; Oxygen consumption – occurrences 6, links 24, TLS 48; Pulmonary disease, chronic obstructive – occurrences 10, links 22, TLS 92; Tai chi – occurrences 9, links 21, TLS 78; Pilot projects – occurrences 5, links 21, TLS 37; Forced expiratory volume – occurrences 5, links 19, TLS 47; Qigong – occurrences 5, links 18, TLS 43.

The third cluster includes 13 keywords. It is shown in blue on the map. The conditional name of this cluster is “Athletic performance”. This is the most significant keyword in this cluster. It occurs 23 times, has 43 links with other keywords in the map, and the total link strength is 182. Further, the occurrence and number of links in decreasing order is as follows: Muscle strength – occurrences 9, links 38, TLS 88; Muscle, skeletal – occurrences 7, links 35, TLS 74; Exercise test – occurrences 11, links 34, TLS 95; Sex factors – occurrences 10, links 34, TLS 96; Physical fitness – occurrences 10, links 34, TLS 93; Time factors – occurrences 8, links 33, TLS 70; Predictive value of tests – occurrences 7, links 29, TLS 59; Age factors – occurrences 5, links 28, TLS 54; Body mass index – occurrences 6, links 27, TLS 49; Heart rate – occurrences 5, links 23, TLS 45; Reproducibility of results – occurrences 5, links 20, TLS 42; Child – occurrences 5, links 20, TLS 38. The keywords of this cluster characterize sports training, the control of fitness, and factors that affect the results.

The fourth cluster is marked in yellow on the map and includes 12 keywords. The most significant keyword is “humans”. It occurs 128 times, has 62 links with other keywords in the map, and the total link strength is 879. The occurrence of other keywords

and the number of links to them in descending order is as follows: Adult – occurrences 52, links 59, TLS 396; Movement – occurrences 8, links 33, TLS 68; Regression analysis – occurrences 8, links 29, TLS 67; Biomechanical phenomena – occurrences 12, links 21, TLS 56; Case-control studies – occurrences 5, links 21, TLS 47; Analysis of variance – occurrences 5, links 20, TLS 39; Acceleration – occurrences 6, links 20, TLS 37; Motor skills – occurrences 6, links 19, TLS 44; Posture – occurrences 5, links 19, TLS 34; Sports – occurrences 8, links 18, TLS 46; Head – occurrences 6, links 13, TLS 30. The keywords of this cluster characterize research methods, techniques, and athletes.

The overlay visualization shows that most of the keywords with the most recent publication dates describe general concepts: martial arts types, athletes, and their activities. Earlier publications reflect more specific studies: anxiety, muscle, skeleton, and regression analysis.

Fig. 3 shows the visualization of density. The interpretation of the results in this figure: the more important is the topic, the larger and brighter is the circle, and the larger is the font size. According to Figure 3 the most popular research topics can be identified. These include studies by topic (in descending order of importance): “humans”, “martial arts”, “male”, “female”.

Discussion

VOSviewer was used to perform bibliometric analysis of PubMed database. A similar design was used to analyze Web of Science Core Collection (WoS) [21], Scopus [22], PubMed [26], and Google Scholar [29].

The design of systematic reviews of various databases and meta-analyses also uses other representations of the results. Krzysztofik et al. [28] conducted a literature review in accordance with the recommendations on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The authors searched the MEDLINE, SPORTDiscus, Scopus and Google Scholar databases for all studies examining the effect of unilateral conditioning on the effect of PAPE until February 2022. Similar studies using PRISMA were performed by Makaruk et al. [29]. The research sought to review methodological procedures in the current literature that analyzed the effects of weight training on strength, speed, and endurance in athletes. Computer-based literature searches of SPORTDiscus, Scopus, Medline, and Web of Science were conducted. The internal validity of individual studies was assessed using the PEDro scale.

Other studies [30] conducted a computerized literature search in PubMed, ISI Web of Knowledge, SPORTDiscus, and Scopus databases (until January 2016) to study the physical and physiological profiles of Brazilian jiu-jitsu athletes. This systematic review

was compiled according to MOOSE (Meta-analysis Of Observational Studies in Epidemiology). A database study resulted in 205 articles. After applying the inclusion and exclusion criteria, 58 studies were included in this systematic review. A total of 1,496 participants were included in all selected studies.

Kwok et al. [31] conducted a systematic review and meta-analysis of the biomechanical evaluation of the effectiveness of strength and conditioning training programs in front crawl sprint swimming performance. Four online databases, including PubMed, EBSCOhost, Web of Science, and SPORTDiscus, were searched according to different combinations of keywords. 954 articles were extracted from the databases, and 15 articles were included in this study after removal of duplicates and articles screening according to inclusion and exclusion criteria. Meta-analyses were adopted when appropriate and Egger's regression symmetry was adopted to assess the publication bias and the results were presented with forest plots and funnel plots, respectively. Fifteen articles studied the effects of strength and resistance, core, and plyometric training. The quality of the investigation was assessed using the checklist developed by Downs and Black. Most investigations found that training programs were beneficial to front crawl sprint swimming performance, stroke biomechanics, force, and muscle strength.

The study [32] performed a systematic literature search in EBSCOhost, MEDLINE, PubMed, Web of Science, and SPORTDiscus with dates ranging from the earliest record to October 2018.

The purpose of this review was to determine the magnitude of changes in muscle strength and power at different stages of an elite rugby league season. The search identified 668 potentially relevant studies that were extracted into a spreadsheet. Following the removal of duplicates, the total remaining was 442. Titles and abstracts were reviewed for inclusion against eligibility criteria by one of the authors. Any doubts on a study meeting the inclusion criteria resulted in two authors reviewing the full text. Disagreements were resolved by discussion between the authorship team. Of these articles, twelve met the selection criteria. The methodological quality of each study was appraised using the Newcastle–Ottawa scale adapted for cross-sectional studies.

A bibliometric review of the literature on prediction in martial arts contributes to the mapping of the field of study and indicates key areas of research. Four thematic clusters were identified using VOSviewer 1.6.19. The first cluster is focused on martial arts. Among the topics of research interest are worth mentioning: the study of different types of martial arts [2], age groups [33], anthropometric and morphofunctional features [34], and psychological preparedness [35].

The second cluster is devoted to the health

preservation by martial arts. Its main research topics are as follows: the use of physical exercises [36], disease prevention [37], recovery from trauma [38], and old age [39].

The third cluster is characterized by more professional sports activities, focusing on athletic training [40], fitness control [41], and factors that influence the results [9].

The fourth cluster concentrates around the keyword "humans". The authors of this cluster studied: research methods [42], technical skills [43], and athletes [44].

The analysis of Figure 1 makes it possible to assert that prediction in martial arts is a relevant and popular topic for research. Studies on this topic have been conducted in many types of martial arts. Latyshev et al. [1] determined the influence of relative age on the achievement of success by elite athletes in wrestling. The data obtained show that the relative age effect does not affect the achievement of success in wrestling and is levelled at the adult stage. However, the analysis has shown that the greatest influence of the relative age effect on athletes was revealed at the cadet level.

Li et al. [13] developed several inertial MEMS sensors to improve the accuracy of training injury risk prediction and reduce physical injuries. By analyzing the data, a martial arts training model and injury risk prediction models were developed that can provide recommendations and suggestions for martial arts training tasks. Similar studies have been conducted before [45].

Ćenanović & Kevrić [19] used machine learning (ML) algorithm and classifier to predict the winners of MMA. The results are presented in percent accuracy for two different types of samples. The percentage of successful fight predictions ranged from 80% to 92% across all subsets. This model can be further extended and modified to predict the winner of future fights.

Holmes et al. [20] presented Markov chain models for predicting MMA mixed martial art competition results. The developed models generate transition probabilities that are used to simulate realistic MMA. Also, a model was developed for predicting judges' decisions based on the bout statistics of opposing fighters. The models presented can be used by fighters when preparing for a particular opponent and when using them as a basis for betting strategies.

Podrigalo et al. [46] analyzed the bodybuild features of elite athletes of combat sports with the application of special indexes. It was determined that a higher body mass index in athletes demonstrates the prevalence of muscular component of somatotype. The Erismann and Pignier indexes, shoulders width index illustrate the best development of muscles in athletes and kickboxing athletes in comparison with karate athletes, and taekwondo. Increase in a

relative body surface of athletes demonstrates the growth of their aerobic opportunities. Increase in the power index confirms the importance of grip strength for success in combat. Indexes of a ratio of segments of extremities reflect features of the technique of combat sports.

Ota and Kimura [14] proposed a statistical model of injuries based on the analysis of performances of professional sumo wrestlers in the highest division. The proposed model provides the estimated probability of the next potential injury occurrence for a sumo wrestler. In addition, it can support making a risk-based injury prevention scenario for sumo wrestlers. The proposed model can also be applied to injury prediction for athletes in other sports.

Latyshev et al. [8] conducted a retrospective analysis of 41 wrestling careers of the six Olympic Games winners in freestyle wrestling from 1996 to 2016. The obtained data can be used for: identifying the main tendencies and regularities specific for each stage of athletic performance; choosing informative predictive indicators, and developing a model of a successful wrestler. A similar analysis was used by Norjali et al. [18]. This study aimed to predict the performance of young judo athletes using linear and nonlinear predictive statistical models. In this retrospective cross-sectional study, a common battery of tests was used, which consisted of five anthropometrical, seven physical performance, and three motor coordination tests. Generic talent characteristics (anthropometry) included in this study allow for successful discrimination between dropout, subelite, and elite judo athletes. In addition to the trainer's opinion and the individual screening of judo-specific performance characteristics, this generic test battery provides opportunities for predicting the judo performance of young athletes.

There are differences in success prediction factors in different types of martial arts: head punches maintaining distance and takedowns landed are the most significant variables that affect the probability of predicting winning fights in MMA [47]; the ranking scores and the CPS of the competitors are important variables in predicting winners in high-

level taekwondo competition [15]; the Random Forests classifier identified seven key success factors in wrestling: anaerobic power, strength endurance, reaction time, special endurance, wrestling-specific fitness and technical wrestling skills performed in a horizontal position.

Analysis of the visualization of Figure 3 allows us to conclude that more studies predicting success are conducted in popular martial arts: boxing, wrestling, judo, taekwondo, karate, and MMA. The popularity of these sports is growing every year, which significantly affects the number of publications. These data are confirmed with earlier results [48, 49, 50].

The results of density visualization actually repeat the results of network visualization. This should be taken as a confirmation of the correctness of the assumptions made.

Conclusions

The conducted bibliometric analysis and analysis of bibliometric maps made it possible to identify trends in scientific research and highlight priority areas. The urgency of the problem of prediction in martial arts is confirmed. An increase in publications in the PubMed database over the past decade has been observed. The main areas of research include martial arts, health, sports training, and humans. Most publications use artificial intelligence and machine learning to predict the results of competitions. Also on the use of analytical tools for revealing regularities in data and determination of key factors influencing results of competitions. Modern technology and the availability of large amounts of data open up new opportunities for predicting success in martial arts.

Acknowledgement

The authors sincerely thank the subjects who participated in this study and contributed to the realization of this study. This research received no funding.

Conflict of interest

The authors declare no conflicts of interest.

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Cite this article as:

Tropin Y, Podrigalo L, Boychenko N, Podrihalo O, Volodchenko O, Volskyi D, Roztorhui M. Analyzing predictive approaches in martial arts research. *Pedagogy of Physical Culture and Sports*, 2023;27(4):321–330. <https://doi.org/10.15561/26649837.2023.0408>

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Received: 11.06.2023

Accepted: 24.07.2023; Published: 30.08.2023

The role of anthropometry, physical, psychological and personality for elite athletes in competitive sports

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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 This study aims to describe and explore the anthropometric, physical, psychological, and personality traits of elite Papuan Indonesian athletes in seven different sports, namely weightlifting, rowing, cricket, futsal gateball, sailing, and hang-glider.

Material and Methods A total of 118 athletes (80 men, 38 women with a mean age of 25.05±6.9) from these seven categories were selected. Furthermore, the anthropometric measurement consists of height, weight, and body mass index. At the same time, physical ability is made up of five components, namely flexibility, arm muscle strength, abdominal muscle strength, leg muscle power, and aerobic endurance. The psychological ability and personality characteristics were also measured using the Psychological Skill Inventory for Sport (PSIS) and the Athlete's Personality Inventory (IKA).

Results There were significant differences in the six variables ($p < 0.01$), but no significant difference in the other variables ($p > 0.05$). The six variables include height, BMI, arm and abdominal muscle strength, leg muscle power, and aerobic endurance with F and p-values of 3.052 and 0.008 ($p < 0.01$), 3.497 and 0.003 ($p < 0.01$), 9.822 and 0.001 ($p < 0.01$), 11.855 and .001 ($p < 0.01$), 52.747 and 0.001 ($p < 0.01$), and 11.298 and 0.001 ($p < 0.01$). The other four variables include weight, flexibility, psychological abilities, and personality traits, showed no significant difference ($p > 0.05$). Aerobic endurance variables, in general, had a significant relationship with anthropometric variables and other physical aspects. However, psychological variables and personality characteristics did not significantly correlate with other variables.

Conclusions The anthropometric and physical aspects of athletes tended to have differences based on sports. However, psychological variables and personality characteristics had no relationship with physical and anthropometric aspects.

Keywords: anthropometric, physical abilities, psychological skills, personality, elite athletes

Introduction

The performance level of athlete is based on multifactorial influences such as anthropometric and physical abilities [1, 2, 3], psychological, mental, personality [4, 5, 6], coaches [7, 8], and the environment [9, 10]. These factors are interrelated and influence the performance of athletes on the field [11, 12, 13]. Data from previous studies reported that anthropometric factors [14, 15], physical abilities, psychological [16], are very important for an athlete to be successful professionally at the competitive sports level in the future. There are at least three primary factors that influence the performance of athletes in the field, namely anthropometrics, physical, and psychological abilities [17,18]. The anthropometric aspect deals with body measurements such as height, weight, arm length, with various urgency levels within

sports [19]. While the physiological traits are related to motoric potential and abilities [20], such as speed, strength, agility, and endurance, and are greatly influenced by a person's physiological condition. However, the psychological aspect is related to mental readiness and the ability to practice and compete for achievement [21]. Many studies have conducted an anthropometric analysis because they believe it perfectly describes the performance and achievements of athletes [17, 22, 23]. Furthermore, each sport has different anthropometric needs that support specific skills. For example, goalkeepers in futsal require higher height characteristics compared to weightlifting. In contrast, body weight tends to be more needed in weight lifting to support athletes in lifting relatively heavy weights.

Physical ability is commonly referred to as physiological, which is an important aspect of competitive sports [24, 25, 26]. Excellent physical could assist athletes play optimally, which supports them to obtain higher achievements [27]. In several

game sports such as futsal, cricket, and football, a physical condition such as aerobic endurance plays a major factor since the game lasts for a long period [28]. Therefore, these athletes need to have a higher VO_{2max} than other athletes in hang-gliding, sailing, and weightlifting. However, arm muscle strength is more required in weightlifting and rowing than futsal and gate ball.

The psychological aspect of athletes is part of the dimensions that greatly determine a competition's outcome [16, 29, 30]. In the event that an athlete feels anxious or unconfident, their skills and good physical condition become ineffectual [31]. According to Lange-Smith, Cabot, Coffee, Gunnell & Tod [32], the key factor to be able to have high performance and compete and be successful in competitive sports is managing the psychological aspect as well as possible. Unfortunately, the psychological aspect is often overlooked because most trainers or coaches focus on building the physical features. Therefore, this psychological aspect often becomes a "scapegoat" for failing to achieve the laid down goals and unsatisfactory performance.

Previous studies have shown that personality characteristic is one of the many factors contributing to an individual's success, especially in sports [33, 34, 35]. Basically personality is closely related to the behavior or actions of athletes when training or when competing. For example, athletes with good personality will have respect for friends, coaches or opponents. Conversely, a bad personality will make the athlete never achieve high success [36]. Data from previous studies reported that personality has a positive relationship with performance in sports [37].

Comprehensively studying the anthropometric, physical, psychological, and personality aspects of athletes from various sports provided more beneficial information. This means it had limitations in the previous studies, which only partially examined every element related to athletes. Researchers had not found any studies that comprehensively investigated athletes' anthropometric aspects, physical fitness, personality characteristics, and psychology. These were essential aspects to enhance performance among athletes. Based on the above description, this study aims to describe and explore in the anthropometric, physical, psychological, and personality traits of elite Papuan Indonesian athletes in seven different sports

Materials and Methods

Participants

This study used subjects that included elite athletes from Papua Indonesia who was undergoing training to prepare for Indonesia's biggest national sports event, called the XXth National Sports Week

(PON). Furthermore, a total of 118 athletes (mean age: 25.05 ± 6.9 years) from seven different sports were involved in this study, namely 18 in Weight lifting (10 males, 9 females), 15 in Cricket (9 males, 6 females), 30 in Rowing (18 males, 12 females), 10 in Futsal (10 males), 15 in Gateball (13 males, 2 females), 19 in Sailing (12 males, 7 females) and 11 in Hang-gliding (8 males, 3 females).

Research Design

Anthropometric characteristics were determined based on height, weight, and Body Mass Index (BMI). The height was measured using a stadiometer (Seca 213; Seca, Japan) nearest 0.1 cm. While the bodyweight was measured using a digital weight scale (HBF-214; Omron, Japan) to the nearest 0.1 kg, and the BMI was calculated based on body weight and height (BW/H^2).

Furthermore, the physical ability (physiological) was measured using five components: flexibility, arm and abdominal muscle strength, leg muscle power, and aerobic endurance. Flexibility was estimated using a vertical trunk flexion meter (TKK 5403; Takei, Japan) to the nearest 0.1 cm. At the same time, the Abdominal and arm muscle strength was measured by doing sit-ups and push-ups for 60 seconds (TKK 5505; Takei, Japan) [38]. The Leg muscle power was measured three times using the vertical jump test [39], and the best results were recorded to the nearest of 0.1 cm. In addition, the aerobic endurance was measured using a multi-stage run 20m test [40].

The psychological ability was determined using the Psychological Skill Inventory for Sport (PSIS) [41] and has been adapted in Indonesian by Dimiyati, Herwin, & Hastuti [42], with a validity and reliability value between 0.54 to 0.89 and 0.8 to 0.92. Furthermore, the personality characteristics were found using the Athlete Personality Inventory (IKA) [43].

Statistical Analysis

Data were analyzed using descriptive techniques such as mean \pm Standard Deviation (SD) using the minimum and maximum values. While further statistical analysis was carried out using the one-way analysis of variance (One-way ANOVA) and to determine the relationships between the variables, Pearson's product-moment correlation analysis was employed. The accepted level of statistical significance was $p < 0.05$, and all data analyses were performed with the assistance of the IBM SPSS version 26 program (Armonk, NY, USA: IBM Corp).

Results

The first analysis results were presented descriptively using the minimum, maximum, average, and standard deviation values (Table 1). The results show that the age of elite athletes undergoing training was between the ages of 17 to 48, with an

average value of 25.05±6.9. In the anthropometric aspect, the athlete's height and body weight was between 138 to 183cm and 43.5 to 120.6kg with an average value of 163.39±8.01, and 67.5±13.49, while BMI was between 17.39 to 43.4 kg/m² with a mean value of 25.27±4.58. Furthermore, for physical and flexibility aspects, arm and abdominal muscle strength, leg muscle power, aerobic endurance, arm muscle strength, abdominal muscle strength had values between 1.5 to 27 cm, 11 to 56, 11-68, 9.7-144 cm, 20.4-54.1 ml/kg/min with an average value of 11.94±5.53, 38.98±9.12 and 20.4-54.1 ml/kg/min. The psychological ability dimension had a value in the range of 68 to 174, with an average value of 131.86±17.78. In addition, the personality characteristics scored 144 to 240 with an average value of 205.5±18.29.

The height, IMT, arm and abdominal muscle strength, leg muscle power, and aerobic endurance variables showed a statistically significant difference with a F and Sig. values of 3.052 and 0.008 (p<0.01), 3.497 and 0.003 (p<0.01), 9.822 and 0.001 (p<0.01), 11.855 and 0.001 (p<0.01), and 52.747 and 0.001 (p<0.01). However, the variables of psychological ability, weight, flexibility and

personality characteristics had no statistically significant difference with an F and Sig. values of 0.568 and 0.755 (p>0.05), 1.096 and 0.370 (p>0.05), 0.865 and 0.523 (p>0.05) (Table 2).

The summary of the relationship analysis among the variables is presented in Table 3. Based on the analysis results, several variables had a significant relationship, but the others did not have relationship. Endurance variables, in general, had a significant relationship with anthropometric variables and other physical aspects. Psychological variables and personality characteristics did not significantly correlate with other variables.

Discussion

Statistically, the result found significant differences in six categories and no difference in the other four categories. First, there were significant differences in height since each sport has different requirements (anthropometrics) [15]. Therefore, it was one of the criteria assessed by the coach in the selection process for elite athletes in Indonesia. The determination of the height criteria between coaches of one sport and another was certainly different due to their requirements and the characteristics

Table 1. Descriptive statistics (N=118; Male=80, Females=38)

Variable	Weightlifting (M±SD)	Cricket (M±SD)	Rowing (M±SD)	Futsal (M±SD)	Gateball (M±SD)	Sailing (M±SD)	Hang-Gliding (M±SD)
Age (year)	31.22±5.1	23.80±5.13	20.27±2.8	19.90±.876	32.40±8.05	24.50±3.85	25.91±4.13
Height (cm)	157.79±8.26	161.86±10.92	166.37±6.89	165.18±6.08	163.59±8.84	162.72±6.77	166.84±7.47
Wight (kg)	70.48±5.81	63.23±11.52	65.04±9.92	65.44±11.36	67.62±12.14	72.78±16.92	68.14±9.61
BMI (kg/m ²)	28.13±18.93	24.17±3.93	23.41±2.63	23.95±3.76	25.26±3.97	27.60±5.32	24.52±3.45
Flexibility (cm)	13.45±6.28	10.40±7.37	12.65±4.86	11.00±5.63	10.17±6.03	11.89±4.42	13.00±5.85
Arm muscle strength (kg)	34.50±5.35	35.87±7.31	42.87±8.08	44.50±5.87	28.53±7.23	43.74±8.64	41.00±6.40
Abdominal muscle strength (s)	42.61±7.34	31.60±6.63	41.10±10.44	26.60±6.78	21.27±5.72	31.42±7.80	38.82±10.98
Leg muscle power (cm)	52.94±12.84	47.00±7.82	47.66±9.12	52.60±5.92	40.28±13.32	105.47±20.32	48.82±11.75
Aerobic endurance (ml/kg/min)	26.50±15.55	32.03±5.13	39.25±7.89	45.28±6.91	30.31±7.54	37.62±8.33	40.23±9.71
Psychological abilities (points)	133.11±5.71	131.87±16.54	134.13±20.45	137.10±12.76	127.13±17.05	127.84±13.65	132.18±22.41
Personality characteristics (points)	205.44±18.78	196.73±16.59	207.40±16.21	206.30±14.91	207.00±15.42	207.16±18.25	206.91±23.24

Table 2. The test result of anthropometric, physical capacity, psychological abilities, and personality

Variable	Mean ± S.D	F	Sig.
Height (cm)	163.4 ± 8.01	3.052	0.008*
Wight (kg)	67.54 ± 13.49	1.096	0.370 ^{n_s}
BMI (kg/m ²)	25.28 ± 4.58	3.497	0.003*
Flexibility (cm)	11.94 ± 5.53	0.865	0.001*
Arm muscle strength (kg)	38.98 ± 9.12	9.822	0.001*
Abdominal muscle strength (s)	34.60 ± 11.7	11.855	0.001*
Leg muscle power (cm)	57.28 ± 25.01	52.747	0.001*
Aerobic endurance (ml/kg/min)	35.59 ± 9.1	11.298	0.001*
Psychological abilities (points)	131.86 ± 17.78	0.568	0.672 ^{n_s}
Personality characteristics (points)	205.52 ± 18.2	0.673	0.755 ^{n_s}

Notes: *p < .01; ^{n_s}: Non-significant

Table 3. Correlation test results between variables

Variable	1	2	3	4	5	6	7	8	9	10
1. Height (cm)	-									
2. Wight (kg)	0.413**	-								
3. BMI (kg/m ²)	-0.093	0.866**	-							
4. Flexibility (cm)	-0.059	-0.024	0.001	-						
5. Arm muscle strength (kg)	0.266**	0.029	-0.115	-0.067	-					
6. Abdominal muscle strength (s)	-0.090	-0.128	-0.092	0.136	0.381**	-				
7. Leg muscle power (cm)	0.048	0.090	0.073	0.003	0.389**	0.038	-			
8. Aerobic endurance (ml/kg/min)	0.356**	-0.165	-0.367**	-0.022	0.652**	0.227*	0.310**	-		
9. Psychological abilities (points)	0.171	0.088	-0.006	0.019	-0.040	0.039	-0.143	0.102	-	
10. Personality characteristics (points)	0.143	0.068	-0.010	0.087	0.141	0.135	0.082	0.138	0.064	-

Note: **Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

of the sports. Reilly et al. [44] also mentioned that each sport's anthropometric characteristics (height) were diverse; for example, the average height of elite rugby and soccer athletes was 1.79±0.06 and 1.77±0.06. Itoh & Hirose [45] studied athletes' anthropometrics and found significant differences in the height category. In certain sports, such as football, the height between the goalkeepers, attackers, and midfielders were mostly different [44]. This means that the height requirements of athletes in each sport, including playing position, were also different [45].

The results also showed that there was no significant differences in body weight since elite Indonesian Papuan athletes were not amateurs. They had been trained for a long time at their respective clubs; therefore, their weights were well preserved, and no one was obese or very thin. These results align with the research conducted by Kovacevic [46], whereby there was no difference in body weight in the athletes. This result contradicted with the research conducted by Gall et al. [47], who

mentioned that there was a significant difference in the bodyweight category between professional and international athletes. It is also in line with the study conducted by Canhadadas et al. [48], however, the difference with this present study was the comparison of subjects based on the age group.

Furthermore, the results also showed a significant difference in BMI. This is supported by the study conducted by Putra and Ita [49], who compared the BMI of athletes in three different sports. The difference in the criteria for ideal body weight in each sport was believed as a factor that contributed to those results. For example, weightlifting requires a relatively heavier body weight than other sports like gliding and sailing. Weightlifters weigh more than any other athletes and even weigh up to 120.60 kg. In contrast with the BMI results, no significant difference was found in the flexibility variable. This is due to the long training process that had been conducted by athletes before entering the camp. They all trained individually and at their respective clubs. Furthermore, these results were

supported by the studies of Itoh & Hirose [45], who found no significant difference in flexibility. A significant difference was found in the arm muscle strength variable due to differences in the physical ability requirements in each sport. For example, weightlifting, rowing, and cricket require greater arm muscle strength than futsal, hang-gliding, and sailing [50]. Under these conditions, athletes must train rigorously to increase their arm muscle strength. Conversely, futsal athletes would also focus more on the physical aspects such as aerobic endurance, speed, agility, and leg muscle power since these physical dimensions are required.

The research data shows that the results of rowing, weightlifting, and cricket athletes were higher than other athletes. However, the results of this study are different from previous study which was conducted by Putra and Ita [49]; there was no significant difference in the arm muscle strength of the athletes in three different sports. Their research reported that data collection was carried out when the athletes had just begun their training concentration programs. This means they had not received any intensive program from the coach concerning physical exercise. However, this study was carried out when the athletes underwent an intensive training program. The research subjects involved were also from different sports. Therefore, it was natural to find different results between the two studies. The study conducted by Vukasevic et al. [51] found no significant difference in the arm muscle strength (push-ups) category. However, there were subject differences between Vukasevic et al and this study, and this is because they compared athletes in the same sport.

There was a significant difference in the abdominal muscle strength variable due to the characteristics of the sport. This is supported by the research data, which shows that the mean value of rowing and weightlifting athletes ($M=41.85\pm 11.6$) was higher than the average score ($M=34.6\pm 11.6$). Previous studies have shown that the strength of the abdominal muscles greatly enhances the performance of rowing athletes and weightlifters. However, these results differ from Vukasevic et al [51], whereby there was no statistical difference in the abdominal muscle strength variable. In addition, the difference between the two research results could not be separated from the differences in the subjects studied.

There was a significant difference in the leg muscle power variable. This is supported by the research conducted by Kobal et al. [52], in four different sports and is also in line with Gall et al. (2010). The reason behind these results was that the seven sports sampled in the study had different game characteristics and physical needs, which affected the physical capacity of the athletes [47]. For example, futsal athletes need leg power muscle

strength to improve their performance on the field, especially when performing kicks and running. However, this is different for the hang-gliding and sailing athletes in which do not require leg muscle power. However, the results of these studies differ from that of Vukasevic et al. [51], whereby there was no significant difference in the leg muscle power of the athletes. Furthermore, the difference in research results was due to the number of sports studied. Significant differences are mostly found in studies that involve several sports [52], compared to those involving one sport.

There was a significant difference in the aerobic endurance variable due to the characteristics of the sport under study. Weightlifting, cricket, rowing, futsal, gateball, sailing, and hang-gliding have different playing methods and require different aerobic endurance. For example, futsal, rowing, cricket, and gateball require a higher physical capacity (aerobic endurance) than hang-gliding, sailing, and weightlifting. These results are supported by previous research conducted on athletes from Papua, Indonesia, which showed significant differences in the aerobic endurance variable [49]. However, a different result was found in Lopez-Plaza et al. [53], whereby they investigated rowing athletes and found no differences in aerobic endurance. The study only compared the numbers in rowing and not between sports. Therefore, there was a tendency to have the same physical capacity (aerobic endurance).

This study found no difference in the psychological abilities of athletes because Indonesian National Sports Committee made a policy or program called "Character Building and Achievement Motivation Training" (CB-AMT) by involving experts in the field of sports psychology. Furthermore, the program's main objective was to form a winning mentality for Papuan athletes [54]. All those undergoing training were required to participate in the CB-AMT. The program was acknowledged as a factor that causes elite Papuan athletes to be at a relatively similar psychological level. However, this study did not analyze and reveal its role in the psychological condition of the athletes [51].

The next results of this study found no differences in the personality characteristics in elite athletes from Papua, Indonesia. The "elite" status indicates that the athletes studied were a set of selected individuals, and not all of them could enter this level because they had to compete among themselves. Furthermore, those involved were psychologically strong and were tested, and there was no difference when measured using the Athlete's Personality Inventory (IKA). This result is in line with the study conducted by Guntoro et al. [55], whereby there were no differences in athletes' personality characteristics in four different sports. It was due to the similarity level in terms of mentality. However,

the results would differ if the research subjects were compared between several groups, such as elite and non-elite athletes and non-athletes.

The result of the correlation analysis among variables shows that, in general, the aspect of endurance had a significant relationship with anthropometric variables (BMI) and other physical capacities. This strengthened the previous evidence that endurance capacity was a key and supporting aspect of several other physical components [28, 24, 27]. Different results were found on psychological and personality variables. The two variables did not have a significant relationship with other variables. Previous study found that psychological and personality dimensions have a relationship with the physical capacity of athletes [56]. However, that study were conducted on one sport and involving only 12 athletes. This was very different from the current research which involved various sports and a lot of athletes.

A number of important limitations need to be considered. First, the tests or measurements were only carried out once. Therefore, further research needs to be conducted by performing several tests or measurements. For example, in four weeks, the same retest was conducted to evaluate the changes that had been occurred, both physically and psychologically, since they were dynamic. Secondly, the characteristics of the sports did not represent the other four type of sports, namely martial arts, games, accuracy, and measurability. Therefore, further studies need to involve more sports and athletes to obtain more comprehensive information. Finally,

coaches, sports administrators, and athletes can use this result to improve less than ideal conditions. This is very important because anthropometric aspects, physical, psychological, and personality capacities affect an athlete's performance in the field.

Conclusions

There were significant differences in the six variables, but the others was not different. The six variables include height, BMI, arm and abdominal muscle strength, leg muscle power, and aerobic endurance. The other four variables which include weight, flexibility, psychological abilities, and personality traits, showed no significant difference. Endurance variables, in general, have a significant relationship with anthropometric variables and other physical aspects. However, psychological variables and personality characteristics do not significantly correlate with other variables. Thus, the anthropometric and physical aspects of athletes tend to have differences based on sports. However, psychological variables and personality characteristics did not have relationship with physical and anthropometric aspects.

Acknowledgement

We would like to express our gratitude to the Research and Development from University of Cenderawasih

Conflict of interest

No conflict of interest in this research.

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Cite this article as:

Guntoro TS, Sutoro, Putra MFP, Kurdi, Németh Z, Setiawan E. The role of anthropometry, physical, psychological and personality for elite athletes in competitive sports. *Pedagogy of Physical Culture and Sports*, 2023;27(4):331–339.

<https://doi.org/10.15561/26649837.2023.0409>

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Received: 15.06.2023

Accepted: 25.07.2023; Published: 30.08.2023

Use of exercises with increased coordination complexity in the training process of young female volleyball players aged 13-14 years

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Abstract

Background and Study Aim In the context of training young female volleyball players, understanding the criteria, extent, and impact of exercises with heightened coordination complexity becomes crucial. This study aims to determine the evaluation criteria, scope, and effects of incorporating exercises with elevated coordination demands on the specific athletic readiness of young female volleyball players aged 13–14 years.

Material and Methods The study involved female volleyball players aged 13–14 years (n=24) with an average of 4 years of professional experience. Participants were divided into a control group (n=12) and an experimental group (n=12). Prior to the study, both children and their parents were thoroughly informed about the research procedures, and parental consent was obtained for participation. The coordination exercises were categorized into five groups, each assigned a complexity rating from 1 to 5. The assessment utilized a battery of tests.

Results The findings reveal that coordination training yielded a more pronounced advancement in the development of various coordination abilities among female volleyball players in the experimental group, as compared to those in the control group. A statistically significant enhancement (p<0.05) was evident across all indices of coordination readiness within the experimental group. In contrast, the control group demonstrated notable progress only in 3 out of 10 instances (p<0.05). In the control group, noteworthy increases (p<0.05) were observed in spatial orientation, motor activity restructuring, and response indicators. Female volleyball players in the experimental group exhibited substantial improvement (p<0.05–0.001) across all indicators of technical readiness, including reception, attack hit, serve, and ball pass. Conversely, the control group players showed comparatively less remarkable changes in this aspect of readiness, with significant enhancement (p<0.05) identified in three parameters.

Conclusions The strategic incorporation of exercises with progressively heightened coordination demands emerges as a valuable approach in substantially enhancing the range of coordination abilities among young female volleyball players. Recognizing this factor provides the means to expedite and optimize the mastery of motor skills more effectively.

Keywords: female volleyball players, abilities, coordination, complexity, method, training.

Introduction

Sports training constitutes an intricate system encompassing a multitude of phenomena,

interrelationships, and behavioral components. In striving to attain the ultimate objective of sports training — that is, cultivating a top-tier athlete capable of optimal performance across diverse conditions — our endeavor rests on a comprehensive comprehension of the young athlete's individuality. Additionally, it hinges on an

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doi:10.15561/26649837.2023.0410

understanding of the nuanced influences of age and gender on players. This collective insight serves as the foundation for crafting a well-founded blueprint for a coherent, multi-year sports training regimen. This strategic framework should encompass the utilization of pertinent and efficacious training tools, methodologies, and instructional formats, as well as an adept calibration of training intensities, frequencies, and the sequential arrangement of training cycles [1, 2].

Verkhoshanski [3], Koryahin et al. [4] propose that the term “training load” encompasses the magnitude of alterations within the athlete’s internal physiological milieu brought about by the impact of physical exercises. It should be noted that physical exercises provoke a reaction from the functional systems of the body, which is reflected in the adaptive mechanisms of its adaptation to specific activities. In addition, the rate of adaptive changes in players’ bodies, their nature and the degree of adaptation achieved are determined by the type, magnitude and direction of the applied loads. Naturally, the experts divide the load into training and competition, specific and non-specific [5, 6]. According to this, the training load includes the amount of exercises that athletes carry out as part of the preparation for a competition. Competition loads are mainly characterized by quantitative and qualitative indicators of competition practice during a competition or multiple competitions that complete a given cycle of player training. In particular, Starosta [5] points out that specific and non-specific loads are typical for each type of motor activity, and the training effect depends on their combination. There is reason to believe that exercises with elements of competitive action create a specific load. Exercises for basic physical training characterize a non-specific load. For example, in the context of sports games, all exercises with the ball give specific loads, while exercises without the ball are non-specific. Specific training aids have a high training effect and are used as a means of special training. Their use ensures a direct and positive transfer of skills and motor qualities. As a rule, the use of training aids from this group results in a rapid increase in sporting and technical results. Specific effect of the training aids of the second group is insignificant and therefore they are used only as a means of basic training [7, 8, 9].

With any physical activity, first of all, that motor qualities develop and improve, on which the result depends. Obviously, the training effect of exercises is determined by the ratio of their components. In particular, in one combination of values of the impact components, this exercise can be aimed at the development of endurance, and in the other one it will develop speed and strength [2, 10]. Characteristically, a session’s training load should provide not only the required value and direction

of the urgent training effect, but also its interaction with the training effects of past and subsequent sessions. Finally, it is known that the interaction of exercises of different directions manifests itself in the fact that “the biochemical shifts caused by this exercise depend on whether the exercise is performed after a long break, whether it is preceded by another exercise, the aftereffect of which is reflected in the urgent training effect of the exercise performed [11].

The size of the loads means the quantitative degree of the training impact [12]. The value of training and competition loads can be characterized from the “external” and “internal” sides. The “external” load is called a motor load and is determined by the duration and speed of the exercises performed, the number of repetitions, approaches, elements, weight lifted, etc. “Internal” or physiological load is a way of mobilizing the body’s functional capabilities while performing exercise and is taken into account in terms of indicators such as oxygen consumption, oxygen debt, heart rate, blood pressure, blood pH, blood lactate, etc. From the point of view of managing the process of physical education and sports training of young athletes, the “external” load is characterized by a direct connection directed from the controlling object (teacher) to the controlled object (student). This connection is visible and is determined by such load parameters as: the content of the exercises, duration of their execution, intensity, number of repetitions in a series, number of series, duration and type of rest intervals between exercises and series [7, 13].

It follows that the most developed and studied characteristics of the training load in child and youth sports include specialization, direction, and magnitude [12]. As for a load characteristic such as coordination complexity, despite its high scientific value and practical importance, this topic is still understudied. In addition, experts [14, 15] note that the importance of this factor for the mastery of technical and tactical techniques of volleyball by young athletes is very high and therefore it is not possible to classify the training loads taking into account, for example, the complexity of the coordination of the exercises can result in misjudgements in planning, since the influence of the coordination complexity significantly influences the extent of training effects.

Thus, a contradictory situation has developed between the need to classify training exercises according to the degree of coordination complexity of young female volleyball players and to determine their connection in the aspect of age, on the one hand, and the insufficient scientific development of methodological support for solving this pedagogical task, on the other hand. This determines the practical and scientific relevance of the study problem.

Hypothesis: We hypothesize that the establishment of methods for categorizing training modalities based on their levels of coordination complexity, coupled with the determination of optimal volumes for these modalities, will enable the fine-tuning of the educational and training processes for young female volleyball players aged 13-14 years. This, in turn, is anticipated to yield a measurable enhancement in specialized fitness indicators and substantial strides in the efficacy of their gameplay.

Study Purpose: The objective of this study is to ascertain the criteria for evaluation, the extent, and the impact of incorporating exercises of elevated coordination complexity on the specific athletic readiness indicators of young female volleyball players aged 13–14 years.

Material and methods

Participants

Female volleyball players aged 13–14 years participated in the experiment (n=24, training experience – 4 years). Female volleyball players were divided into a control group (n=12) and an experimental group (n=12). The groups formed were identical in terms of coordination readiness, physical qualities and technical and tactical skills. Prior to the study, both children and their parents were thoroughly informed about the research procedures, and parental consent was obtained for participation. The inclusion criteria for players were being at a stage of specialized basic training with no musculoskeletal or psychophysical disorder. A professional volleyball coach supervised and

regulated young athletes' training programs.

Research Design

Pedagogical experiment lasted 8 months. Well-known motor tests were used to determine the level of coordination readiness of female volleyball players [16, 17, 18]. The tests were carried out at the beginning and at the end of the experiment. As part of the study, the level of kinesthetic differentiation, spatial orientation, reaction, restructuring and coordination of movements and balance skills was determined:

Test 1. Throwing a ball directed at a target standing with one's back to it (number of times);

Test 2. Ten eight figures (s);

Test 3. Stepping over a gymnastics stick (s);

Test 4. Running to the numbered balls (s);

Test 5. Time difference between running to the numbered balls and shuttle running (5x3 m), s;

Test 6. Static equilibrium evaluation by Bondarevsky's method (s);

Test 7. Turns on the gym bench (dynamic equilibrium), number of turns;

Test 8. Shuttle run with back forward (3x10 m) (s);

Test 9. Difference in time between running "Shuttle run (3x10 m)" and "Shuttle run with back forward (3x10 m)" (s);

Test 10. Measurement of the complex motor reaction (sm).

To determine the level of technical and tactical readiness of female volleyball players, the following tests were used [19]:

Test 11. Overhead Passing to Wall (fig. 1);

Test 12. Serving Accuracy (fig. 2);

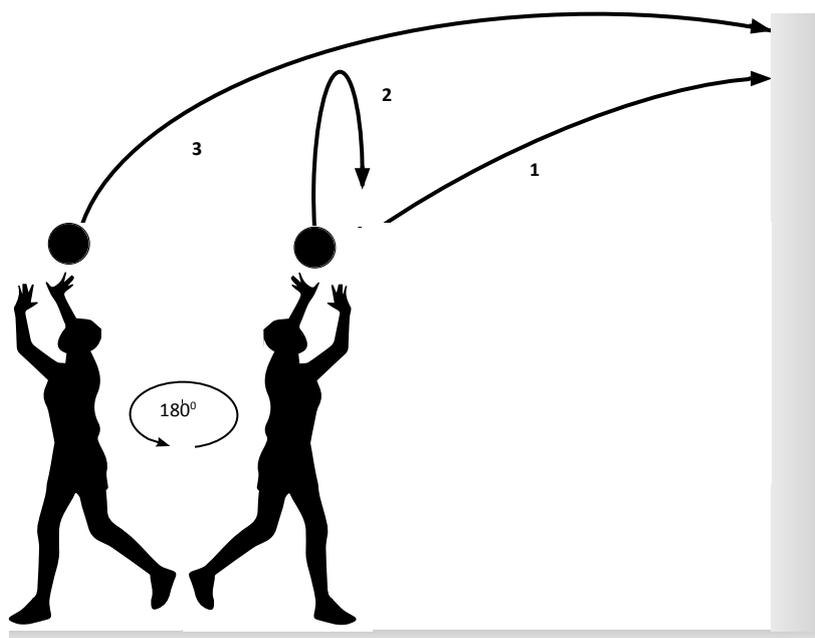


Figure 1. Scheme of the test "Overhead Passing to Wall"

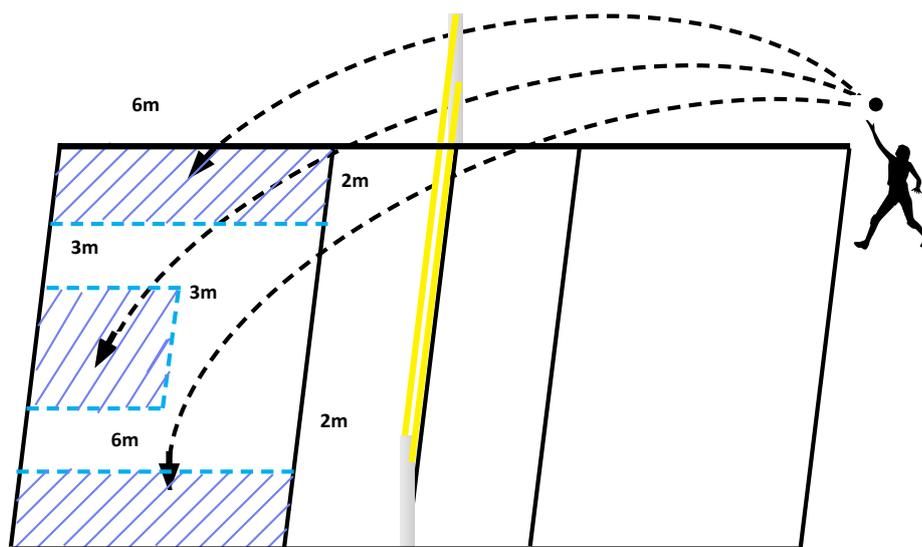


Figure 2. Scheme of the test "Serving Accuracy"

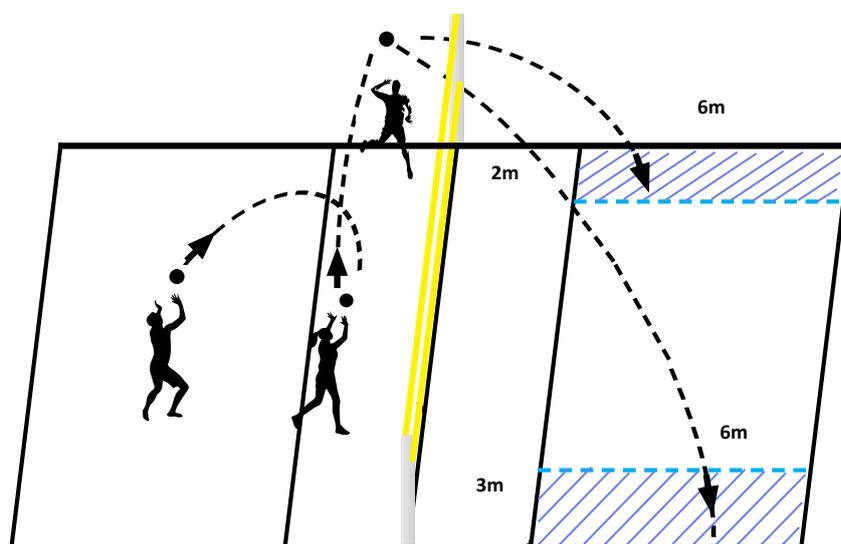


Figure 3. Scheme of the test "Accuracy of Spike"

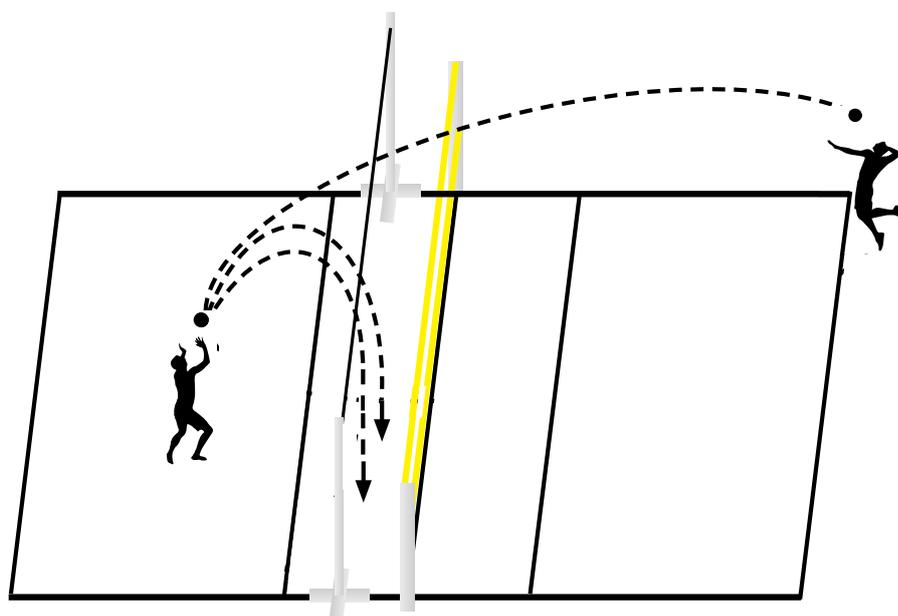


Figure 4. Scheme of the test "Serve Reception"

Test 13. Accuracy of Spike (fig. 3);

Test 14. Serve Reception (fig. 4).

The control and experimental groups trained five times a week for two hours. Lesson content and training loads were similar in both groups. The only exception was the method of using coordination exercises. The focus was on the targeted development of seven coordinative abilities in combination with elements of volleyball technique. Roughly the same amount of time was spent on training the individual coordinative skills. At one training session, specific coordination exercises lasting 8-12 minutes were performed, with no more than 2-3 types of coordination skills being improved. According to methodological recommendations [20], the approximate distribution of time for general and special coordination training to other types of training was as follows (Table 1).

Table 1. Approximate distribution of training types in the experimental training program [20]

Training type	Partial volumes, %
General coordination	10
Special coordination and technical	45
Conditional	25
Tactical	20

When developing the experimental program, there was a need to objectify the criteria for controlling the coordinative complexity of exercises used in the training process of young female volleyball players. The main study method was the analysis of training plans. In particular, the study materials were obtained based on the analysis of the yearly training cycle of young female volleyball players aged 13-14 years. The first step was to establish the observation scheme. Based on the recommendations of researchers [21, 22], the coordination exercises were divided into five groups and their complexity was rated from 1 to 5 (Table 2). In developing this rating scale, criteria such as accuracy, speed, punctuality, and economy that a volleyball player should demonstrate when performing appropriate motor actions were

taken into account. We also took into account the conditions under which these motor actions were performed, the number of players participating in the exercise, their skill level, performing exercises due to lack of time, in an uncomfortable direction, in a mirror image, with a non-conducting limb, in a state of fatigue etc.

When implementing the experimental program, the approximate proportions of exercises of different coordination complexity in the training process of athletes of all ages involved in sports games were taken into account (Table 3).

Table 2. Conditional evaluation of the complexity of coordination exercises

Coordination complexity of exercises	Evaluation of coordination complexity of exercises, points
Low	1
Medium	2
High	3
Submaximal	4
Maximum	5

According to the table we see that when training young athletes, with age it is necessary to reduce the volume of exercises of low and medium coordination complexity by 30-40%, and by 35-45% at the age of 8-12 up to 10-15 and 35 to 45% at the age of 17 to 18 years (if you reach the highest sporting levels). The proportion of exercises with high, submaximal and maximum coordinative complexity should be considered from 10-20% and 0-5% (8-12 years) to 30-40% and 10-15% (17-18 years).

A gradual increase in the volume of exercises of increased coordination complexity in the training process is of no small importance. In particular, an exercise only has a positive effect on improving the ability to control and regulate motor actions if it causes the player some coordination difficulties [13, 23]. An increase in the coordination complexity of the exercises was achieved through the following methodical techniques.

1. Introduction to the performance of motor actions that are complex in terms of coordination

Table 3. Approximate ratio of exercises of different coordination complexity when training athletes of all ages in team sports, % [20]

Age, years	Exercises of low coordination complexity (1 point)	Exercises of medium coordination complexity (2 points)	Exercises of high coordination complexity (3 points)	Exercises of submaximal and maximum coordination complexity (4-5 points)
8-12	30-40	35-45	10-20	0-5
13-14	20-30	45-55	15-25	0-5
15-16	15-20	40-50	25-35	5-10
17-18	10-15	35-45	30-40	10-15

- (e.g. performing an attack hit after performing defensive actions);
2. Increasing the requirements for the accuracy of performing motor actions, subsequently for accuracy and speed, and finally for accuracy, speed, stability and resourcefulness in performing motor actions in changing conditions;
 3. Limiting the time for performing motor tasks (e.g. trying to perform as many attack hits as possible in a given period of time);
 4. Changing the way of performing motor actions and individual movement parameters:
 - Performing technical elements with a non-conductive hand or in an uncomfortable direction;
 - Changing the direction and pace of movement;
 - Changing the magnitude of the force components (e.g. passing the ball to different distances);
 - Changing the starting and ending positions during the exercise (e.g. performing a reception after the movement);
 - Execution of controlled motor actions in various combinations (alternate execution of several elements that are complex in terms of coordination);
 - Change in technique when performing the same motor action (e.g. the way of receiving the ball after the serve);
 5. Changing conditions and situations when performing motor actions:
 - Introduction of active opposition on the part of the defenders;
 - Use of different forms of play – tasks (e.g. playing one or two touches of the ball);
 - Changing the spatial parameters, reducing the field of action (e.g. playing on a reduced area);
 - Limiting the action of individual motion analyzers (receptors) that provide the player with relevant information (e.g. limiting visual control, playing with a darkened net);
 - Performing actions on accuracy, accuracy and speed under psychological stress, for example, rivalry in the serve execution);
 - Carrying out coordination tasks during exercises to develop certain physical qualities (strength, speed, speed and endurance) or carrying out these exercises against the background of physical fatigue;
 - Complication of tasks with additional movements (for example, taking protective measures after a roll);
 - Performing technical elements with balls of different sizes and masses (e.g. passing or hitting a ball that is smaller and lighter in size than usual);
 - Execution of motor actions after “stimulation” of the vestibular analyzer (e.g. passing the ball after quick rollovers, turns, etc.);
 - Conducting exercises on an atypical surface (e.g. performing technical and tactical actions, on sand, an unstable surface, etc.) [17, 24, 25].

Statistical analysis

Statistical data processing was carried out using Microsoft Excel and SPSS programs. The following parameters were determined for each indicator: arithmetic mean (X), standard deviation (S), standard error (m), confidence interval (Δx), significance of differences according to Student's t-test with the corresponding significance level (p). Differences were considered significant at a significance level of $p < 0.05$ [26].

Results

Before the start of the pedagogical experiment, there were no statistically significant differences between the indicators studied in the experimental and control groups. It was shown that the variant of coordination training used in female volleyball players in the experimental group contributed to a higher rate of increase in the level of development of most coordination skills compared to the control group. A significant improvement ($p < 0.05$) in the experimental group was shown for all indicators that characterized the level of coordination readiness of young female volleyball players (Table 4). At the same time, as in the control group, there was a significant improvement in results in only 3 out of 10 cases ($p < 0.05$) (Table 5).

The improvement in kinesthetic differentiation ability occurred by 11.9% in the experimental group and by 14.3% in the control group. Indicators of the ability to coordinate movements improved by 6.5–8.5% ($p < 0.05$ – 0.001) in the experimental group and by 1.2–2.4% ($p > 0.05$).

The comparison of indicators characterizing the subjects' spatial orientation ability showed that the representatives of the experimental group were significantly ($p < 0.05$) ahead of their peers from the control group. It should also be added that one of the indicators of this ability recorded a significant increase in the representatives of the control group, which, in our opinion, indicates the presence of an effective training process in this team. Thus, the indicators of running to the numbered balls and the difference between the 5x3 m shuttle run and the pre-test in the experimental group improved by 6–33%, while in the control group these indicators increased by 4.3–8.3 %, respectively. The indicator characterizing the trainees' static balance ability in the experimental group improved by 83% ($p < 0.05$), while the increase in the control group was 38%

Table 4. Changes in indicators of coordination readiness among female volleyball players of the experimental group (n=12)

No	Indicator	Before experiment		After experiment		Δx	t	p
		\bar{X}	s	\bar{X}	s			
1	Throwing a ball directed at a target, (number of times)	12.22	3.03	13.67	3.16	1.98	3.51	0.008
2	Ten eight figures, s	10.19	0.80	9.39	0.70	0.53	5.23	0.001
3	Stepping over a gymnastics stick, s	11.49	1.56	10.79	1.08	1.02	2.63	0.030
4	Running to the numbered balls, s	13.20	1,06	12.35	0.74	0.70	4,18	0.003
5	Time difference between running to the numbered balls and shuttle running (5x3 m), s	2.94	0.33	2.21	0.37	0.21	5,40	0.001
6	Static equilibrium evaluation, s	16.42	8.6	30.2	15,3	5.65	4.33	0.003
7	Turns on the gym bench, number of turns	6.32	0.87	7.22	0.46	0.51	4.08	0.004
8	Shuttle run with back forward (3x10 m)	11.91	0.46	11.7	0.44	0.30	1.66	0.002
9	Difference in time between running "Shuttle run (3x10 m)" and "Shuttle run with back forward (3x10 m)"	3.44	0.34	3.22	0.39	0.22	2.63	0.030
10	Complex motor reaction, cm	106.2	3.99	101.7	4.27	2.6	4.16	0.003

Table 5. Changes in indicators of coordination readiness among female volleyball players of the control group (n = 12)

No	Indicator	Before experiment		After experiment		Δx	t	p
		\bar{X}	s	\bar{X}	s			
1	Throwing a ball directed at a target, (number of times)	9.8	3.07	11.2	3.4	2.74	1.70	0.128
2	Ten eight figures, s	11.22	0.98	10.96	1.04	0.64	2.00	0.081
3	Stepping over a gymnastics stick, s	14.4	1.93	14.23	1.96	1.26	1.84	0.102
4	Running to the numbered balls, s	14.55	1	13.95	0.92	0.65	3.07	0.015
5	Time difference between running to the numbered balls and shuttle running (5x3 m), s	2.63	0.35	2,44	0.40	0.76	1.69	0.130
6	Static equilibrium evaluation, s	14.9	8,95	20.5	11.55	5.85	2.19	0.060
7	Turns on the gym bench, number of turns	5.77	1.39	6	1.58	0.91	0.595	0.569
8	Shuttle run with back forward (3x10 m)	12.49	1.05	11.76	0.66	0.69	3.54	0.008
9	Difference in time between running "Shuttle run (3x10 m)" and "Shuttle run with back forward (3x10 m)"	2.98	0.64	2.69	0.45	0.42	2.44	0.041
10	Complex motor reaction, cm	106.8	5.04	103.4	5.05	2.29	4.04	0.004

($p > 0.05$). Somewhat similar results were obtained in the analysis of dynamic balance ability. In particular, an improvement of 14% ($p < 0.05$) was observed among the representatives of the experimental group, while the control result improved by 4% ($p > 0.05$).

When analyzing the changes in the indicators characterizing the ability of volleyball players to reorganize motor activity and complex reactions, significant improvement ($p < 0.05$) was revealed in both groups. In the experimental group, these indicators improved by 2.6–6.8%, and in the control

Table 6. Changes in indicators of technical readiness among female volleyball players in the experimental group (n = 12)

No	Test	Before experiment		After experiment		Δx	t	p
		\bar{X}	s	\bar{X}	s			
1	Serve	3	0.60	4.1	0.70	0.46	5.5	0.001
2	Attack hit	3.2	0.66	4.1	0.60	0.44	4.4	0.002
3	Serve Reception	2.67	0.70	3.78	0.67	0.46	5.5	0.001
4	Passing	9.55	5.1	15.22	7.2	3.35	3.1	0.014

Table 7. Changes in indicators of technical readiness among female volleyball players of the control group (n = 12)

No	Test	Before experiment		After experiment		Δx	t	p
		\bar{X}	s	\bar{X}	s			
1	Serve	3.11	1.05	3,78	0.66	0.69	2.31	0.050
2	Attack hit	3.33	1.22	4	1	0.80	2.82	0.022
3	Serve Reception	3.33	0.88	3.88	1	0.57	2.29	0.051
4	Passing	9.11	3.17	9.89	2.67	2.07	1.50	0.174

group by 6.2–10.7% respectively. The complex reaction indicator, in turn, improved by 4.4% in the experimental group, while this indicator improved by 3.3% in the control group.

The analysis of the results showed that the optimal use of exercises with increased coordination complexity resulted in an improvement in technical training in both groups. On four indicators of technical readiness (reception, attack hit, serving, passing), female volleyball players in the experimental group improved their scores significantly ($p < 0.05 - 0.001$) (Table 6).

In female volleyball players of the control group, significant changes in this type of readiness were less noticeable. Significant improvement ($p < 0.05$) was found in three parameters. There was no statistically significant improvement in the results of the test “Overhead Passing to Wall” among female volleyball players in the control group ($p > 0.05$) (Table 7).

Discussion

It is known that training and competition loads are the basis of sports training. The question of determining the size of the training load, taking into account the age and individual characteristics of young athletes, is one of the main issues in the modern system of long-term sports training. When developing this problem, the characteristics of the physical development of those involved should first be considered – age patterns, gender differences and individual characteristics [27, 28, 29].

Various studies [4, 30, 31] indicate that controlling the specialization of training loads is important as it is associated with an assessment of the quality of training work. Usually, a coach’s work is considered decent when his students perform large amounts

of loading with high results. However, such an assessment is biased until the ratio of specific work to non-specific work is determined. In fact, it is quite common, especially in sports games, for training exercises to be externally based on a game exercise in terms of their technical and tactical orientation and therefore apparently to be classified as specialized. However, determining the heart rate or any other physiological criterion shows that there is no connection between the intensity of the game and the intensity of these exercises. It is only possible to really specialize these exercises if the conditions for their implementation (movement speed of the players, active resistance of the opponent, etc.) are as close to the game ones as possible [32, 33].

Our study, in turn, confirmed the expediency of maintaining a rational ratio of general and special means of training young athletes in the process of age development. A similar opinion is held by other researchers [34, 35, 36], who point to the avoidance of significant amounts of specialized training loads at primary and secondary school age. After all, in their opinion, this will certainly result in an acceleration of training and a violation of the natural process of forming athleticism in the system of long-term improvement. The main tasks of the educational and training process at this age are the multifaceted development of the body’s motor skills, strengthening the health of those involved, eliminating deficits in their physical development and physical fitness, and creating motor potential that will help them to acquire diverse motor skills (including those that correspond to the specifics of the future sport specialization). In her opinion, special attention should be paid to the formation of a lasting interest in sports among students. Versatile training in this phase with a

few special exercises is more beneficial for further improvement than special training. Sports activities at these ages are characterized by an abundance of means and methods, the widespread use of material from various sports and outdoor games, and the introduction of a game method.

The results of the pedagogical experiment indicate the need to use a variety of general coordination exercises in the training process of young female volleyball players in the initial and preliminary training phase. This allows young athletes to create a broad coordinative basis, a pool of different movements in muscle memory. In addition, if this fund is accumulated for thousands of exercises, which are manifested in cyclic and acyclic locomotion, gymnastic and acrobatic exercises, throwing with an emphasis on range and accuracy, outdoor games, sports and game actions, when using training tools in a targeted manner at the improving the ability to link motor actions and to transform the forms of movement developed or to switch from one requirement to another according to changed conditions, exercises are also used systematically to develop general perceptions of movement in the form of a sense of space, time, dosing of muscular effort, sensorimotor reactions, development of speech and thought processes, motor memory and movement representation, then this is excellent material for the further successful technical and tactical improvement of those involved, even at the stage of subject-specific basic training. In this regard, Platonov [12] and Bompa [37] note that in the process of assimilation of technical material, in no case should one try to stabilize the technique of movement in order to achieve stable motor ability, which will allow one to practice certain sports exercise results. During this time, young athletes develop a versatile technical basis that enables them to master a wide variety of motor actions. This approach is the basis for further technical improvements. It is noteworthy that these experts stubbornly emphasize that the game method is best justified when working with primary and secondary school-age students in the context of their sporting activities, as it creates a positive emotional background in the classroom. Furthermore, after analyzing the biographies of leading athletes, these researchers concluded that the game orientation of initial training was mostly associated with a low overall workload. At the initial stage, they worked less intensively than their peers, who did not achieve high results in the future.

After the pedagogical experiment, the assumption about the possibility of developing coordination skills in combination with improving speed, speed and strength, strength, endurance and flexibility was confirmed. In particular, special physical training methods were used, which not only resemble the structure of the main motor skills, but also fully

correspond to the performance regime in the main movement phases. In order to improve special motor and technical readiness and increase the coordination skills of those involved, the possibility of using loads as a means of additional mobilization of analyzers was confirmed. Movements with weights, performed as part of a specific technique, contributed to an effective improvement in the coordination structure of motor action and the efforts that strengthen it. In this regard, Zatsiorsky [1] points out that when intensifying the work of muscles, movements with weights contribute to the development of intermuscular coordination, which is necessary for the rational organization of dynamic accents of the coordination structure of motor action. Weights contribute to additional excitement of the nerve centers and an increase in the number of motor units involved in muscular work. The optimal weighting of the movement reduces the variability in the structure of muscle work, bringing it closer to the most rational model. The weight of the weights should be such that some heaviness is felt during the exercise, but the structure of the movement is not distorted. In addition, Sadowski [38] states that the combined method is a variation of the holistic method. Its essence lies in the fact that the mastery of certain motor actions and their improvement occurs with significant muscular effort and a high level of coordinative complexity. With such motor actions, the athlete shows his/her maximum motor qualities, that means at the same time there is a kind of combined improvement in both movement technique and motor qualities. In particular, the researcher argues that this method should be used in the process of improving trained motor actions in order to improve the quality of their performance. When applying this approach, it is important that the technique of the movements under study does not deteriorate and their integral structure is not violated. This is one of the most effective ways to improve movement technique against the background of developing the motor qualities that are leading for these exercises.

After the pedagogical experiment, the assumption about the positive effect of special coordination exercises on the growth of technical readiness indicators was confirmed. The main aim is to use the trained techniques in a targeted manner in coordinatively more complex conditions that put forward increased requirements for such coordinative abilities of young players, such as the ability to adapt and restructure motor actions, kinaesthetic differentiation of movement parameters, a sense of rhythm, ability and balance. Similar results have previously been obtained by other researchers [39, 40, 41] working with young athletes. The authors came to similar conclusions and recommended extensive use of the combined influence method in the training process of young athletes in order

to simultaneously improve coordination, technical and tactical abilities and skills. In fact, as the researchers note, in practice there are cases where a young player possesses motor action technique under standard conditions, but is unable to use it optimally in changing situations. The qualitative education and improvement of the special readiness of young volleyball players largely depends on the rational use of forms, means and methods of sports training, which allow to simultaneously develop motor qualities and improve motor skills. Lyakh et al.[17] consider this fact as a result of a positive interference (transfer) of one more integral factor (abilities) to another less integral factor (game technique).

Coordination complexity is one of the most important characteristics of training load. The influence of this factor is particularly important in sports games and volleyball in particular. Accordingly, in order to avoid planning errors, trainers should not only control the scope, intensity and specialization of the load, but also take into account the coordinative complexity of the training means used. The conducted study resulted in the conclusion that the targeted use of exercises with a gradual increase in their coordination complexity can significantly improve the development level of various coordination abilities of young female volleyball players aged 13-14 years. Our data are fully consistent with the studies of other authors who have studied movement coordination in young athletes [22, 42, 43, 44, 45]. The researchers showed that the use of general and specific exercises with increased coordination complexity in training sessions with athletes of all ages and qualifications achieves a high training effect. The inclusion of such exercises in the training process in combination with a rational method of their application can significantly increase the level of development of motor coordination, indicators of technical and tactical mastery, as well as conditional qualities (speed, explosive strength and endurance) of volleyball athletes.

Thus, the results of the study show that it makes sense to use the optimal amount of exercises with increased coordination complexity in the training process of young female volleyball players aged 13-

14 years. The optimal combination of developing coordination abilities and improving the elements of volleyball playing technique will help improve the game activity of players. In addition, further study is needed to develop criteria for assessing the coordinative complexity of exercises used in the training process of young volleyball players of all ages. It seems that it is time to pay more attention to the experimental substantiation of different variants of coordination training in volleyball.

Conclusions

By dividing the coordination training of young volleyball players into a separate training section, the tasks of this activity could be formulated. The range of specific and non-specific means for players of all ages was shown, and the optimal duration of this process was examined on a separate session. The need for an optimal combination of exercise to improve coordination abilities with other indicators of motor function was demonstrated, and the most important types of motor coordination for a successful volleyball game activity were identified.

Coordination complexity is one of the main characteristics of the training load. The targeted use of exercises with a gradual increase in coordination complexity can significantly improve the development of various coordination abilities in young female volleyball players aged 13 to 14. Taking this factor into account when choosing training means makes it possible to master motor actions much faster and more rationally, to master new ones at the highest level and quickly rebuild old training programs, to rise faster to sports excellence and to stay in sports longer.

Further study shall be conducted to improve criteria for assessing exercise coordination complexity and to test the effectiveness of different variants of coordination training for volleyball players at all stages of long-term sports improvement.

Conflict of interests

The authors declare that there is no conflict of interests.

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Cite this article as:

Boichuk R, Iermakov S, Nosko M, Nosko Y, Vaskan I, Korop M, Kurtova H, Grashchenkova Z. Use of exercises with increased coordination complexity in the training process of young female volleyball players aged 13-14 years. *Pedagogy of Physical Culture and Sports*, 2023;27(4):340–352.
<https://doi.org/10.15561/26649837.2023.0410>

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Received: 28.06.2023

Accepted: 19.08.2023; Published: 30.08.2023

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Information Sponsors, Partners, Sponsorship:

- Ukrainian Academy of Sciences.
- SCIENTIFIC EDITION (journal)
Pedagogy of Physical Culture and Sports, 2023;27(4)

designer: Iermakov S.S.
editing: Yermakova T.
designer cover: Bogoslavets A.
administrator of sites: Iermakov S.S.

passed for printing 30.08.2023
Format A4.
Certificate DK №7472 07.10.2021.
P. O. Box 11135, Kharkiv, 61068, Ukraine