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ORIGINAL SCIENTIFIC ARTICLE

IMPROVEMENT OF THE STRUCTURE AND CONTENT OF AN ANNUAL TRAINING MACROCYCLE FOR YOUNG PANKRATION ATHLETES

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

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Abstract

The study objective is to improve the structure and content of the annual training macrocycle for athletes aged from 15 to 16 years old in pankration, taking into account the specifics of their competitive performance.

Materials and methods. Theoretical analysis and generalization were used during work with literary sources on the problems of the research. Survey (questionnaire) was used for studying general approaches to the structure and content of young athletes' training (aged from 15 to 16 years old) in pankration. There were also analyzed official programs for experienced pankration athletes which are used in Ukraine. Pedagogical experiment was held during September 2018 – July 2019. Its total duration was 10 months and 906 hours. Two identical six-month training macrocycles were performed. The control (21 athletes) and experimental (22 athletes) groups were formed.

Results. It was more effective for the development of technical and tactical actions and special physical fitness of young athletes aged from 15 to 16 years old. It was confirmed by significant intra-group increases in indicators of athletes' preparedness ($p \leq 0.05$-0.01). The total number of significant changes in the experimental group ($p \leq 0.05$–0.01) during the first and second stages of the experiment was 12 of 13 indicators, and their values were higher than in the control group. In the control group, significant positive changes ($p \leq 0.05$-0.01) were found in 6 indicators during the first stage of the experiment and 8 – during the second one. After the second stage of the experiment athletes of the experimental group performed about half of the technical and tactical actions with a higher level of stability, economy, efficiency in various situations during sparring matches.

Conclusions. An experimental program made it possible to achieve an earlier deployment of adaptation processes to the specific physical activity available in training and competitive activities in pankration.

Keywords: pankration, macrocycle, experimental program, training, athletes.

Introduction

Problem statement. Mixed martial arts become more and more popular all over the world. The basis of technique in mixed martial arts is a combination of elements taken from different kinds of classical wrestling (Greco-Roman and freestyle wrestling, judo, jujutsu, etc.) and traditional combat sports (boxing, kickboxing, taekwondo karate, etc.) (Del Vecchio, Hirata, & Franchini, 2011; Tota, Drwal, Maciejczyk, Szyguła, Pilch, Pałka, & Lech, 2014; Marchenko & Bezpalko, 2020). Instead of Olympic combat sports, scientific information concerning mixed martial arts at the national level is significantly limited (Marinho, Follmer, Del Conti Esteves, & Andreato, 2016; Skrypka, & Cherednichenko, 2018; Nakonechny, 2020).

Analysis of recent research and publications. Inmodern scientific works, the issues of pankration have been studied fragmentally. At the same time, some scientists emphasize the importance of composition the proper training process (Del Vecchio, Hirata, & Franchini, 2011; Menescardi, & Estevan, 2017; Sogor & Pityn, 2018). According to them, anadequate training process should include the improvement of special physical qualities, technical elements (professional

and applied aspects such as punches, kicks and wrestling elements) (Bridge, Ferreira da Silva Santos, Chaabène, Pieter, & Franchini, 2014; Marchenko & Satdyiev, 2021), development of moral qualities and psychological states (Garanin & Kuznetsov, 2015; Radchenko, 2015; Biletsky & Ponomarev, 2017). In general, the authors point out that achieving a high level of athlete's performance in pankration is impossible without self-regulation, internal self-discipline, balance, restraint.

It is mentioned that the first step to high achievements in pankration is the development of physical skills in combination with psychological qualities. Such an approach allows demonstrating the best results in the competitions of different level (Wojciech, Jong-Hoon, & Przemysław, 2017; Meyer, 2018; Prystupa, Okopnyy, Hutsul, Khimenes, Kotelnyk, Hryb, & Pityn, 2019). The basis of training for adult pankration athletes was discussed in works by (López-López, Menescardi, Estevan, Falcó, & Hernández-Mendo, 2015; Menescardi, Lopez-Lopez, Falco, Hernandez-Mendo, & Estevan, 2015). The main accent was made on studying combinations which consisted of punches (hand strikes) and wrestling elements. López-López, Menescardi, Estevan, Falcó, and Hernández-Mendo (2015) and Menescardi, Lopez-Lopez, Falco, Hernandez-Mendo, and Estevan (2015) emphasizes that in mixed combat sports fighters usually develop their skills by performing classic sports (boxing, kickboxing or wrestling) and then try to adapt them to the rules of particular mixed combat sports (Zadorozhna, Briskin, Pityn, Smyrnovskyy, Semeryak, Khomiak & Hlukhov, 2020). In our opinion, this approach to the athletes' long-term development is not scientifically and methodologically justified (Sasanfar, Pourkiani, & Sasanfar, 2011; Meyer, 2018) and doesn't take into account peculiarities of particular kinds of mixed sports.

At the same time, recent changes in pankration rules (Arvanitis, 2019; Georgiou, 2005) are aimed at distinguishing technical and tactical actions in the competitive activities of different disciplines (grappling, full and traditional), which affects the specialization of the athletes' long-term training process.

In pankration the specifics of training process for athletes aged from 15 to 16 years old should be seen in the need to redistribute the training load between general and special, training, widespread use of exercises in related sports with a transition to a narrower specification of the structure and content of training, taking into account the requirements of modern competition rules (Arvanitis, 2019). That is why, our research is actual.

The article's goal deals to improve the structure and content of the annual training macrocycle for athletes aged from 15 to 16 years old in pankration, taking into account the specifics of their competitive performance.

Materials and methods

Study participants

Our research included few stages. Theoretical analysis and generalization were used during work with literary sources on the problems of research. Survey (questionnaire) was used for studying general approaches to the structure and content of young athletes' training (aged from 15 to 16 years old) in pankration. There were also analyzed official programs for experienced pankration athletes which are used in Ukraine (Pankration, 2010).

The next step of the research was pedagogical observation. There was compared competitive activity of two groups of sportsmen – 15-16 years old and elite fighters (middle weight categories, adult athletes). The observation aimed to determine the difference between competition performances of athletes with different experience. There were made several conclusions on the content and structure of competition performance and expediency of studying different technical elements by athletes aged 15-16 years old depending on their effectiveness for adult fighters and at higher level competitions.

The analysis of athletes' performance atthe age of 15-16 years was conducted at Ukrainian National Championship and official Ukrainian tournaments in Sumy, Chernivtsi, Lviv in 2017. There were analyzed 25 fights of athletes in medium weight categories, beginning from the stage of ¼ final. As for adult athletes (middle weight categories), we analyzed 25 fights of the World Pankration Championship, which took place from 09/29/2016 to 10/02/2016 in Georgia. The detailed analysis and comparison of these results are represented in previous papers (Sogor & Pityn, 2018).

The next step was a survey. We recruited 16 coaches (their average age was 31,31±4,76 years old, an average experience in pankration training – 7,63±3,95 years). The questionnaire included different types of questions concerning the structure and content of training process for young pankration athletes. It was found that at the age of 15-16 years old athletes should attend 6 training sessions per week (46.67% of coaches confirmed this fact). 75.0 % of coaches indicated that training session should last during 120 minutes. 93.75% of coaches are assured that athletes should use exercises from related sports which are basis of technique in pankration. Sparring as a training method should be used once per week (62.50% of coaches). 56.25% indicated the need for parallel training and improvement of punch elements (hand strikes) and wrestling actions. Another 31.25% of respondents focus only on wrestling and one respondent indicated the priority of improving punch technique.

Study organization

This information was the basis of the experimental program. Pedagogical experiment was held during September 2018 – July 2019. Its total duration was 10 months and 906 hours. Two identical six-month training macrocycles were performed. The control (21 athletes) and experimental (22 athletes) groups were formed. We used three identical testing sessions at the beginning of the first macrocycle (before experiment), between training macrocycles (in the middle of experiment) and at the end of the annual training (after experiment).

We redistributed the load and offered 160 hours for selective training of technical elements. Selective improvement of tactical training was carried out within 70 hours. This formed a reserve of 110 hours, which we proposed to allocate for the use of combined technical and tactical training.

We have proposed a similar approach for athletes' physical training. General physical training lasted during 50 hours, special physical training – during 70 hours, and

for the means of combined action with technical and tactical training – 40 hours.

The next difference between the traditional and author's programs in pankration was reduction of hours used for control standards for technical training and tests for general and special physical fitness (by 20 and 30 hours respectively) (Kostikiadis, Methenitis, Tsoukos, Veligekas, Terzis, & Gregory, 2018). We also reduced the number of classes using swimming exercises, track-and-field, sports games etc., but added classes involving the exercises of more related to pankration sports (boxing, wrestling, kickboxing, etc.) (Marinho, Del Vecchio, & Franchini, 2012; Khudolii, Ivashchenko, Iermakov, Veremeenko, & Lopatiev, 2019; Prystupa, Okopnyy, Hutsul, Khimenes, Kotelnyk, Hryb, & Pityn, 2019).

In addition, we used the same amount of hours (140 hours) for sparring matches, but the main accent was made on the planned fights, when an athlete has special tactical and technical scheme for every sparring depending on the opponent (in traditional program the main accent is made on free fighting and control bouts).

To compare the results in the control and experimental groups before, in the middle and after experiment we used different types of tests: for general physical fitness, special physical fitness, psychophysiological reactions, technical and tactical skills.

Special physical fitness was estimated in such exercises:

- rope-climbing (5-meter rope) at standing position without the help of legs was used to determine speed and strength endurance;
- burpee test (number of repetitions during 30 seconds) was conducted to determine speed and strength endurance. The athlete performed as quickly as possible consistently squatting – lying down – squatting – starting position;
- squats with a 20 kg disk (number of repetitions during 60 seconds) were used to determine special endurance of the muscles of the upper and lower extremities;
- rotation with a 20 kg disk (number of repetitions during 60 seconds) – to determine the special endurance of the muscles of the arms and torso;
- imitation of passages in the legs with pulling partner with shock-absorbing rubber (number of repetitions during 60 seconds);
- the pull of the damping rubber (number of repetitions during 60 seconds) was used to determine the speed and strength endurance of the torso muscles. The athlete stands at a certain distance from the fixed shock-absorbing rubber so as to obtain individually optimal tension and performs twisting of the torso (alternately to the right and left) at the maximum speed for himself for 1 minute.

To estimate technical and tactical skills we used such tests:

- "Drill №1" – a complex of subsequent technical and tactical actions with a limit of performance by 10 times. The complex includes such pain techniques at a fast pace: "armbar" (bottom of the guard), "triangle" (bottom of the guard), "kimura" (bottom of the guard), passage of the guard, pain element on the leg (to Achilles Tendon from standing position). Time for series of identical receptions and the general time of continuous performance was registered;
- "Drill №2" ("dead zone") – a complex of technical and tactical actions with a time limit of 180 seconds (number of repetitions). The subsequence of actions was the same, but the partner could use painful or suffocating techniques with possible resistance;
- "Work on a bag" – series of exercises to determine the quantitative indicators of technical and tactical skills. Athletes carried out serial work to perform maximum speed strikes for 30 seconds. There were performed such strikes: 1 – work with hands ("jab", back straight, side punches, etc.); 2 – footwork ("low kick", "high kick", "middle kick", direct kick, etc.); 3 – combined work with hands and feet using the same punches;
- "Sparring duel with the task (free fight)". It was proposed to perform consecutive sparring matches with several opponents lasting 3-5 minutes. The quality of technical and tactical actions was evaluated in conditions close to competition. The evaluation was conducted by three experts (coaches, adult qualified athletes) on external grounds (kinematic and dynamic characteristics of movements and their correctness). Grades were divided into "unsatisfactory" (gross errors, or action is not performed at the proper level), "satisfactory" (action is mostly consistent with the basic technique), "good" (action has minor errors, but may give preference to the athlete in a competitive match).

The study of psychophysiological indicators included: choice reaction time (a method of determining the reaction time to signals with the condition of analysis of their color and choice); distinction reactions as a kind of complex sensorimotor reaction, which involved clarifying it to one specific stimulus from several different stimuli; reactions on a moving object aimed at measuring the degree of balance of excitation and inhibition; tapping test as an express method of diagnosing the strength of nervous processes by measuring the dynamics of the pace of hand movements.

Statistical analysis

Statistical processing of the data was carried out on a computer using the standard STATISTICA 7.0 programs.

Results

To obtain objective information on the dynamics of indicators during the experiment, we used several blocks of test exercises (Tables 1-3).

As shown in Table 1, the indicators of hand-held dynamometry (wrist strength measurement of stronger hand) there are slight increases in the results during the research. Only some of them acquire reliable values ($p \leq 0.05$). For representatives of the experimental group at the first stage of the experiment, the changes were only 0.50% ($p > 0.05$) and the second – 6.91% ($p \leq 0.01$). For representatives of the control group for the first stage – 1.04% ($p > 0.05$) and for the second – 5.24% ($p \leq 0.01$).

A different situation was observed for the indicators of back extensor muscle dynamometry. Athletes of the experimental group in the first and second stages were able to increase the result by 1.26% ($p \leq 0.01$) and 2.27% ($p \leq 0.01$). Representatives of the control group did not experience significant changes during the first (0.62%) or during the second stage of the pedagogical experiment (0.41%).

In the exercise "a stuffed ball throwing" athletes of the experimental group improved the results by 6.92% ($p \leq 0.01$)

Table 1. General physical fitness of young pankration athletes during the experiment

Test		Indicators of general physical fitness						The difference between groups		
		before experiment		in the middle of experiment		after experiment				
		EG	CG	EG	CG	EG	CG	p*	p**	p***
Hand-held dynamometry (wrist strength measurement)	X	36.6	36.8	36.8	36.4	39.4	38.3	0.90	0.69	0.32
	SD	3.4	2.5	3.4	2.3	3.1	2.8			
Back extensor muscle strength test	X	183.6	186.3	186.0	187.4	190.2	188.2	0.15	0.40	0.24
	SD	5.3	4.2	4.6	4.5	3.7	4.9			
Standing long jump, cm	X	195.6	194.7	200.4	199,0	207.6	201.2	0.67	0.56	0.01
	SD	5.7	5.5	7.1	5,4	7.6	4.7			
A stuffed ball throwing, meters	X	12.7	12.9	13.6	13.3	14.2	13.7	0.68	0.17	≤0.01
	SD	0.9	0.9	0.6	0.6	0.6	0.5			
Running 1000 m, seconds	X	243.3	238.3	232.4	233.9	218.5	228.1	0.11	0.53	≤0.01
	SD	9.5	7.2	6.8	6.5	4.3	6.2			
Running 20 m, seconds	X	4.0	4.0	4.0	4.0	3.9	3.9	0.54	0.71	0.76
	SD	0.1	0.1	0.1	0.1	0.1	0.1			
Push-ups, number of repetitions	X	39.3	39.4	42.7	40.9	44.4	42.6	0.87	≤0.01	0.01
	SD	2.9	2.4	1.2	2.0	1.7	1.7			
Crunches, number of repetitions in 30 seconds	X	20.3	20.9	22.0	21.4	23.1	22.7	0.26	0.19	0.36
	SD	1.4	1.4	1.3	1.2	1.3	1.2			
Hanging on bent arms, seconds	X	22.9	27.7	28.5	30.4	34.0	32.8	≤0.01	0.24	0.38
	SD	4.0	5.5	3.0	5.0	3.8	3.4			
Chin-ups on a horizontal bar, number of repetitions in 30 seconds	X	13.3	13.9	14.7	15.0	16.7	15.7	0.18	0.44	0.11
	SD	1.2	1.2	1.1	1.0	1.7	1.4			
Shuttle run 4×9 meters (seconds)	X	10.0	10.0	9.9	9.9	9.7	9.8	0.40	0.78	0.11
	SD	0.2	0.2	0.1	0.2	0.2	0.2			
Torso tilt sitting, cm	X	4.2	5.1	6.7	5.9	8.0	7.5	0.14	0.12	0.55
	SD	1.5	1.8	1.5	1.2	1.9	2.0			
Twist the ruler behind the back, cm	X	49.0	45.3	45.9	44.3	40.5	40.4	≤0.01	0.10	0.91
	SD	2.8	2.3	1.7	2.9	3.0	2.4			

Legend: CG – control group; EG – experimental group; p* – the difference between experimental and control groups before experiment; p** – the difference between experimental and control groups in the middle experiment; p*** – the difference between experimental and control groups after experiment.

and 4.47% ($p \leq 0.01$) in the first and second stages of the pedagogical experiment. Athletes of the control group were inferior to their colleagues in percentage terms. The results increased by 3.25% and 2.90% (in both cases $p \leq 0.01$).

In the test "Running 20 m" the changes in the experimental group were 1.15–2.14% ($p > 0.05$) and the control 1.06–1.20% ($p > 0.05$). At all stages there were no significant differences, the advantage in results was 0.37-0.67% ($p > 0.05$) in favor of one or another group of athletes.

In the test "Push-ups" we observed significant changes in the experimental group for the first stage by 8.80% ($p \leq 0.01$) and for the second – 3.83% ($p \leq 0.01$). Similar trends were observed in the control group.

Athletes of the experimental group significantly improved their results in the test "Crunches" both on the first (8.74%, $p \leq 0.01$) and on the second (4.74%, $p \leq 0.01$) stages of experiment. Similarly, the representatives of the control group in the first stage improved the results in this exercise by 2.58% ($p > 0.05$) and the second – 5.78% ($p \leq 0.01$).

In the test "Chin-ups on a horizontal bar" at the first stage of the study sportsmen of the experimental group were able to improve their results by 10.58% ($p \leq 0.01$) and in the second – by 13.27 ($p \leq 0.01$). Their colleagues from the control group in the first stage improved the results by 8.58% ($p = 0.02$) and in the second – by 4.43% ($p = 0.17$).

During all stages of testing there were no significant changes ($p > 0.05$) for athletes of both groups in the test "Shuttle run 4×9 meters".

When determining the flexibility of the spine and hip joints and mobility in the shoulder joints during the first stage of the experiment, the athletes of the experimental group improved the result by 59.14% ($p \leq 0.01$), and the control – 18.02% ($p = 0.21$). At the second stage of the experiment, the representatives of both groups were able to significantly increase their results, the experimental group – by 18.24% ($p \leq 0.05$), and the control – 27.42% ($p \leq 0.05$).

When testing the mobility in the shoulder joints, it was found that the representatives of the experimental group significantly improved their results – by 6.40% ($p \leq 0.01$) after the first and 11.60% ($p \leq 0.01$) after the second stage of the experiment. For athletes in the control group, the values of improvement were also high, the first stage – by 2.04 ($p > 0.05$) and the second – 8.81% ($p \leq 0.01$).

The indicators of special physical fitness of young athletes aged from 15 to 16 years old in pankration during the experiment in both groups were the following (Table 2).

Table 2. Special physical fitness of young pankration athletes during the experiment

Test		Indicators of special physical fitness						The difference between groups		
		before experiment		in the middle of experiment		after experiment				
		EG	CG	EG	CG	EG	CG	p*	p**	p***
Rope-climbing, seconds	X	17.1	16.4	15.0	15.2	14.0	14.6	0.19	0.49	0.09
	SD	1.3	1.4	0.8	08	1.0	0.9			
Burpee test, number of repetitions in 60 seconds	X	12.5	12.9	13.7	13.6	14.7	14.1	0.35	0.74	0.07
	SD	1.0	1.3	0.9	1.0	0.9	0.9			
Squats with a 20 kg disk, number of repetitions in 60 seconds	X	23.4	23.5	26.0	24.1	26.7	24.7	0.92	0.01	≤0.01
	SD	1.7	1.8	1.8	1.3	1.4	1.1			
Rotation with a 20 kg disk, number of repetitions in 60 seconds	X	19.7	19.8	22.3	21.6	23.2	22.9	0.84	0.27	0.49
	SD	1.7	1.5	1.8	1.2	1.4	1.2			
Imitation of passages in the legs with pulling partner, number of repetitions in 60 seconds	X	9.1	10.8	11.1	12.4	13.1	12.7	≤0.01	≤0.01	0.27
	SD	1.0	1.4	1.3	1.0	0.9	1.1			
Pull of the damping rubber, number of repetitions in 60 seconds	X	41.5	42.4	43.6	43.2	46.5	44.6	0.29	0.63	0.02
	SD	2.2	2.1	1.9	1.7	2.2	1.8			

Legend: CG – control group; EG – experimental group; p* – the difference between experimental and control groups before experiment; p** – the difference between experimental and control groups in the middle experiment; p*** – the difference between experimental and control groups after experiment.

Table 3. Psychophysiological indicators of young pankration athletes during experiment

Test		Psychophysiological indicators						The difference between groups		
		before experiment		in the middle of experiment		after experiment				
		EG	CG	EG	CG	EG	CG	p*	p**	p***
Choice reaction time, seconds	X	336.0	323.2	329.4	323.2	326.7	319.7	0.42	0.66	0.65
	SD	40.9	42.0	38.8	36.2	39.0	41.4			
Distinction reaction time, seconds	X	352.9	346.7	344.4	345.0	344.0	341.9	0.56	0.95	0.84
	SD	29.2	23.2	28.9	20.5	29.6	24.5			
Reaction on a moving object, seconds	X	0.4	0.4	0.9	0.6	0.1	1.0	0.30	0.66	0.20
	SD	2.3	1.9	1.7	1.6	1.8	2.2			
Exact reproductions	X	12.6	12.0	15.0	12.3	18.3	11.3	0.56	≤ 0.01	≤ 0.01
	SD	2.5	2.6	2.8	1.4	2.4	1.6			
Tapping test	X	243.3	259.0	253.5	261.6	281.2	273.8	0.38	0.56	0.63
	SD	45.0	45.8	35.6	36.5	45.7	37.6			

Legend: CG – control group; EG – experimental group; p* – the difference between experimental and control groups before experiment; p** – the difference between experimental and control groups in the middle experiment; p*** – the difference between experimental and control groups after experiment.

As shown in Table 2, the highest increase in the experimental group was indicated in test "Imitation of passages in the legs with pulling out a partner" – 21.39%; "Rotation with a 20 kg disk" – 13.16%; "Rope-climbing" – 12.50%. Slightly lower results were observed in other tests ("Burpee test", "Squats with a 20 kg disk", "The pull of the damping rubber"). They amounted to 5.04-11.07% of the initial level. In the second stage, the experimental group for most indicators showed an increase in results from 6.67 to 18.03% ($p \leq 0.01$). The exception was the control exercise "Squats with a 20 kg disk" – 2.80% ($p = 0.06$).

As for the control group, at the first stage of the experiment, significant changes at the level of $p \leq 0.01$ were received only in four exercises: "Rope-climbing", "Burpee test", "Rotation with a 20 kg disk", "Imitation of passages in the legs with pulling out a partner". Their values ranged from 5.33 to 17.72%. In the second stage of the experiment the results were improved only in three of the six tests ("Rope-climbing", "Rotation with a 20 kg disk", "Pull of the damping rubber"). The positive changes were 3.08–5.73% ($p \leq 0.01$). According to other tests, the changes were not statistically confirmed and amounted to 2.17–3.86% ($p > 0.05$).

There were also found some positive changes in athletes' psychophysiological characteristics (Table 3).

At the first stage of the study athletes of the experimental group showed significant increases in the results ($p \leq 0.01$) in such tests: "Choice reaction time", "Reaction on a moving object" and " Distinction reaction time" from 1.98% to 19.06 %. At the second stage, the changes were in "Exact reproductions test", "Reaction on a moving object" (21.45%, $p \leq 0.01$) and "Taping test" (10.94%, $p \leq 0, 01$).

In the control group at the first stage of the experiment athletes did not achieve a significant increase in any test. The

Table 4. Technical and tactical preparedness of young pankration athletes during the experiment

Test		Indicators of technical and tactical preparedness						The difference between groups		
		before experiment		in the middle of experiment		after experiment				
		EG	CG	EG	CG	EG	CG	p*	p**	p***
Drill №1	X	230.5	225.6	219.3	221.0	210.6	216.3	0.01	0.33	≤ 0.01
	SD	4.7	4.8	4.1	4.3	5.8	3.7			
Drill №2	X	14.9	15.4	16.7	15.6	17.9	16.3	0.14	0.01	≤ 0.01
	SD	0.8	1.0	1.3	1.0	1.3	1.2			
Work on a bag with hands, number of repetitions in 30 seconds	X	19.0	19.9	20.7	21.0	22.2	21.0	0.14	0.53	≤ 0.01
	SD	1.2	1.8	1.1	1.3	1.2	1.2			
Work on a bag with feet, number of repetitions in 30 seconds	X	13.3	13.7	14.8	14.7	15.3	15.0	0.34	0.86	0.33
	SD	1.1	1.2	0.9	0.8	0.9	0.9			
Combined work with hands and feet, number of repetitions in 30 seconds	X	21.0	20.2	22.2	21.9	23.2	22.6	0.09	0.40	0.16
	SD	1.2	1.0	1.2	1.2	0.9	1.1			

Legend: CG – control group; EG – experimental group; p* – the difference between experimental and control groups before experiment; p** – the difference between experimental and control groups in the middle experiment; p*** – the difference between experimental and control groups after experiment.

relative values ranged from 0.01 to 2.26% (the difference was from 0.46 to 0.98). However, at the second stage of the experiment they managed to improve the results of most psychophysiological tests. Significant changes were found for the "Reactions on a moving object" ($p = 0.03$) and "Tapping Test" ($p \leq 0.01$) with relative values of 4.64%. According to other tests, the changes ranged from 0.91 to 8.49 ($p = 0.08$ to 0.28).

We also estimated technical and tactical preparedness of athletes in both groups (Table 4).

The highest increase in the experimental group was found in Drill №2 ("dead zones"), which was 12.20% of the initial level ($p \leq 0.01$). The same level of confidence ($p \leq 0.01$) was observed in the results for other exercises, although their values were slightly lower from 4.83% to 10.92%. In the second stage, the growth rates were slightly lower, but still significant ($p \leq 0.01$–0.05). In all tests the increase ranged from 3.69% to 7.47% and the highest values were found in the results of Drill №2 and Work on a bag with hands – 7.07% and 7.49% respectively.

There were also significant positive changes in most tests in the control group. The highest increase was observed in combined work with hands and feet (7.71%, $p \leq 0.01$) and Drill №1 (2.00%, $p \leq 0.01$). The same concerned the work on a bag with hands (6.02%, $p \leq 0.05$) and feet (7.51%, $p \leq 0.01$). However, in the second stage of the experiment, the values of reliability were lower. Thus, significant indicators were available only for the Drill №1 (2.11%, $p \leq 0.01$) and combined work with hands and feet (3.49%, $p = 0.02$). As for other tests, during the second stage of the experiment, the changes were insignificant ($p = 0.07$–0.87) and the percentage values ranged from 0.23 to 4.27%.

In addition, we used special training sparring match with the task for assessment of athletes' technical and tactical skills. It was discovered that at the first stage of the study the athletes of the experimental group have significant changes in six of the eight indicators. Sportsmen have become more successful in "low kick" (by 15.34%, $p \leq 0.01$). As for other technical and tactical actions, the percentage values of improvement ranged from 4.17% to 8.67% at $p \leq 0.01$–0.03. At the second stage of the experiment, significant changes were found in "throws through the thigh", throws "hook", types of suffocating from the back and pain actions on the knee and leg – from 8.51% to 13.44% with values of $p \leq 0.02$.

In the control group at the first stage of the research we received positive changes in seven of the eight indicators. The exception was the performance of throws "hook" where the changes were within 3.03% ($p = 0.09$) in comparison with the initial data. For all other indicators, the improvement in the quality of technical and tactical actions ranged from 4.82% to 11.06% ($p \leq 0.01$–0.03) in comparison with the initial data. At the second stage of the pedagogical experiment, there were no significant positive changes in any of such indicators. All assessments ranged from 0.57 to 11.70% of the level in the middle of the pedagogical experiment ($p = 0.09$-0.90).

Discussion

Pankration as s kind of mixed martial sports becomes more and more popular, especially in Ukraine. However, a lot of issues are still described fragmentally (Sasanfar, Pourkiani & Sasanfar, 2011; Marinho, Del Vecchio & Franchini, 2012; Nakonechny, 2020). First of all, it concerns the composition of long-term training process and development of different sides of athletes' preparedness: physical skills, technical and tactical mastership, psychological qualities, etc. In our opinion, the main problem is the fact that main approaches to the development of athletes' preparedness are accommodated from other martial arts. On the one hand, technique and tactics in pankration are similar to classic combat sports (boxing, kickboxing or wrestling). On the other hand, competition rules are different, that is why the requirements for the level of technical and tactical actions and their arsenal are different (Arvanitis, 2019).

Analysis of official programs for sports clubs indicated the presence of some shortcomings in the construction of the training process for athletes aged from 15 to 16 years old. In the future, these shortcomings may lead to the impossibility of achieving high results in competitions of various levels, because the adaptive capabilities of young athletes were not developed in time and in adequate manner (Karpowicz, &

Karpowicz, 2013; Koryagin, Blavt, & Grebinca, 2016). To avoid this, we have developed author's training program and verified it in the pedagogical experiment. The obtained data allowed us to make conclusions on the dynamics of athletes' preparedness during an annual macrocycle and to compare its' influence with the traditional one.

According to many experts in martial arts and other sports, it is quite difficult to influence on the speed qualities of athletes (Garanin & Kuznetsov, 2015; Artioli, Gualano, Franchini, Batista, Polacow, Lancha, 2009; Biletsky & Ponomarev, 2017). We can confirm this data with the obtained results. As for other indicators of general physical preparedness, they increased both in the experimental and control groups. During the first stage of experiment the increase of results in most tests was significant in both groups. Instead, during the second stage of experiment the level of general physical fitness of in both groups remained stable. In addition, the priority should be given to improvement of speed and strength. This situation is typical not only for pankration, but also for other kinds of martial arts (Tota, Drwal, Maciejczyk, Szyguła, Pilch, Pałka, & Lech, 2014; Meyer, 2018; Prystupa, Okopnyy, Hutsul, Khimenes, Kotelnyk, Hryb, & Pityn, 2019).

During the first stage of study in the experimental group there were positive changes in all indicators of special physical fitness. The reliability of changes was at a high level ($p \leq 0.01$). It is interesting that intra-group changes were more significant in the experimental program in comparison with the control group. This allows asserting the pronounced effectiveness of author's training program, which takes into account the current trends in competitive activities and the recommendations of experts.

In our opinion, certain differences in the results obtained by athletes of the control and experimental groups during the first and second stages of experiment are connected with increasing requirements for athletes' technical and tactical training. That is, in the case of athletes of the experimental group managed to maintain a positive dynamics of growth in the second stage, although their values were slightly lower in the first stage of the experiment. At the same time, the athletes of the control group, having higher positions during the first stage, could not, to some extent, maintain the growth rate in the second part of the pedagogical experiment, which was reflected in the relevant assessments for technical and tactical actions.

Another confirmation of the effectiveness of the author's program is the fact that after the second stage of the experiment athletes of the experimental group performed about half of the technical and tactical actions with a higher level of stability, economy and efficiency in various situations during sparring matches.

Conclusions

Pankration as s kind of mixed martial sports becomes more and more popular, especially in Ukraine. However, a lot of issues are still described fragmentally. One of the main problems is composition of training process for young athletes.

An experimental program made it possible to achieve an earlier deployment of adaptation processes to the specific physical activity available in training and competitive activities in pankration. It was more effective for the development of technical and tactical actions and special physical fitness of young athletes aged from 15 to 16 years old. It was confirmed by significant intra-group increases in indicators of athletes' preparedness ($p \leq 0.05–0.01$).

The total number of significant changes in the experimental group ($p \leq 0.05–0.01$) during the first and second stages of the experiment was 12 of 13 indicators, and their values were higher than in the control group. In the control group, significant positive changes ($p \leq 0.05–0.01$) were founding 6 indicators during the first stage of experiment and 8 – during the second one.

Conflicts of interest

The authors declare that they have no competing interests.

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ВДОСКОНАЛЕННЯ СТРУКТУРИ І ЗМІСТУ РІЧНОГО НАВЧАЛЬНОГО МАКРОЦИКЛУ ДЛЯ ЮНИХ СПОРТСМЕНІВ У ПАНКРАТІОНІ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

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Мета дослідження – розвідка вдосконалення структури та змісту щорічного тренувального макроциклу для юних спортсменів 15-16 років у панкратіоні з урахуванням особливостей їх змагальних результатів.

Матеріали та методи. Теоретичний аналіз та узагальнення використовувались під час роботи з літературними джерелами над проблемою дослідження. Опитування (опитувальник) було використано для вивчення загальних підходів до структури та змісту підготовки юних спортсменів (15-16 років) у панкратіоні. Також були проаналізовані офіційні програми для досвідчених спортсменів з панкратіону, які використовуються в Україні. Педагогічний експеримент, тривалістю 10 місяців 906 годин проводився протягом вересня 2018 р. – липня 2019 р. Були проведені два однакові шестимісячні тренувальні макроцикли. У дослідженні приймали участь контрольна (21 спортсмен) та експериментальна (22 спортсмени) групи.

Результати. Експериментальна програма виявилась ефективною у розвитку техніко-тактичних дій та спеціальної фізичної підготовленості юних спортсменів (15-16 років). Це було підтверджено значним підвищенням показників підготовленості спортсменів у межах групи ($p \leq 0,05–0,01$). Загальна кількість значущих змін в експериментальній групі ($p \leq 0,05–0,01$) протягом першого та другого етапів експерименту становила 12 із 13 показників, і їх значення були вищими, ніж у контрольній групі. У контрольній групі значущі позитивні зміни ($p \leq 0,05–0,01$) були виявлені у 6-ти показниках на першому етапі експерименту та 8-ми – на другому. Після другого етапу експерименту спортсмени експериментальної групи виконали близько половини техніко-тактичних дій з більш високим рівнем стійкості, економічності, ефективності в різних ситуаціях під час спаринг-поєдинків.

Висновки. Експериментальна програма дозволила досягти більш раннього розгортання процесів адаптації до конкретних фізичних навантажень, доступних під час тренувань та змагальних занять з панкратіону.

Ключові слова: панкратіон, макроцикл, експериментальна програма, тренування, спортсмени.

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ORIGINAL SCIENTIFIC ARTICLE

VOLLEYBALL FUNDAMENTAL MOVEMENT LEARNING MODEL IN PRIMARY SCHOOL

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Abstract

The study purpose. This study aims to develop a volleyball fundamental movement learning model with a game-centered approach and test its effectiveness in improving the volleyball learning outcomes of elementary school students

Materials and methods. The research method used is research and development (R&D) which adopts the10 steps of Borg and Gall R&D model. The data analysis techniques used in this study were qualitative and quantitative. This study used a pretest-posttest control group design to determine the initial abilities of the experimental and the control group (n = 40). The significance test of the learning model effectiveness used a t-test. Normality test was carried out before the data analysis on the results of the experimental group and the control group improvement in the fundamental movement of volleyball with the significance level = 0.05.

Results. The results of this study indicate a significant improvement for the experimental group data (0.97) and the control group data (0.42). Because the significance value of the two groups is more than 0.05, the overall data for the study group is normally distributed. The learning model effectiveness test results show the value of t-count -71.065.

Conclusions. The fundamental movement improvement of the experimental group is higher or more effective than that of the control group. So it can be concluded that the volleyball fundamental movement learning model with a game-centered approach is effective and efficient to be given to elementary school students.

Keywords: learning model, fundamental movement, volleyball.

Introduction

Physical education (PE) is a learning process through physical activities designed to improve physical fitness, develop motor skills, knowledge and behavior for healthy and active living, sportsmanship, and emotional intelligence. PE promotes physical activity which are linked to physical (Griffo et al., 2020) and mental benefits (Haverkamp et al., 2020; Singh et al., 2019). PE intend to provide beneficial effects in supporting academic achievements, fostering non-cognitive skills, improving motor skills, encouraging physical activity, and improving health (Knaus et al., 2020). The learning environment is carefully regulated to foster the growth and development of all students, physical, psychomotor, cognitive, and affective domains (Arfa et al., 2020). Volleyball in PE learning is one of the main materials for big ball games (Jati et al., 2019), which has a strategic role in promoting the healthy habits of students. Volleyball has a positive effect on physical aspects so that it can be applied to students on account of it easily being applicable, and having low injury risk (Sozen, 2012). To achieve good learning outcomes in volleyball, especially basic volleyball techniques, teachers must find effective ways to teach the fundamental movements so that learning outcomes in volleyball learning are expected to be successful (Makadada et al., 2019).

Most elementary students are beginners in Physical and Sports Activities (PSA) because they do not know how the rules are implemented, even though it has been explained by the teacher in previous classes. This finding assumes that there are facts that hinder the volleyball learning in normal elementary school classroom situations. These facts explain that there are problems in elementary school volleyball learning that must be highlighted (Basile et al., 2019). Fur-

thermore, these facts can be found in many regions, including Indonesia.

The learning method chosen by the teacher must consider the characteristics of students' development. Some of the characteristics of elementary school students are: students love to play; students love to move; students love to work in group; students love to feel, do, and demonstrate directly. Students must be taught to improve their technical execution through practical assignments for the development of skills and understanding of the meaning of techniques obtained when contextualized in the play. This is important because students learn in a play-like context that allows the best opportunity to transfer their skills (Morales-belando et al., 2018). PE teachers can use game-centered approach so that the PE learning process can reflect DAP (Developmentally Appropriate Practice) according to the development stage approach, which means that learning tasks must pay attention to the changes in students' abilities or conditions and help encouraging these changes (Hambali, 2018). Moreover, the approach in the learning process of the volleyball fundamental movements must be able to make the players (especially beginners) happy and provide variations so that the players do not easily get bored (Islam, 2019).

Several studies related to volleyball learning models have been conducted before, but none has developed a volleyball fundamental movement learning model with a game-centered approach. Previous studies focused on volleyball passing (Ajayati, 2017; Syafrizar & Hermanzoni, 2020) and serving model (Budiarti et al., 2019; Islam, 2019), while some others focused on cooperative learning (Nieves et al., 2019; Maya Ningrum et al., 2020) and instructional and representative criteria (Hutagalung et al., 2020). In this study, the items of variations in the learning model include all the fundamental movements of volleyball. All activities are developed based on the characteristics of elementary students, suitable facilities and infrastructure, and interesting methods. Activities are developed using game-centered principles, so they become more interesting and fun. The product developed has internalized volleyball learning activities with active student learning methods..

Materials and methods

The research method used in this study is research and development (R&D) which adopts the 10 steps of Borg and Gall R&D model. The data analysis techniques used in this study were qualitative and quantitative. This study used a pretest-posttest control group design to determine the initial abilities of the experimental and control group. 40 students participated in the effectiveness test which separated into experimental and control group. The design of the model development in this study will be carried out in several stages as follows (fig. 1).

N-Gain test was used to analyze the effect of the learning model, while paired sample correlation and the paired sample test was respectively used to analyze the effectiveness of the model and the significancy of students after being given the volleyball learning (fig. 1, tabl. 1).

Results

N-Gain test was carried out to find out the improvement of students which devided in to experiment group which was given the volleyball fundamental movement learning model and control group which was given the usual volleyball learning model. The following table contains the results of the N-Gain test (tabl. 2).

Based on the results above, it can be concluded that the improvement of the N-Gain score in the experimental group after being given treatment reaches the high category, while in the control group it reaches the medium category.

Based on the results on the table above, the coefficient of the volleyball fundamental movement learning model in Elementary School before and after being given the volleyball learning model is 0.275 with a p-value of 0.00 < 0.05. So in can be stated that the learning model is effective to be applied (tabl. 4).

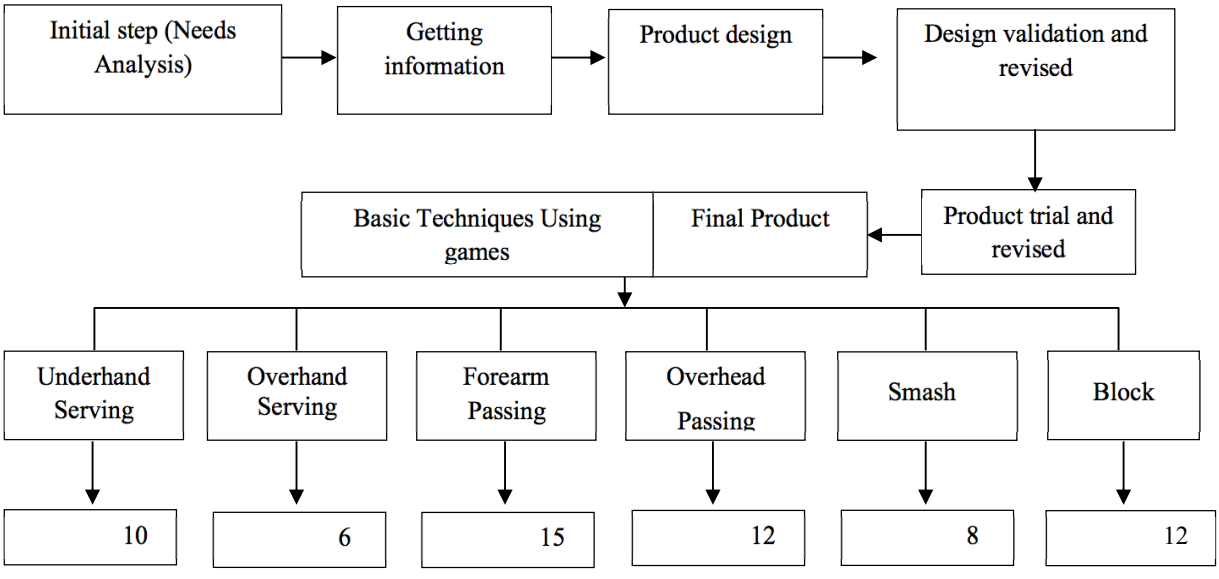

Fig. 1. Steps of R&D Model

Table 1. Variation of Volleyball basic techniques with the types of games

Volleyball Basic Techniques	Types of Games	
Underhand Serving	1. Throw Without Kick	6. Obstacle Blow
	2. Throw Without Kick Pair	7. Cardboard Hurdle Blows
	3. Shadow Blows	8. Plastic Rope Hurdle Blows
	4. Lightning Punch	9. Shadow Barrier Blows
	5. Face Punch Without Obstacles	10. Ninja Hatori's Punch
Overhand Serving	1. Service blow over	4. Flying Balloon Blows
	2. One-Handed Punch	5. Blow the ball to the wall
	3. Happy Ball Punch	6. Target Punch
Forearm Passing	1. Controlled Throw in Place	9. Chase Throw Catch Chase the Ball
	2. Beautifully Controlled Throw	10. Ball Catch Aisle
	3. Chasing the Rope	11. Parallel Ball Catcher Hallway
	4. Chase the ball	12. Estapet Ball Catcher Hallway
	5. Pairing Passing	13. Obstacle course
	6. Passing the Ball in Place	14. Right Target Circle
	7. Beautiful Forward Ball Passing	15. Obstacles to Ball Cooperation
	8. Throwing the horses	
Overhead Passing	1. Throw Ball Catch	7. Beautiful Forward Horses
	2. Happy Throws	8. Throwback and forth Hator
	3. Passing Up in Place	9. Throw Snake Catch
	4. Passing Up Fun	10. Throw Catch Tsubasa
	5. Joyful Rope	11. Throw a Falling Ball
	6. Joyful Rope Estapet	12. Clock Basket
Smash	1. Target Throw	5. Colourful Steps
	2. Empty Hand Kick	6. Run for your dreams
	3. Power Kick	7. Color Ball Step Cardboard
	4. Hula Hup Hurdles	8. Hanging Ball Cardboard Punch
Block	1. Jumping on the spot	7. Throw of Sacred View
	2. Clap Couple	8. Happy Ball Throws
	3. Couple Jumps	9. Beautiful Cardboard Throw
	4. Sweet sit	10. Like Cardboard
	5. Beautiful hand	11. Hip-hip Carton
	6. Knee Sitting Throws	12. Happy Circle (Tiktok)

Table 2. Results of the N-Gain Score Test

N	Experiment Group		Control Group	
	Gain score	Information	Gain score	Information
40	0.97	High	0.42	Medium

Table 3. Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre & Post	40	.275	.033

In the difference significance test with SPSS 21, the results of t-count = -71.065, db = 39 and p-value = 0.00 <0.05, which means that there was a significant difference in the volleyball fundamental movement skills of elementary school students before and after being given the learning (tabl. 4).

Discussion

1. Product Design

The results of the design validation that carried out in this research and development produced 63 models of game-based fundamentall volleyball fundametal movement, consisting of 10 models of underhand serving, 6 models of overhand serving, 15 models of forearm passing, 12 models of overhead pasing, 8 models of smash, and 12 models of block. Previously, the initial design was planned and validated so that it can produce development products in the form of 63 learning models that are ready to be implemented. According to (Huang et al., 2020), the basic stage of research and development activities aims to analyze the physical structure and various object relationships through experimental analysis or theoretical research. All game models were designed according to the volleyball fundamental movement through in-depth need analysis, theoretical study, and planning.

2. Operational Product Revision (Revision of Large Scale Trial Results)

The main field testing that have been carried out by researchers have resulted in several notes to be used as material for correction and evaluation. Some of the notes collected by the researcher are as follows:

- When students did all the volleyball fundamental movement models, it took a large area because students can make movements freely.

Table 4. Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre - Post	-11.80000	1.28617	.16604	-12.13225	-11.46775	-71.065	39	.000

- The safety factor is very important in the learning process.
- There are several models that need to be considered; when students did a running motion followed by jumping upwards, some students did it in the wrong timing.
- Discipline must always be considered, so that unwanted results do not occur.

The main field testing led to the extent to which the learning process can take place. Based on the notes, suggestions, and findings on the main product field test above, it can be concluded that all the fundamental movement learning models for volleyball are feasible and can be used in physical education learning in elementary schools. Bisagno and Morra (2018) stated that students need attentional resources to learn volleyball gesture. The play approach was used to improve the interest and attention of the students. By learning the fundamental volleyball movements through the play approach, it can be continued in the effectiveness test, in order to determine the extent to which this development product achieves the goal of improving the basic volleyball learning outcomes of elementary school students.

3. Operational Field Testing / Effectiveness Test

At this stage, the researcher used a volleyball basic movement skill instrument that the researcher made and has been validated. In this effectiveness test using subjects as many as 40 students of Bekasi 27 State Elementary School. The results of the assessment of 40 students on the effectiveness of volleyball fundamental movement learning model development through the play approach for elementary school students. Based on the results on effectiveness test, the coefficient of the volleyball fundamental movement learning model shows that the learning model is effective to be applied in elementary school. Furthermore, a paired sample test was carried out and the results show that there was a significant difference in the volleyball fundamental movement skills of elementary school students before and after being given the learning. Based on this information, it can be stated that the volleyball fundamental movement learning model that was developed is effective and can improve volleyball fundametal movement of elementary schools students.

4. Final Product Revision

After the main field test and effectiveness test were carried out, the volleyball fundamental movement learning model through the play approach became the final product. The final model is the result of a large group trial, which meets the eligibility standards for use. Volleyball is a sport with a relatively large range, so once the action is not standard, it is very easy to cause damage to the player (Zhang & Zhong, 2021). The final model of the fundamental movement learning model for volleyball through the play approach for elementary school children is packed in the form of a book.

5. Dissemination and Implementation

This step is the final stage in research on the development of a fundamental movement learning model for volleyball through a play approach. At this stage, the product was disseminated and implemented in several elementary schools in Jakarta, Indonesia.

Conclusion

According to this research and development, it can be concluded that the product in the form of a volleyball fundamental movement learning model was designed based on volleyball fundamental movements with in-depth need analysis, theoretical study, and planning. The results of the design validation that carried out in this research and development produced game-based 63 models.

The volleyball fundamental movement model with play approach, in a complex manner, is very suitable to be used for elementary school students in the volleyball learning. The volleyball fundamental movement model was packed in a book to make it easier for teachers to use or apply the learning materials and improve the variety and effectiveness of the ongoing teaching and learning process. The learning model was empirically proven effective to be applied in elementary school.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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МОДЕЛЬ НАВЧАННЯ ОСНОВНИХ РУХІВ ВОЛЕЙБОЛУ В ПОЧАТКОВІЙ ШКОЛІ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 6 с., 4 табл., 21 джерело.

Мета дослідження. Дане дослідження має за мету розробити модель навчання основних рухів волейболу із застосуванням ігрового підходу та перевірити її ефективність у поліпшенні результатів навчання волейболу учнів початкової школи.

Матеріали та методи. У дослідженні використано метод дослідження та розробки (R&D), який ґрунтується на 10 кроках моделі R&D Борга та Галла. Застосовано якісні та кількісні методи аналізу даних. Використовувався план групового контролю до і після тестування для визначення початкових здібностей експериментальної та контрольної груп (n = 40). Значущість ефективності моделі навчання перевірялася за допомогою t-критерію. Тест на нормальність розподілу проводився перед аналізом результатів поліпшення основних рухів волейболу експериментальної та контрольної груп з рівнем значущості = 0,05.

Результати. Результати дослідження вказують на значне поліпшення даних експериментальної (0,97) та контрольної груп (0,42). Оскільки рівень значущості двох груп перевищує 0,05, загальні дані для досліджуваної групи розподілені нормально. Результати тестування ефективності моделі навчання показують значення t-count -71,065.

Висновки. Поліпшення основних рухів у експериментальній групі вище або більш результативне, ніж у контрольній групі. Таким чином, можна зробити висновок, що модель навчання основних рухів волейболу із застосуванням ігрового підходу є ефективною та дієвою для учнів початкової школи.

Ключові слова: модель навчання, фундаментальний рух, волейбол.

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ORIGINAL SCIENTIFIC ARTICLE

TECHNOLOGICAL ASPECTS OF INTRODUCTION OF 8-WEEK MODEL AT THE PHASE OF DIRECT TRAINING FOR COMPETITIONS OF HIGHLY QUALIFIED MULTI-SPORT ATHLETES IN TRACK-AND-FIELD ATHLETICS

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Abstract

The purpose of study was to develop and to substantiate experimentally the efficiency of the 8-week model of the stage of direct training for main competitions of highly qualified multi-sport athletes in track-and-field athletics.

Material and Methodology. 5 highly qualified multi-sport athletes having a sports qualification of the Master of Sports of Ukraine took part in the pedagogical experiment. The average age of the participants was 25.2±1.79 years. The technological basis for introduction of combined events competitions of track-and-field athletes into the requirements of the 8-week model of the phase of direct training for main competitions was constituted by: an algorithm of the individual program for training multi-sport athletes for competitions, which reflects the consistency of actions for the purpose of preparing the athletes to perform given tasks; programming of the training process, which shows the directions of performance of tasks during specific mesocycles while taking into account the feasibility of the development of components of technical and physical preparedness and types of combined events competitions in track-and-field athletics; structuring the process of straining and recovery, which determines the permissible levels and intensity of training loads during separate sessions and microcycles.

Results. We reduced the magnitude of training loads (up to 3233 min) and increased their intensity (up to 6.51 points·min-1) during the forming experiment at the phase of direct training for competitions, which allowed to achieve peak sports form and evoke additional resources in the organism of athletes.

The introduction of the developed 8-week model of the direct training stage contributed to a statistically significant improvement in the indicators of physical preparedness of the studied multi-sport athletes in running tests by 2.3-3.1%, while it made 4.4-4.9% in the tests representing speed and strength qualities and 4.5-4.9% in strength control exercises ($p < 0.05$). The improvement of the results of most disciplines in the range of 1.7-5.3% ($p < 0.05$) confirms the efficiency of the developed 8-week model of the phase of direct training.

Conclusions. Solution of specific tasks during final weeks before the main starts requires the establishment of optimum volumes of training work and load dynamics, combining training sessions with training loads of various orientation and magnitude, using rest and recovery means as a whole complex, ensuring operative and current control over the course of recovery and adaptation processes. Taking the aforementioned problems into account, we have developed an 8-week model at the phase of direct training for competitions, in which three mesocycles were determined with strictly defined tasks and corresponding training content.

Keywords: track-and-field, combined events, decathlon, the phase of direct training, competitions, model, programming, training process.

Introduction

Modern system of training in track-and-field athletics is at the stage of constant development and is characterized by a variety of competitions of a significant magnitude as well as financial and rating incentives. It puts heavy demands on the sports results, however there is no further possibility of their improvement on account of the increase in the volume and intensity of training and competitive loads in athletes and it may cause pathological changes in their organism

(Platonov, 2013; Kozina, Sobko, Bazulyuk et al., 2015; Drachuk, Bohuslavska, Pityn et al., 2018). The existing problem was first addressed in the 60s of the 20th century by the prominent Australian specialist F. Carlyle and the soviet specialist L.P. Matveev who established that no more than 25% of track-and-field athletes could show their best results at the main competitions and other athletes demonstrated their best results at other competitions which often were of minor importance. Under these conditions, participation in competitions with maximum training load started losing sense due to fact that athletes often had to perform in a situation of physical and psychological load (Matveev, 2010).

In view of the above, optimization of training influences at the stage of direct training in order to bring athletes into their optimal sports form for main competitions in order to demonstrate their best results (Dobrynskaya, Kozlova, 2013; Kozlova, Wei, Kozlov, 2020). A variety of significant differences in training of athletes who specialize in certain types of track-and-field athletics complicate the resolution of the mentioned problem in combined track-and-field events. These differences consist in the necessity of daily improvement in three or more types of decathlon under conditions of strict time limitations, a variety of motor coordination, high energy consumption (Zwols, Sierksma, 2009; Bilić, Balić, 2015; Adamczyk, Olszewska, Boguszewski et al., 2016).

The phase of direct preparation for main competitions of the year by its essence changed the long-existing term "narrowing", i.e. tapering (Mujika, Padilla, 2003; Thomas, Busso, 2005; Leonard, 2008). Two models of the phase of direct training for main competitions are used in the modern world sports practice: 5-week West-European and 8-week East-European model. 5-week model includes a control and a preparatory mesocycle with intense load which exceeds previous intense loads by 1015 % in order to mobilize concealed energy resources and achieve an adaptation jump as well as recovery mesocycle ("narrowing") (Platonov, 2013).

The disadvantage of the 5-week model is the lack of special preparation for loads and its limitation only by recovery measures in the pre-competitive mesocycle. These disadvantages were eliminated in the improved 8-week model which includes a two-week basic mesocycle, three-week control and preparatory mesocycle and three-week pre-competitive mesocycle. The advantages of the 8-week phase consist in the gradual preparation of the athlete during basic mesocycle and combining special work of integral character with recovery measures in the final pre-competitive mesocycle (Matveev, 2010; Platonov, 2013). Main principles serving as basis for this variant are fundamental and after a minor correction may be successfully used in the majority of sports (Platonov, 2013).

Despite a relatively short duration, the phase of direct training for important competitions, and namely its final competitive mesocycle, plays a significant role in achieving the final result of the long-term work as well as successful participation in competitions (Nedoshchak, Suhinin, 2013). Simultaneously, until now, 8-week scheme of organization of direct training for main competitions has not been used in the combined events competitions in track-and-field athletics. It is primarily connected to the impossibility of conducting loads and simultaneously using several competitive disciplines of combined events competitions during a training session.

Some studies (Dobrynskaya, Kozlova, 2013) have proposed to pay attention to the development of disciplines of combined events competitions, which an athlete displays a greater propensity for, and have determined the types of group models of competitive activity. It brought the scientists much closer to resolving the problem, however, the lack of comprehensive targeted programming of the phase of direct training for main competitions of the year and reliable methods for controlling individual marginal level of physical load do not allow the athletes to show their best results at the main competitions.

In view of the above, and also taking into account the effectiveness and prospects of using the modelling and programming methods in the process of athlete training which was underlined many times in the works by Kutek, Akhmetov, Vovchenko et al. (2018), Khudolii (2019), Kostiukevych, Lazarenko, Shchepotina et al. (2019) and other experts, we consider to be well-timed the development of 8-week model of the phase of direct training for main competitions of highly qualified multi- athletes in track-and-field athletics and its application on practice.

Study hypothesis: it is foreseen that the development of the 8-week model of the phase of direct training will contribute to the more efficient training of highly qualified multi-athletes in track-and-field athletics, will allow them to achieve their peak sports form and evoke additional reserves in the organism of athletes.

The purpose of study was to develop and to substantiate experimentally the efficiency of the 8-week model of the stage of direct training for main competitions of highly qualified multi-athletes in track-and-field athletics.

Material and methodology

Study participants

5 highly qualified multi-athletes having a sports qualification of the Master of Sports of Ukraine took part in the pedagogical experiment. Average age of participants made up 25.2±1.79 years. The study was approved by ethics committee of Vinnytsia State Pedagogical University named after Mykhailo Kotsiubynskyi and all the procedures were in compliance with the Helsinki Convention. The participants gave informed consent for participation in the experiment.

Study organization

The study was conducted from 2018 to 2020. A scheme of consecutive pedagogical experiment was used. In the course of the ascertaining experiment (2018-2019), pedagogical supervision of training process was performed along with time-keeping of the training work. It allowed to determine the volume of training loads and their division into different types of training of multi-athletes.

Recording the nature and duration of exercises and heart rate of multi-athletes on special forms while performing such exercises using Polar RS800CX heart rate monitor allowed to determine the coefficient of the value load (CVL) using the method by V.A. Sorvanov (Godik, 2006). CVL was calculated as a product of exercise duration and its intensity in points, depending on the heart rate (Kostiukevich, Stasiuk, Shchepotina et al., 2017): exercise intensity with a heart

rate of 114 bpm was assessed as 1 point; 120 bpm – 2 points; 126 bpm – 3 points; 132 bpm – 4 points; 138 bpm – 5 points; 144 bpm – 6 points; 150 bpm – 7 points; 156 bpm – 8 points; 162 bpm – 10 points; 168 bpm – 12 points; 174 bpm – 14 points; 180 bpm – 17 points; 186 bpm – 21 points; 192 bpm – 25 points; 198 bpm – 33 points (CVL, points). Load intensity using the coefficient of training load intensity (CItl) was determined as a ratio between CVL and the duration of a training session in minutes (CI_{tl}, point·min^{-1}).

Pedagogical testing was performed in order to determine the level of physical preparedness of multi-athletes using the following test exercises:

- 30 m run from the spot – assessment of speed abilities: testing participant got on the track at a distance of 10-15 meters from the start of a 30-meter distance and started running with a maximum speed by himself; time countdown began after crossing the start line of the 30-meter distance. The best time out of two attempts was recorded, up to within 0,01 seconds. Period of rest between attempts made up 3-5 minutes.
- 60 m run from high start: testing participant got behind the start line in a high start position; he had to run the given distance after a signal. The best time out of two attempts was recorded, up to within 0.01 seconds. Period of rest between attempts made up 3-5 minutes.
- 200 m run and 200 m run after 1 minute of rest – speed endurance assessment: testing participant started running from high start from the 40 m run mark; an athlete had to run 200 meters with a maximum speed; then the athlete had a 1 minute rest, then got behind the starting line from a high position and ran another 200 meters. Testing result constituted total time for running two distances. Test was performed once;
- triple long jump from the spot – assessment of speed and strength qualities: a take-off line was marked on the track near the jumping pit, jump length was recorded starting from it; testing participant stood with his toes near the line and performed 3 consecutive jumps, pushing alternately with one leg and then with another, the last jump was performed into the landing pit. Jump length was measured from the take-off line before touching the surface of the jumping pit with heels. The best result out of three attempts was recorded;
- two-handed throw of the shot from below – assessment of speed and strength qualities: the participant holding the shot with two hands stands facing the direction of throwing; feet are shoulder width apart, front part of the foot is on the segment; the shot is thrown from below to the front. The best result out of three attempts was recorded;
- squats with a barbell on shoulders – assessment of strength qualities: the exercise was performed from the initial position of the bar on stands; the athlete approached the stands and took the barbell off putting in on his shoulders from a squatting position. After making a step back, the athlete assumed a position before squatting, then performed a squat and stood back up into the initial position. The athlete returned the barbell back onto the stands with the assistance of the helper. The 1st squat attempt with a maximum weight for each athlete was recorded;
- lifting the barbell onto the chest into a half-squat – assessment of strength qualities: exercise was performed from the starting position when the barbell was on the platform; then the athlete took the initial position with his legs at shoulder width, with the bar being as close as possible to his ankles, with his feet pressed against the floor, a straight back and knees bent at approximately 45°. From this position the athlete lifted the bar onto the chest in a half squat. Lifting of the barbell with a maximum weight per 1 rep was recorded.

Pedagogical testing was performed at the beginning and at the end of the phase of direct preparation for competitions during shock microcycles in the process of performing main training work.

Main purpose of the forming experiment (years 2019-2020) was to develop the programs of structural units of the training process (training sessions, microcycles, mesocycles, phase of direct training for main competitions) and experimental substantiation of the programming and organization of the training process of highly qualified all-round track-and-field athletes.

Technological basis for introduction of combined events competitions of track-and-field athletes into the requirements of 8-week model of the phase of direct training for main competitions was constituted by: an algorithm of individual program for training multi-athletes for competitions which reflects the consistency of actions for the purpose of preparing the athletes to perform given tasks; programming of training process which shows the directions of performance of tasks during specific mesocycles while taking into account the feasibility of the development of components of technical and physical preparedness and types of combined events competitions in track-and-field athletics; structuring the process of straining and recovery which determines the permissible levels and intensity of training loads during separate sessions and microcycles.

The development of an algorithm for creating individual programs included the following sequence of actions:

- assessing the preparedness of athletes for performing the tasks at the phase of direct readiness for main competitions of the year;
- in the determination of direct disciplines with a propensity for development and referral of athletes to the corresponding type of competitive activity;
- construction of the structure of individual program at the phase of direct training for competitions.

The results of indicators of physical preparedness of highly qualified multi- athletes at the phase of direct training for competitions allowed to determine the preparedness of athletes for performing the tasks at the phase of direct training for competitions as well as to conduct a comparative analysis with model characteristics and a result of 8100 points (World Championship norm) as proposed by the authors (Kupchinov, 1998; Cherepyakin, 2014).

According to the data received by us in the process of pedagogical testing, one can note model indicators which are higher than the indicators of speed qualities (60 m run – 6.83±0.09 compared to 7.06 s); lag of indicators in the triple jump – 8.94±0.23 compared to 9.51 m and prevalence of results in throwing the shot with two hands from below – 15.57±0.27 compared to 15.12 m.

The results of decathlon competition at the phase of the ascertaining experiment allow to distinguish the existing successful disciplines in each of the athletes and the disciplines in which the lagging is observed. The analysis of competitive activity allowed to include three athletes into the second type of group models of competitive activity (speed and strength) and two athletes to the third type (speed). It also allowed to predict the increase in the success during competitions in the 100 m run, long jump, 400 m run, 110 m run with hurdles and to use the respective means of training sessions during mesocycles of the 8-week model of the stage of direct training for main competitions of the year.

The approach used for programming the training process in athletes foresaw the program of training sessions, microcycles, mesocycles; the fulfilment of models of the training programme; assessment of the training effect; correction of the training programme; repeated assessment of the training effect. The scheme of construction of the individual program of the phase of direct training for main competitions of multi-athletes consists of four blocks – determination of purpose, targeted tasks, general stock of training means, model characteristics of physical preparedness (fig. 1).

8-week model of the phase of direct training for main competitions of the year was used in the research.

Control and preparatory mesocycle was started in 5-6 days after active rest. The mesocycle foresaw the performance of a large volume of work directed towards the development of speed, speed and strength qualities, endurance. Over the first days, the load gradually grew which allowed the athletes to adapt to the loads during the next mesocycle. Intense work regimen was maintained for 7-8 days and then the load was gradually decreased and the cycle ended with a rest day. The peculiarity of the control and preparatory mesocycle consisted in the use of dominant technical and physical qualities and competitive disciplines in the training process.

Pre-competition mesocycle foresaw the creation of conditions for forming a delayed training effect and its full implementation in the competitions. During the mesocycle, the main task consisted in the achievement of the peak of supercompensation by ensuring maximum recovery after loads on the background of the limited training regimen and the use of recovery means.

Introductory, shock and pre-competition microcycles, which became part of control, preparatory and pre-competition mesocycles, were used for programming the training process of highly qualified multi-athletes during the phase of direct training for main competitions

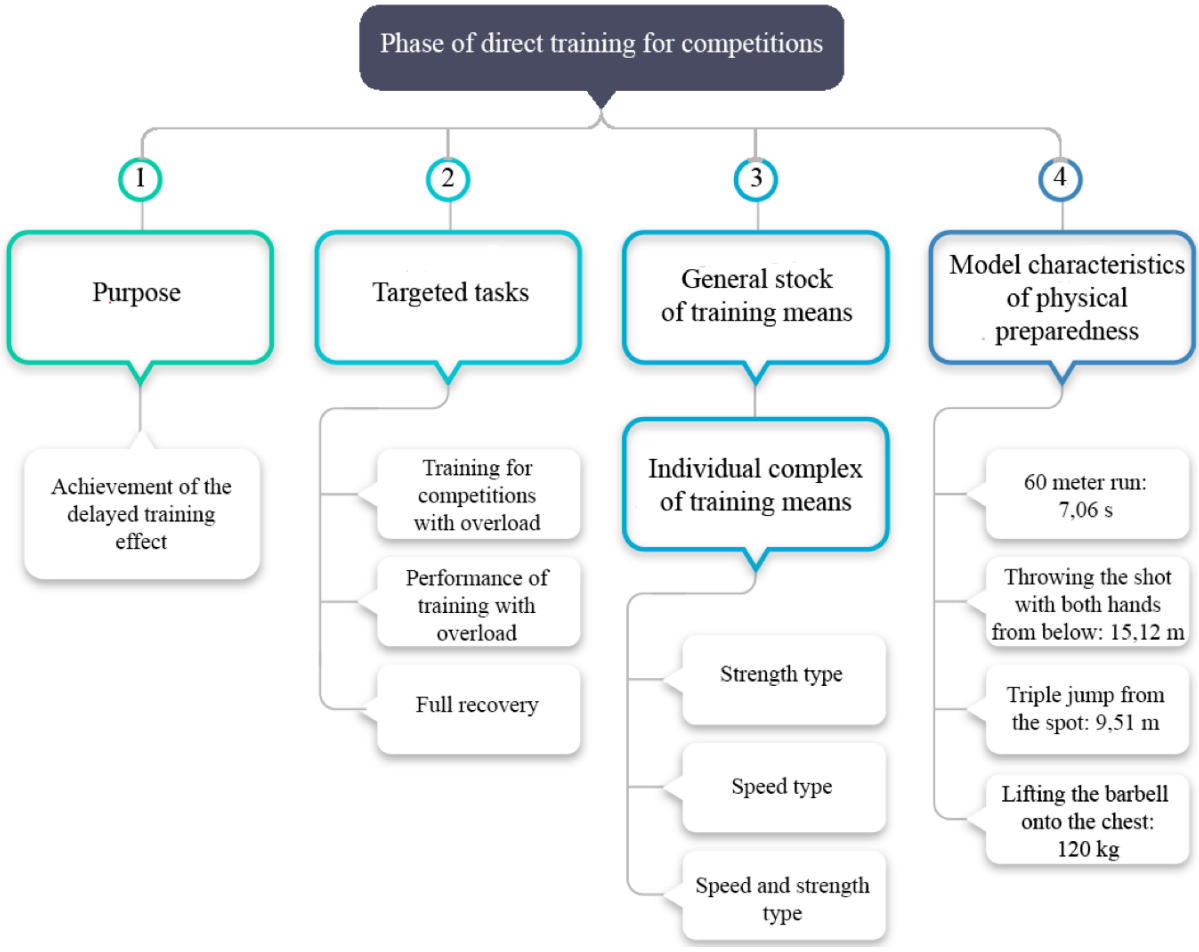

Fig. 1. Scheme of construction of the individual program at the phase of direct training for main competitions of the year

Table 1. Program of 7-day introductory microcycles of direct training for competitions

Types of training	Days of the microcycle						
	1st	2nd	3rd	4th	5th	6th	7th
General physical training (GPT)	GPT 1.1(a)–20[4]	GPT 1.1(a)–20[4]	GPT 1.1(a)–20[4]	–	GPT 1.1(a)–20[4]	GPT 1.1(a)–20[4]	–
Special physical preparation (P, S, SP, E)	P-1.4(a) – 5[5] P-1.5(a) – 7[5] P-1.25 – 3[4]	S-1.6(a)–10[10]	–	–	–	S-1.12 – 8[13]	–
Technical preparation (TP)	TP-3.5 – 12[7] TP-3.7 – 15[8] TP-1.3 – 3[4] TP-7.4 – 4[4]	TP-5.1 – 5[4] TP-5.2 – 15[5]	TP-1.14–20[12] TP-2.4 – 20[5]	–	TP-4.6 – 35[9] TP-5.1(b) – 5[4] TP-5.2(b) –10[5]	–	–
Competitions	–	–	–	–	–	–	–
Σ of the training work, min	69	50	60	–	70	28	–
CVL, points	384	275	440	–	465	184	–
CItl, points·min-1	5.57	5.50	7.33	–	6.64	6,57	–

Remarks: record of the exercise TP-3.5 – 127: TP-3.5 – code of the training exercise; 127 – duration of exercise in minutes (12) and intensity of exercise in points (7) by Sorvanov; TP – special technical preparation: TP-1 – hurdling; TP-2 – high jumps; TP-3 – long jumps; TP-4 – pole vaulting; TP-5 – shot throwing; TP-7 – spear throwing; P – strength training; S – special speed training; SP – speed and strength training, E – general endurance; S-1 – speed endurance; GPT – general technical and physical training; CVL – value load coefficient; CI_{tl} – coefficient of intensity of the training load

Table 2. Program of 7-day shock microcycle at the phase of direct training for competitions (speed and strength type)

Types of training	Days of the microcycle						
	1st	2nd	3rd	4th	5th	6th	7th
General physical training (GPT)	GPT 1.1(a) – 25[4]	GPT 1.1(a) – 25[4]	GPT 1.1(a) –25[4]	–	GPT 1.1(a) –25[4]	GPT 1.1(a) – 25[4] GPT 1.3 – 18[5]	–
Special physical preparation (P, S, SP, E)	SP 1.7– 20[6]	P 1.4(a) – 15[4] P 1.5(a) – 15[5]	S 1.6(a) – 15[6]	–	–	P 1.2 – 30[6] SP-1.5 – 25[10]	–
Technical preparation (TP)	TP-1.14 – 28[13] TP-6.1– 10[5] TP-6.2– 22[6]	TP-4.3(a) – 40[7] TP-7.1(b) – 10[4] TP-7.2(b) – 15[5]	TP-3.4– 10[7] TP-3.5– 15[7] TP-3.7– 8[14]	–	TP-1.5(a) –30[8] TP-2.4 –30[5] TP-5.6 –15[5]	TP-5.1(b) – 5[4] TP-5.2(b) – 15[5]	
Competitions	–	–	–	–	30[10]	40[10]	–
Σ of work, min	105	120	73	–	130	158	–
CVL, points	766	655	502	–	890	1025	–
CI_{tl}, points·min^{-1}	7.30	5.45	6.87	–	6.85	7.32	–

Remarks: record of the exercise SP-1.7 – 206: SP-1.7 – code of the training exercise; 206 – duration of exercise in minutes (20) and intensity of exercise in points (6) by Sorvanov; TP – special technical preparation: TP-1 – hurdling; TP-2 – high jumps; TP-3 – long jumps; TP-4 – pole vaulting; TP-5 – shot throwing; TP-7 – spear throwing; P – strength training; S – special speed training; SP – speed and strength training; GPT – general technical and physical training; CVL – value load coefficient; CI_{tl} – coefficient of intensity of the training load

During the introductory microcycles (table 1), main attention was given to the increase of the training load with the inclusion of anaerobic-alactate energy system for the purpose of achieving optimum level of preparedness for subsequent shock loads. Also, during this microcycle multi-athletes performed control runs, jumps or throws, depending on the dominant type in competitive disciplines.

The task of 7-day shock microcycles (table 2) consists in the creation of incentives for forming a marked delayed training effect on account of intense training with the use of concealed inner resources for increasing the adaptation to significant training loads. The peculiarity of shock microcycles is the specificity of work of multi-athletes of different types (roughly divisible into "speed" and "speed and strength"). Thus, the programming of preparatory microcycles was performed separately for athletes who belonged to a certain type. During shock microcycles the athletes took part in the preparatory and control competitions.

Recovery microcycles (table 3) were planned after taking part in control competitions and after shock microcycles. The duration of training sessions and value load grew from the first up to the last day of the microcycle. The content of training sessions included general and preparatory exercises for primarily developing general endurance and strength. Special technical training exercises were added only on the 6th day of the microcycle. The intensity of load during the recovery microcycle had a wavy dynamics.

Table 3. Program of the 7-day recovery microcycle at the phase of direct training for competitions

Training sections	Days of the microcycle						
	1st	2nd	3rd	4th	5th	6th	7th
General physical training (GPT)	GPT 1.1(a) – 20[5]	–	GPT 1.1(a) – 20[5]	–	GPT 1.1(a) – 20[5]	GPT 1.1(a) – 20[5]	–
Special physical preparation (P, S, SP, E)	E-1.1 –15[6]	–	E-1.1 – 21[5] P-1.7 – 5[4]	–	SP-1.7 –15[5] S-1 – 10[14]	P-1.4(b) – 15[5]	–
Technical preparation (TP)	–	–	–	–	–	TP-4.3(a) – 25[7]	–
Competitions	–	–	–	–	–	–	–
Σ of the training work, min	35	–	46	–	45	60	–
CVL, points	190	–	225	–	315	350	–
CI_{tl}, points·min^{-1}	5.43	–	4.89	–	7.00	5.83	–

Remarks: record of the exercise E-1.1 – 156: E-1.1 – code of the training exercise; 156 – duration of exercise in minutes (15) and intensity of exercise in points (7) by Sorvanov; TP – special technical preparation: TP-4 – pole vaulting; P – strength training; SP – speed and strength training, E – general endurance; S-1 – speed endurance; PT – general technical and physical training; CVL – value load coefficient; CI_{tl} – coefficient of intensity of the training load

Statistical analysis

Mathematical processing of results was conducted using the package "Data analysis" of the software MS Office Excel (Byshevets, Denysova, Shynkaruk et al, 2019). Descriptive statistics was used which foresaw the determination of a means (X) and standard deviation (S). Statistical reliability in the difference of results of pedagogical testing and competitive activity of multi-athletes at the beginning and at the end of the ascertaining and forming stages of pedagogical experiment was determined by the nonparametric Wilcoxon T-test. Differences between groups were considered to be statistically reliable at $p < 0.05$.

Results

On the basis of the obtained data of the training programs of microcycles for further substantiation of results, we have managed to generalize the load parameters which were used at the stages of direct training for competitions in the spring and summer annual macrocycles during the ascertaining and forming experiment (fig. 2).

Based on the data of fig. 2, we managed to demonstrate that during the forming experiment at the phase of direct training for competitions we reduced the magnitude of training loads (up to 3233 min) and increased their intensity (up to 6.51 points·min-1) which allowed to achieve peak

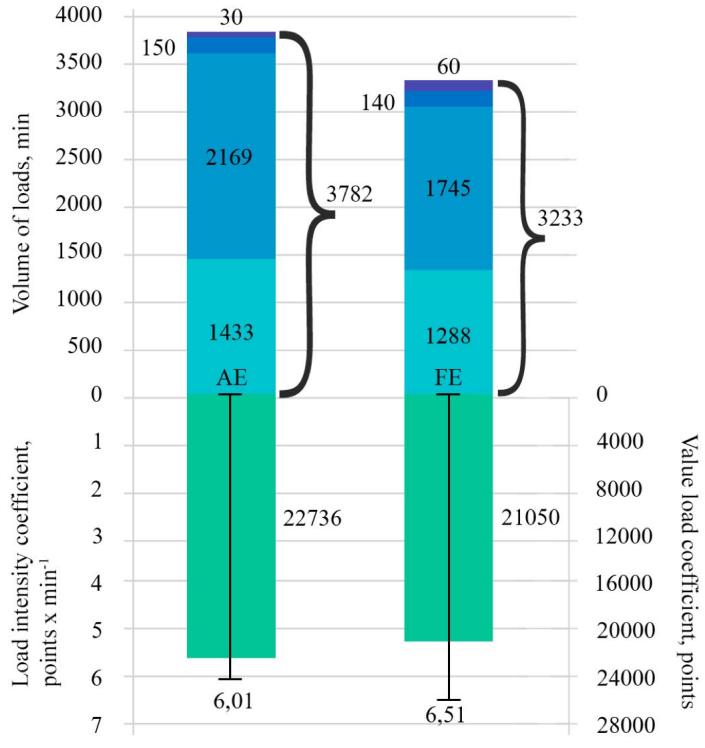

Fig. 2. Parameters of loads at the phase of direct training for competitions (spring and summer cycle) of highly-qualified multi-athletes during the ascertaining (AE) and forming (FE) experiment:
– value load coefficient; – technical preparation; – physical training; – participation in competitions; – testing; ⊢– load intensity coefficient

Table 4. Indicators of physical preparedness of decathletes at the phases of the ascertaining and forming experiments

Test	Phase	Statistical indicators						T	p
		Output data		Final data		Changes			
		X	S	X	S	Absolute	%		
30 m run from the spot, s	AE	2.96	0.08	2.95	0.04	0.01	0.4	2	>0.05
	FE	2.89	0.07	2.80	0.07	0.09	3.1	0	<0.05
60 m run from high start, s	AE	6.92	0.05	6.85	0.09	0.07	1.0	1	>0.05
	FE	6.83	0.09	6.67	0.17	0.16	2.3	0	<0.05
200 m and 200 m run after 1 minute of rest, s	AE	49.95	1.15	49.89	1.00	0.06	0.1	2	>0.05
	FE	49.70	0.64	48.33	0.52	1.37	2.8	0	<0.05
Triple jump from the sport, m	AE	8.92	0.23	9.04	0.21	0.12	1.3	1	>0.05
	FE	8.94	0.23	9.38	0.30	0.44	4.9	0	<0.05
Throwing the shot with two hands from below, m	AE	15.25	0.43	15.51	0.58	0.26	1.7	2	>0.05
	FE	15.57	0.27	16.26	0.64	0.69	4.4	0	<0.05
Squats with a barbell, kg	AE	140	6.44	147	8.58	7	5.0	0	<0.05
	FE	152	6.44	160	10.73	8	5.2	0	<0.05
Lifting the barbell onto the chest, kg	AE	102	6.44	106	8.58	4	3.9	1	>0.05
	FE	112	4.29	115	10.73	3	4.5	0	<0.05

Remarks: AE – ascertaining experiment; FE – forming experiment

Table 5. Results of competitive activity of athletes at the stages of the ascertaining and formation experiments

Competitive type of decathlon	Statistical indicators						T	p
	AE		FE		Changes			
	X	S	X	S	Abs.	%		
100 m run, s	11.40	0.29	11.34	0.46	0.06	0.5	1	>0.05
Long jump, m	6.92	0.71	7.07	0.42	0.15	2.2	0	<0.05
Shot put, m	13.72	0.87	13.95	0.74	0.23	1.7	0	<0.05
High jump, cm	192.80	7.72	197.60	9.01	4.80	2.5	0	<0.05
400 m run, s	51.17	1.05	51.35	1.20	0.18	0.4	2	>0.05
110 m hurdles, m	15.40	0.69	15.32	0.38	0.08	0.5	1	>0.05
Discus throw, m	38.80	2.05	40.84	2.71	2.04	5.3	0	<0.05
Pole vault, m	4.30	0.25	4.44	0.19	0.14	3.3	0	<0.05
Javelin throw, m	50.66	5.64	52.28	5.23	1.62	3.2	0	<0.05
1500 m run, min	4.58	0.36	4.48	0.09	0.10	2.2	0	<0.05
Amount of points	7085.60	647.64	7332.00	326.18	246.4	3.5	0	<0.05

Remarks: AE – ascertaining experiment; FE – forming experiment; Abs. – Absolute Changes

sports form and evoke additional resources in the organism of athletes.

The duration at the phase of direct training for competitions of the second cycle (spring and summer) of the annual training process made 8 weeks. Control and preparatory mesocycle consisted of 7-day introductory, three 7-day shock, 7-day and 4-day recovery microcycles. Pre-competition mesocycles included 7-day and 3-day shock microcycles divided by 7-day recovery microcycle. Athletes also took part in the preparatory and control competitions with a monthly interval. During each microcycle, at the phase of direct training for competitions the training was held once a day and specific tasks were resolved during it. The effectiveness of performance of the program at the phase of direct training for main competitions of the year is demonstrated by the data in table 4.

Based on the data in table 4, we can state that as a result of performing the developed individual training programs at the phase of direct training for competitions, the athletes experienced significant positive changes in the state of preparedness for participation in main competitions in decathlon. And namely, statistically reliable differences ($p < 0.05$) were achieved in comparison with an ascertaining experiment in all indicators of physical preparedness. Moreover, the increase in the indicators of the running tests made 2.3-3.1%, while it made 4.4-4.9% in the tests representing speed and strength qualities and 4.5-4.9 % in strength control exercises.

Participation in competitions in the spring and summer seasons also showed an increase of the results of highly qualified athletes in types of decathlon which were included into the pedagogical experiment (table 5).

Summarizing the obtained results of performances of highly qualified athletes at competitions we can state that there was a significant increase in the results regarding the total amount of points in all athletes. The analysed data give sufficient grounds to believe that the influence of the program of training sessions and the program of microcycles at the phase of direct training for competitions allowed the ath-

letes to achieve their peak sports form and to demonstrate high sports results.

Discussion

In spite of the existing need to improve the training of highly qualified of multi- athletes, the problem of introduction of 8-week model of the phase of direct training for main competitions into the combined events competitions in track-and-field athletics has not been sufficiently discussed in the special literature. So, the algorithm of construction of individual programs which was developed by us and included the assessment of preparedness of athletes, determination of propensity for corresponding sports disciplines and, specifically, the construction of individual programs at the phase of direct training as well as the approach used for programming structural formations of the training process (training sessions, microcycles, mesocycles) represent a significant contribution to the scientific achievements related to the theoretical and methodical foundations and peculiarities of practical training of multi-athletes (Kenny, Sprevak, Sharp et al., 2005; Dobrynskaya, Kozlova, 2013; Pavlović, Vrcić, Petrović, 2020).

In particular, we associate the improvement of indicators of physical preparedness in multi-athletes with a well-balanced distribution of work and rest during training sessions, positive influence of all qualitative and quantitative components of training means. Besides, the increase in the test results may be explained by programming the training process in compliance with the principles of overload, supercompensation and specificity, rational distribution of intensity and magnitude of training loads while performing training loads during specific training sessions and microcycle at the phase of direct training for competitions (Bompa, Haff, 2009; Platonov, 2013, 2015).

In such manner, the approaches with respect to modelling (Kostiukevych, Imas, Borysova et al., 2018; Kostiukevych, Shchepotina, Shynkaruk et al., 2019; Kostiukevych, Shchepotina, Vozniuk, 2020) and programming (Kostiukevich, Stasiuk, Shchepotina et al., 2017; Kostiukevych, Lazarenko, Shchepotina et al., 2019) of competitive activity and structural formation of the training process of qualified athletes of team game types of sports during the annual training cycles, which were approved in our previous studies, were also reflected in the practice of training highly qualified multi-athletes (Adamchuk, 2019, 2020). The proposed 8-week model of the phase of direct training for main competitions of the year may be used in the combined events competitions in track-and-field athletics as a reference point and, after respective corrections, it may be also used in the practice of training qualified female and male athletes.

The results of our study confirm the available data regarding the feasibility of targeted and differentiated approach of training efforts in mesocycles at the phase of direct training for main competitions for the purpose of developing priority physical qualities and successful competitive disciplines (Dobrynskaya, Kozlova, 2013; Nedoshchak, Suhinin, 2013), as well as the efficiency of the use of programming in the process of athlete training (Kutek, Akhmetov, Vovchenko et al., 2018; Khudolii, 2019; Kostiukevych, Lazarenko, Shchepotina et al., 2019).

Besides, we have contributed to the existing scientific achievements related to the problem of management of training qualified athletes during combined events competitions in track-and-field athletics (Zwols, Sierksma, 2009; Cherepyakin, 2014; Adamczyk, Olszewska, Boguszewski et al., 2016) as well as to the rational distribution of training loads of highly qualified athletes at the phase of direct training for competitions (Sikorski, 2011; Dobrynskaya, Kozlova, 2013; Kutek, Akhmetov, 2018).

At the same time, it is worth noting that the used innovative approaches do not represent the only solution of existing problems in training multi-athletes in track-and-field athletics for competitions at the high level. Despite significant increase in the opportunities for achieving sports successes while using 8-week model at the phase of direct training for competitions, in which key role belongs to the creation of conditions for maximum delayed training effect by way of physical overloads, the promising capabilities of this model are limited by physiological ability of the human body for increasing physical loads (Wilmore, Costill, Kenney, 2012).

Conclusions

1. Solution of specific tasks during final weeks before the main starts requires the establishment of optimum volumes of training work and load dynamics, combining training sessions with training loads of various orientation and magnitude, using rest and recovery means as a whole complex, ensuring operative and current control over the course of recovery and adaptation processes. Taking the aforementioned problems into account, we have developed an 8-week model at the phase of direct training for competitions, in which three mesocycles were determined with strictly defined tasks and corresponding training content.

2. The program of the training process at the phase of direct training for main competitions of the year was developed in accordance with fundamental provisions of 8-week model. Fulfilment of the program and structuring training sessions according to the tasks of control, preparatory and pre-competition mesocycles helped to solve the following main tasks: performance of loads for maintenance of the achieved training level; verification and clarification of technical elements; objective control of intensity of training sessions, effectiveness of urgent and delayed recovery; psychological preparation for competitions; providing acting rest before competitions.

3. Statistically reliable improvement of all parameters of physical preparedness in the studied multi-athletes from 2,3 to 5,2 % and the results of the majority of the competitive activity within the limits of 1,7 – 5,3 % ($p<0,05$) confirms the efficiency of the developed 8-week model of the phase of direct training for main competitions of highly qualified multi-athletes and the prospects of the use of the programming method in the practice of training of athletes of this type of sports.

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Conflict of interests

The authors state that there is no conflict of interests.

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ТЕХНОЛОГІЧНІ АСПЕКТИ ВПРОВАДЖЕННЯ 8-ТИЖНЕВОЇ МОДЕЛІ ЕТАПУ БЕЗПОСЕРЕДНЬОЇ ПІДГОТОВКИ ДО ЗМАГАНЬ ВИСОКОКВАЛІФІКОВАНИХ БАГАТОБОРЦІВ З ЛЕГКОЇ АТЛЕТИКИ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 2 рис., 5 табл., 33 джерел.

Мета дослідження – розробити й експериментально обґрунтувати ефективність 8-тижневої моделі етапу безпосередньої підготовки до головних змагань висококваліфікованих багатоборців з легкої атлетики.

Матеріал і методи. У педагогічному експерименті брали участь 5 висококваліфікованих багатоборців, спортивна кваліфікація яких – Майстер спорту України. Середній вік учасників становив 25,2±1,79 років. Технологічну основу 8-тижневої моделі етапу безпосередньої підготовки до головних змагань складали: алгоритм індивідуальної програми підготовки багатоборців до змагань, що відображає послідовність дій у досягненні готовності до виконання поставлених завдань; програмування тренувального процесу, що демонструє напрями реалізації завдань специфічних мезоциклів з урахуванням доцільності розвитку компонентів технікофізичної підготовленості та видів легкоатлетичного багатоборства; структурування тренувально-відновлювального процесу, що визначає допустимі обсяги й інтенсивність тренувальних навантажень в окремих заняттях і мікроциклах.

Результати. У формувальному експерименті на етапі безпосередньої підготовки до змагань ми зменшили обсяг тренувальних навантажень (до 3233 хв) і збільшили їх інтенсивність (до 6,51 бал·хв$^{-1}$), що дало змогу вийти на пік спортивної форми та викликати додаткові резерви в організмі спортсменів. Впровадження розробленої 8-тижневої моделі етапу безпосередньої підготовки сприяло статистично достовірному покращенню показників фізичної підготовленості досліджуваних багатоборців у бігових тестах на 2,3-3,1%, у тестах, що відображали швидкісно-силові якості – на 4,4-4,9%, у силових контрольних вправах – на 4,5-4,9% ($p < 0,05$). Покращення результатів більшості дисциплін змагальної діяльності в межах 1,7-5,3% ($p < 0,05$) підтверджує ефективність розробленої 8-тижневої моделі етапу безпосередньої підготовки.

Висновки. Вирішення специфічних завдань у заключні тижні перед головними стартами вимагає встановлення оптимальних обсягів тренувальної роботи та динаміки навантаження, поєднання занять з тренувальними навантаженнями різної спрямованості й величини, використання відпочинку, відновлювальних засобів у вигляді цілісного комплексу, забезпечення оперативного та поточного контролю за перебігом відновлювальних і адаптаційних процесів. З урахуванням зазначених проблем, розроблено 8-тижневу модель етапу безпосередньої підготовки до змагань, у якій було виділено три мезоцикли з суворо окресленими завданнями і відповідним їм змістом підготовки.

Ключові слова: легка атлетика, багатоборство, десятиборство, етап безпосередньої підготовки, змагання, модель, програмування, тренувальний процес.

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ORIGINAL SCIENTIFIC ARTICLE

ASSESSMENT OF A HEALTHY LIFESTYLE AND QUALITY OF LIFE OF MEN AND WOMEN IN MODERN SOCIETY BASED ON SF-36

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Abstract

Quality of life (QL) is defined as the subjective perception of one's own well-being in a socio-cultural context, the satisfaction of one's desires and the achievement of an ideal level of well-being. Quality of life is related to health (HRQOL), refers to the functioning and well-being in the physical, mental and social dimensions of life.

Research purpose: to analyze the main factors of quality of life of male and female population in modern Ukrainian society.

Material and Methods. 482 men and women aged 20-60 took part in sociological research.

The following research methods were used to solve the problemsset in the work: analysis and processing of special literature and data from the Internet; pedagogical observation; questionnaires (SF-36); methods of mathematical statistics.

Results. The results of their own research show that the male population had a better quality of life on all scales of the SF-36 questionnaire compared to women ($p < 0.05$). Respondents under the age of 20-29 had indicators of quality of life above average on the scales of physical and role physical functioning; pain in this age group did not have a significant impact on quality of life. The general state of health was assessed above the average level by respondents aged 20-29 and 30-39, regardless of gender, they were characterized by high scales of social activity and viability.

Conclusions. It is established that the indicator General health is a system-forming factor of quality of life for men and women in terms of the number of correlations. The obtained results allowed to determine the expediency and speed of implementation of preventive measures for men and women depending on the content of certain scales. Decreased overall health (GH) in men and women after the age of 50 significantly affects their quality of life, as evidenced by the large number of significant correlation coefficients. In women over 50 years of age, there is a sharp decrease in RP (role functioning due to physical condition) to 46 points, vital activity (VT) to 50 points, role functioning (due to emotional state) (RE) to 53 points. In men at this age, role functioning increases to 90 points, and social functioning (SF) to 89 points, which may indicate an uneven distribution of family and social functions in the lives of people of different sexes, overloading women with household chores, which prevents them from spending free time, affects the emotional state.

Keywords: quality of life, lifestyle, physical activity, health, adults.

Introduction

Quality of life (QOL) is defined either as a subjective perception of one's own well-being in a socio-cultural context, the satisfaction of one's desires and the achievement of an ideal level of well-being. Quality of life is related to health (HRQOL), refers to the functioning and well-being in the physical, mental and social dimensions of life (Ware & Sherbourne,1992; Brazier, 1993; Wassertheil-Smoller & Smoller, 2015).

The world community of scientists concludes that there is a relationship between well-being, quality of life and ob-

jective health indicators at the level of quadratic correlation coefficients equal to 0.14, and then health affects well-being, and subjective well-being affects to prolong life by 7-10 years (WHO, 2007; 2013; 2018).

When it comes to human well-being, it is often associated with economic well-being and only then pay attention to quality of life and health (Hardman & Stensel, 2003; Cavill, Kahlmeier, & Racioppi, 2006; Krutsevich & Bezverhnia, 2010).

In countries where the majority of the population feels disadvantaged and disenfranchised, there are disproportionately poor outcomes both in terms of health and other social determinants. Of great importance is the systematic assessment of the health effects of rapidly changing environmental conditions, especially the effects of technology, working conditions, energy production and urbanization, and this assessment should include actions to achieve health benefits (Lee, Shiroma, Lobelo, Puska, Blair, Katzmarzyk, 2012; World Health Organization 2013; Imas, Dutchak, & Trachuk, 2013).

WHO defines quality of life as a person's perception of his life, including physical, mental and social well-being (WHO Quality of Life Assessment Group,1996).

Quality of life is always associated with health, although it is a complex characteristic of physical, psychological, emotional and social functioning of man, based on his subjective perception (Krutsevich, Imas, 2013).

Due to the extreme importance of the problem of the impact of lifestyle, physical activity on the duration and quality of life of the population of Ukraine, which, unfortunately, differs from the statistics of the European Union, it is necessary to determine the main factors of quality of life on the state of health and life expectancy.

The aim of our work is to identify in the population aspect the main factors of quality of life of male and female population in modern Ukrainian society.

Material and method

Study participants

482 men and women aged 20-60 took part in sociological research.

Study organization

The SF-36 Health Assessment Questionnaire is one of the most common methods for measuring health-related quality of life and is used to compare different populations (Brazier,1993; Ware, Kosinski, & Keller, 1994; Brazier, Roberts, Deverill, 2002).

36 items of the questionnaire are grouped into eight scales: physical functioning, role activity, physical pain, general health, viability, social functioning. All scales form two components of psychological and physical well-being.

1. Physical Functioning (PF), reflects the degree of physical condition that limits the performance of physical activity (self-care, walking, climbing stairs, weight transfer, etc.).

2. Role-Physical Functioning (RP) – the influence of physical condition on daily role activities (work, performance of daily duties).

3. Bodily pain (BP) intensity and its effect on the ability to engage in daily activities, including housework and out-of-home work.

4. General Health (GH) is a general assessment of your health.

5. Vitality (VT) means feeling full of strength and energy or, conversely, exhausted.

6. Social Functioning (SF) is defined by the degree to which a physical or emotional state limits social activity (communication).

7. Role-functioning due to emotional state (Role-Emotional – RE) involves assessing the extent to which the emotional state interferes with the performance of work or other daily activities (including large expenditures of time, reducing the amount of work, reducing its quality, etc.).

8. Mental Health (MH) – characterizes the mood, the presence of depression, anxiety, a general indicator of positive emotions.

Each answer is evaluated in points. When forming a scale, these points are added and mathematically calculated by standard formulas. Scores on each scale can range from 0 to 100, where 100 means complete health.

Results

The results of the analysis of responses of men and women in adulthood to the questionnaire SF-36 to determine the quality of life based on individual aggregate characteristics of the person in physical and mental terms at the time of completion of the questionnaire and during the last four weeks of life.

The questionnaire reflects the general well-being and the degree of satisfaction with those aspects of human life that are affected by health (Table 1).

For all scales, the Z-value was calculated in relation to the difference of the transformed value of each scale with its average value in the population to the standard deviation. When calculating the values used Z-values that correspond to the standards obtained for the US population (Brazier,1993).

Physical functioning, as an indicator that reflects the highest amount of daily physical activity in men 20-29 years is at the level of 99 points, which indicates that physical activity is not limited to health, this can be seen on the general condition scale where the figure is above average and is 77 points, which may indicate certain interrelated predictors determining this condition.

In the group of men aged 20-29, there was a charitable influence of role functioning due to emotional state (100 points), which minimally limits the daily activity of men. However, all this against the background of possible depression, anxiety, disturbances, which is reflected in the indicator of the scale of mental health, which is 69 points. Perhaps all this is happening against the background of a high manifestation of social functioning (91 points), where communication, spending time with friends, neighbors and reflects the degree to which their physical and emotional state limits them.

A decrease in physical function to 71 points is observed in the age group of men 50 years and older. Tendencies to decrease are observed in the indicators of general condition (60 points), although the role of physical functioning according to the scale is equal to 90 points, which indicates that daily activities are not limited to the physical health of men 50 years and older.

Table 1. Indicators of quality of life of men in the age plane SF-36, y.o

Quality of life scales for SF-36	20-29, n = 60		30-39, n = 60		40-49, n = 64		50 and more, n = 60	
	Mean	Z	Mean	Z	Mean	Z	Mean	Z
Physical functioning (PF)	99	0.63	93	0.37	92	0.33	71	-0.59
Role functioning (due to physical condition) (RP)	81	-0.01	83	0.05	80	-0.04	90	0.26
Pain intensity (BP)	86	0.45	79	0.15	82	0.28	73	-0.11
General condition (GH)	77	0.24	73	0.04	65	-0.36	60	-0.61
Vital activity (VT)	71	0.48	63	0.09	65	0.19	61	0.00
Social functioning (SF)	91	0.33	88	0.20	82	-0.07	89	0.24
Role functioning (due to emotional state) (RE)	100	0.57	82	0.02	84	0.08	67	-0.43
Mental Health (MH)	69	-0.32	69	-0.32	73	-0.10	70	-0.27

Table 2. Indicators of quality of life of women in the age plane SF-36, points

Quality of life scales for SF-36	20-29, n = 66		30-39, n = 52		40-49, n = 60		50 and more, n = 60	
	Mean	Z	Mean	Z	Mean	Z	Mean	Z
Physical functioning (PF)	91	0.28	91	0.28	82	-0.11	73	-0.50
Role functioning (due to physical condition) (RP)	75	-0.42	60	-1.07	82	-0.11	46	-1.68
Pain intensity (BP)	91	0.28	73	-0.50	87	0.11	74	-0.46
General condition (GH)	61	-1.03	72	-0.55	67	-0.77	50	-1.51
Vital activity (VT)	61	-1.03	63	-0.94	69	-0.68	50	-1.51
Social functioning (SF)	79	-0.24	83	-0.07	81	-0.15	63	-0.94
Role functioning (due to emotional state) (RE)	78	-0.28	87	0.11	78	-0.28	53	-1.38
Mental Health (MH)	65	-0.85	58	-1.16	72	-0.55	57	-1.20

In general, in the age groups of 30-39 years and 40-49 years there are similar downward trends, although with some heterochrony on certain scales.

The mental health rate of men of all ages is almost constant and is slightly above average, which coincides with men's responses to the Zapisochny's test, where more than 70% of men indicated that they live in a state of stress, but with age there is a slight tendency to increase the indicator, and men aged 20-39 years assess their mental health at 69 points, at 40-49 years at 73 and after fifty at 70 points.

Indicators of women's quality of life need to be considered in detail by age, as the episodicity and inconsistency of data to increase or decrease by decades have been determined. It is possible that the wave-like changes in indicators are related to the traditional functions assigned to women, due to which they feel the burden of problems caused by the specifics of social roles and statuses (Table 2).

The only subjective indicator based on the results of the survey, which is stable at different ages, is physical functioning. In 20-39 years, women feel quite well, as evidenced by a high rate (91 points), in 40-49 years and after 50 years, the rate decreases (82 points, 73 points).

Role functioning, which is largely due to physical condition in 20-29 years is 75 points, decreases in the age group of 30-39 years (60 points), at the age of 40-49 years is a high level – 82 points, and after 50 years is determined at the level of 46 points. Low scores on this scale previously indicate that daily activities and social position are significantly limited by the physical health of women 50 years and older.

The intensity of pain in women is quite high for all ages: 20-29 years (91 points), 30-39 years (73 points), 40-49 years (87 points), after fifty – 74 points. Low values of the scale indicate that pain for physical reasons significantly limits the physical activity of women, in particular in the age groups: 30-39 years and 50 years and older.

The indicator of role functioning (due to emotional state) is above the scale in the age range of 20-29 and 40-49 years (equally 78 points), in the age group of 40-49 years its value increases to 87 points, but after 50 years decreases to 53 points. This trend directly indicates the significant impact of emotional state, which interferes with and limits daily activities, in particular the performance of work or other normal daily activities, including the high cost of time to perform them, reducing the amount of work done, reducing its quality.

The tendency to increase the confidence of women in middle age can be traced in the indicator of social functioning, in women 20-29 years it was 79 points, in the age group 30-39 years it increases to 83 points, in 40-49 years is at 81 points. After the age of 50, women's social functioning decreases to 63 points, which means a significant restriction of social activity and social contacts, a decrease in the level of communication due to deteriorating health..

The indicator of the general condition determines the heterochronous curve of the obtained results with increase: in 20-29 years – 61 points, in 30-39 years – 72 points, in 40-45 years the indicator is 67 points and after 50 years – 50 points.

Correlation analysis revealed that in all age groups of men and women, the highest number of probable correlations is observed between general health and other scales. (fig.1).

With a decrease in the indicator (GH) in the age aspect, its influence on other indicators of quality of life increases.

In the age group of 20-29 years of men, there is a relationship between general health (GH) and physical func-

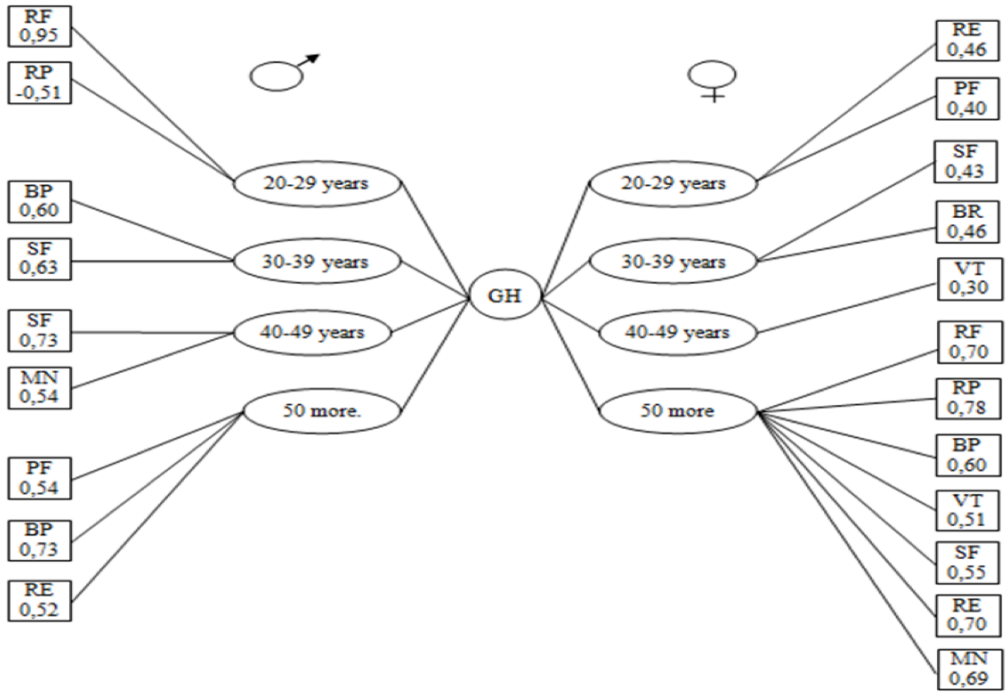

Fig.1. Correlation analysis of quality of life indicators of men and women

tioning ((PF) r = 0.95) and feedback on role functioning due to physical condition ((RP) r = -0.51).

In men 30-39 years of age, general health (GH) is likely to correlate with pain intensity ((BP) r = 0.60) and social functioning / activity (SF) r = 0.63.

In the group of men aged 40-49, it was found that general health (GH) has even greater correlations with social functioning ((SF) r = 0.73) and has an impact on mental health ((MH) r = 0.55).

In the group of men aged 50-59, this indicator has the highest number of probable correlations: with physical functioning (PF) r = 0.54), pain intensity ((PI) r = 0.73), emotional state ((ES) r = 0.52).

In women aged 20-29, general health (GH) is associated with emotional state ((ES) r = 0.46) and physical functioning ((PF) r = 0.40).

In women aged 30-39 years, there is a correlation between general health (GH) and social functioning (SF) r = 0.43 and pain intensity (PI) r = 0.46.

In the age group of women 40-49 years, a weak relationship was found between general health (GH) and vital activity ((VA) r = 0.30).

With a decrease in general health (GH) to 50 conventional units of women aged 50-59 have the highest number of probable correlations: with physical functioning (PF) r = 0.70), with role functioning due to physical condition ((PC) r = 0.78), pain intensity ((PI) r = 0.60), vital activity ((VA) r = 0.51), social functioning ((SF) r = 0.55), role functioning due to emotional state ((ES) r = 0.70), mental health ((MH) r = 0.69). This shows that the decline in general health significantly affects all indicators of quality of life of women over 50 years.

As can be seen in Fig.2, there are differences between the generalized indicators of quality of life, taking into account the age of men.

In all age groups, the quality of life is maintained at a stable high level, and the physical component of quality of life prevails over the psychological. However, in men 50 years

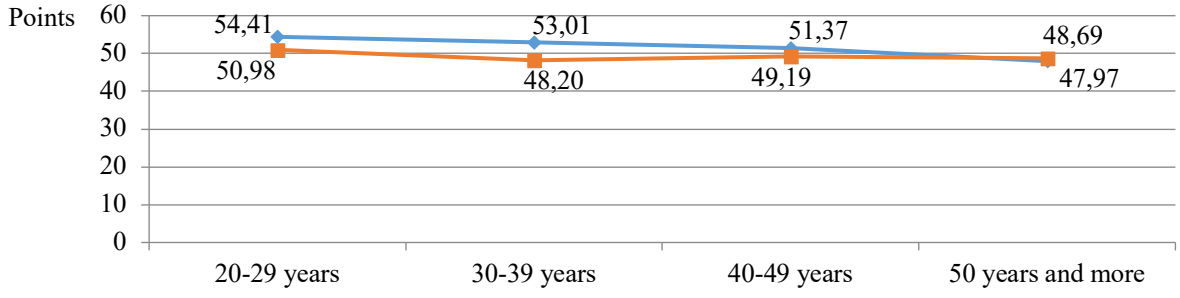

Fig. 2. Comparative rating of life quality of men considering age criteria

Physical health component (PH) Psycho health component (MH)

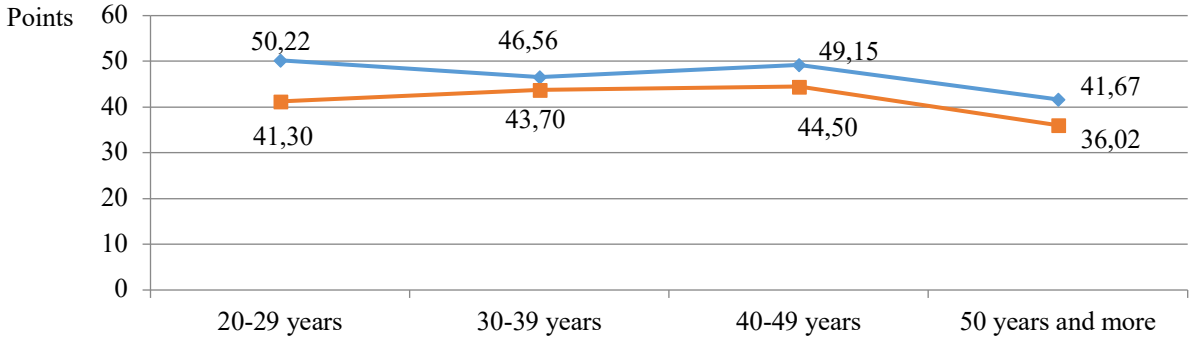

Fig. 3. Comparative rating of life quality of women considering age criteria

and older, the psychological component of health slightly dominates over the physical component.

In women of all ages, quality of life in relation to the physical component of quality of life prevails over the psychological component of quality of life (fig.3).

The overall health and mental health scales of both women and men are steadily declining with age. Deterioration of quality of life, ie physical and emotional factors of a person, which were not at a high level, and are important for a person and affect him – deteriorate and increase the negative impact on overall health.

It is possible to allocate separately the indicator of vital activity at women which during a life does not rise above average value and makes 61 points in 20-29 years, 63 points in 30-39 years, in 40-49 years grows to 69 points and after 50 makes 50 points.

The cardinal differences between men and women, the indicators of the SF-36 test, if we take into account the arithmetic mean, are observed in three scales – role functioning (due to physical condition), social functioning and role functioning (due to emotional state).

Thus, role functioning (due to physical condition) in men is 83.5 points, and in women 65.75, which is noted on the components of quality of life. Role functioning (due to emotional state) on a certain scale is also much lower in women – 74 points than in men – 83.25 points. The indicator of social functioning is 10 units higher in men (85.5 points) than in women (76.5 points).

Discussion

The high level of quality of life on the one hand is the problem of ensuring a safe life for people, life without war, oppression, discrimination, material restrictions, bureaucratic manipulation of the human person. The key is the problem of organizing such a life, in which a significant place is given to relationships between people, where along with work that brings pleasure, a rational role is played by rationally organized leisure, active recreation for physical improvement and health, and pleasure and good mood (WHO, 2013, 2018).

Cavill, Kahlmeier, Racioppi (2006) called the cost-benefit ratio of healthy lifestyle programs as 1 to 8. According to the World Health Organization, lack of proper physical activity leads to economic losses of 150-300 euros per person per year, which is directly correlated with quality life of the population (World Health Organization, 2007, 2008; World Health Organization Regional Office for Europe, 2013).

It is well known that leading a healthy lifestyle to maintain and promote health is five times more effective than medical and diagnostic procedures (Hallal, Andersen, Bull et alt., 2012; Gesell, Tesdahl, & Ruchman, 2012; Health-Enhancing Physical Activity, 2013; Hotting & Roder, 2013)

In Manual of physical activity for Americans (US Department of Health and Human Services, 2008; 2018) referring to the latest scientific data state that today about half of all American adults – 117 million people – have one or more chronic diseases preventable. However, almost 80 percent of adults do not meet the basic guidelines for aerobic and muscular activity. Lack of physical activity leads to $ 117 billion in annual health care costs and about 10% of premature mortality.

At the same time, the WHO document (2018): «Global Action Plan on Physical Activity for 2018-2030: more active people for a healthier world», mentions a plan to increase physical activity by 15% among adults and adolescents by 2030.

The WHO Global Plan of Action (2018) is defined with full awareness that countries are at different starting points in terms of efforts to increase physical activity and sedentary behavior. In addition, it recognizes that the priorities and preferences in relation to different types of physical activity in different conditions and in different population subgroups vary by culture, context and resources.

The established age features coincide with the data of previous sociological and scientific researches. According to research by foreign scientists, the contribution of various factors in maintaining good health is unequal. About 54% is a lifestyle in which negative factors / determinants play a significant role: unbalanced diet, smoking, lack of physical activity, excessive alcohol consumption (Cavill, Kahlmeier, & Racioppi, 2006; Kirk-Sanchez & McGough, 2014).

One of the most important indicators of health and well-being is life expectancy. Comparing WHO statistics for Ukraine and the EU, we note a difference in life expectancy of 10 years not in favor of Ukraine. The number of years of

dysfunctional life, ie when a person begins to fight diseases, also attracts attention. In Europe, this figure is 9-11, and in Ukraine 11-13 years.

Krutsevich, Pangelova, Trachuk and Ivanik (2019) examining the place of physical activity in the quality of life of different age groups note the lack of its volume and non-compliance with modern recommendations. This factor in combination with negative lifestyle habits affects the indicators of physical, mental and social health, which leads to a decrease in the quality of life and reduce its duration in men and women in modern society.

In our studies, we found that the general health of groups of women 50-59 years has the highest number of probable correlations: with physical functioning; with role functioning due to physical condition; pain intensity; vital activity; social functioning; role functioning due to emotional state; mental health.

Massalsky (2015) examining the quality of life of the population in Germany using the SF-36 questionnaire, notes the importance of paired relationships for maintaining health as an important factor in quality of life for both men and women. The author suggests that the differences between men and women are related not only to differential psychophysiology, but also to the social pressure of gender roles.

Content analysis of the latest documents of the World Health Organization on the strategy in the field of physical activity for the European region (World Health Organization, 2008, 2010, 2013, 2018) and analyzed the components of quality of life using the SF-36 questionnaire, allowed to determine their leading components. Thus, we observe that life roles and inherent social stereotypes are clearly expressed in the nature of behavior depending on biological sex. There are bursts of vital activity and social functioning in the period of life when most women become professional.

Krutsevich, Imas (2013) in the study of types of employment in leisure time also note the characteristics that are inherent in men and women in the age aspect, but the general trends are clearly defined. Among the common and significant types of employment for men were watching TV (56%), communicating with friends (37%), housework (36%), car repair (28%), reading the press (30.5%) and physical activity. (17%). Among women, household chores (83%), watching TV (46%), reading fiction (46.5%), communicating with friends (47%), raising children (44.5%), physical activity were singled out. (15.5%).

Role functioning due to emotional or physical condition directly depends on biological sex because the roles that society assigns to men are considered more valuable than women.

Conclusion

General health (GH) has been shown to be a systemic factor in the quality of life for males and females in terms of the number of correlations. The obtained results allowed to determine the feasibility and speed of implementation of preventive measures for men and women depending on the content of the defined scales. Decreased general health (GH) in men and women over the age of 50 significantly affects their quality of life, as evidenced by the large number of significant correlation coefficients. In women over 50 years of age, there is a sharp decrease in RP (role functioning due to physical condition) to 46 points, vital activity (VA) to 50 points, role functioning (due to emotional state) (ES) to 53 points. In men at this age, role functioning increases to 90 points, and social functioning (SF) to 89 points, which may indicate an uneven distribution of family and social functions in the lives of people of different sexes, overloading women with household chores, which prevents them from actively spending free time , affects the emotional state.

It should be noted that all our researches were conducted before the Covid-19 pandemic, and in this aspect need additional research and analysis, because there have been many reformatts in the world.

Conflict of interests

The authors state that there is no conflict of interests.

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ОЦІНКА ЗДОРОВОГО СПОСОБУ І ЯКОСТІ ЖИТТЯ ЧОЛОВІЧОГО І ЖІНОЧОГО НАСЕЛЕННЯ В СУЧАСНОМУ СУСПІЛЬСТВІ НА ОСНОВІ SF-36

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Мета дослідження – проаналізувати головні чинники якості життя чоловічого і жіночого населення в сучасному українському суспільстві.

Матеріали та методи. У соціологічних дослідженнях брали участь 482 чоловіків і жінок 20-60 років. Для вирішення поставлених завдань використовувалися наступні методи дослідження: аналіз та обробка спеціальної літератури та даних з Інтернету; педагогічне спостереження; анкетування (опитувальник SF-36), методи математичної статистики.

Результати. Результати власних досліджень свідчать, що чоловіче населення мало кращі показники якості життя за всіма шкалами опитувальника SF-36 в порівнянні з жіночим ($p < 0,05$). Показники якості життя вище середніх мали респонденти у віці 20-29 років за шкалами фізичного, рольового фізичного функціонування; больовий синдром в цій віковій групі не чинив істотного впливу на якість життя. Загальний стан здоров'я оцінювався вище середнього рівня респондентами 20-29 років і 30-39 років незалежно від статі, для них були характерні високі показники шкал соціальної активності та життєздатності.

Висновки. Встановлено, що показник «загальний стан здоров'я» є системоутворюючим чинником якості життя для чоловічого і жіночого контингенту за кількістю коре-

ляційних зв'язків. Отримані результати дозволили визначити доцільність та швидкість впровадження превентивних заходів для чоловіків і жінок в залежності від контенту визначених шкал. Зниження показника (GH) загального стану здоров'я у чоловіків і жінок після 50-ти років значно впливає на складові якості їх життя, про що свідчить велика кількість значущих коефіцієнтів кореляції. У жінок після 50 ти років відмічається різке зниження показника RP (рольове функціонування, обумовлене фізичним станом) до 46 балів, життєвої активності (VT) до 50 балів, рольового функціонування (обумовленого емоційним станом) (RE) до 53 балів. У чоловіків в цьому віці рольове функціонування підвищується до 90 балів, а соціальне функціонування (SF) до 89 балів, що може свідчити про нерівномірне розподілення сімейних і соціальних функцій в житті осіб різної статті, перевантаження жінок побутовими справами, що заважає їм активно проводити вільний час, впливає на емоційний стан.

Ключові слова: якість життя, фізична активність, здоров'я, особи зрілого віку.

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ORIGINAL SCIENTIFIC ARTICLE

PERSONALITY DIMENSIONS DRIVE ACHIEVEMENT LEVELS OF CRICKET PLAYERS: A STUDY ON THE FIVE-FACTOR MODEL

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Abstract

Aim of study. Cricket is considered a mental game among elite level performers. Specific personality traits characterize elite-level endeavors and high-potential athletes. Previous studies on psychological characteristics of cricket players reported that more skilful cricketers deal more consistently and effectively with their emotions and pressure. Therefore the objective of the present study was analysis of personality traits of cricket players at national, state, and district levels with the help of Five-Factor Model.

Materials and Methods. Sample size included 120 male subjects (60 batsmen and 60 pace bowlers) recruited from cricket academies/training facilities/competition venues in India. Big-Five Personality Inventory (BFI-44) was utilized to measure personality dimensions. Differences among personality variables at different competition levels of batsmen and pace bowlers were analyzed using One-way MANOVAs.

Results. National level pace bowlers scored high on openness (national vs. district, Mean Difference (MD) = 4.25, $p < 0.05$; national vs. state, MD = 2.75, $p < 0.05$) and agreeableness (national vs. district, MD = 4.70, $p < 0.05$; national vs. state, MD = 3.40, $p < 0.05$). Similarly, national level batsmen scored high on extraversion (national vs. district; MD = 4.350; $p < 0.05$), agreeableness (national vs. state; MD = 3.70; $p < 0.05$), and conscientiousness (national ns. district, MD = 3.25, $p < 0.05$; national vs. state, MD = 3.450, $p < 0.05$).

Conclusions. National level pace bowlers exhibited greater agreeableness and openness whereas similar level batsmen showed greater agreeableness, openness, extraversion, and conscientiousness as compared to lower levels of participation. Since the concept of "Form" demands multi-factorial approach in the game of cricket, other facets of personality such as focus, mental toughness, self-belief, optimism etc. should also be explored for effective talent identification and coaching in cricket.

Keywords: Personality, Big-Five, Batsmen, Pace Bowlers, BFI-44.

Introduction

Elite performance in sports is a multi-factorial outcome and an athlete requires both skill sets and psychological attributes to excel in their respective sports (Weissensteiner et al., 2012). Self-esteem, low neuroticism, conscientiousness, mental toughness, resilience, perfectionism, self-belief, confidence, and coping skills (Bojanić et al., 2019; Weissensteiner et al., 2009) are all but a few most important factors characterizing the elite players.

Cricket is the second most popular sport in the world, after soccer (Ribeiro et al., 2012). Apart from physical and physiological prowess, elite level cricket players possess great "mental strength" to withstand long hours of play and cope with the pressure of fatigue, intimidating opposition, and crazy fans (Baumeister & Showers, 1986). Whether batting, bowling, or fielding, a player's psychological strength has been identified by coaches, players, and commentators as a critical ingredient for winning cricket matches.

Previous studies on psychological characteristics of cricket players reported that more skilful cricketers deal more consistently and effectively with their emotions and pressure (Durand-Bush & Salmela, 2002; Gould et al., 2002; Orlick & Partington, 2016). Also, they train and develop their minds to perform more effectively and consistently throughout the game. An important consideration is the determination of future performance through the possibility that elite athletes possess personality characteristics that make them successful in their particular sport (Allen et al.,

2011). Thus identification of these personality traits proves to be a plausible area that might assist in discovering trainable attributes and screening of promising athletes for superior performance in cricket at elite level. In recent years, Five Factor Model (FFM) of personality has gained considerable traction in the identification and evaluation of personality traits among players at different achievement levels in various contexts such as organized sports achievements, academic performance and professional success (Allen & Laborde, 2014).

Aim of study. Although the role of big five personality traits has been extensively studied in competitive success in other sports; there are limited research evidences for their role in elite-level cricket performance. Therefore, our purpose was to investigate the difference in big five personality traits at different levels of pace bowlers and batsmen (District, State and National level).

Material and Methods

Study Participants

A total of 120 male cricket players (60 Batsmen, 60 Pace bowlers) of age group 18-25 years were purposively selected from various cricket academies/training facilities/ competition venues in India. As per the objective of the study, 20 participants were selected from each of the three levels of participation (District, State, and National) in both batsmen and pace bowlers category. The objectives of the study were explained to them and all the participants agreed to voluntarily participate in the study and provided their written consent. The study was conducted in accordance with the guidelines of the World Medical Association Declaration of Helsinki, 2013.

Study Organization

In the present study, 44-item Big Five Personality Inventory (BFI-44), originally developed by Oliver P. John and Sanjay Srivastava (John & Srivastava, 1999) was used. This psychological inventory measures five dimensions of personality: Openness to experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Before filling up the questionnaire, the test administrator explained each item of the BFI-44 thoroughly and responded to the doubts of the participants, if any. Every participant was asked to answer a set of 44 items with each item being responded on a 5-point Likert scale ranging from "Disagree Strongly (1)", "Disagree a little (2)", " Neither agree nor disagree (3)", "Agree a little (4)", to "Agree Strongly (5)". Some of the items were then reverse-scored to compute overall score of the BFI-44 for an individual player. Sufficient time was given to the participants to record their responses in the inventory. All the assessments were carried out at their respective training places by the test administrator who was blind to the allocation of the intervention throughout the study.

Statistical analysis

The statistical analysis was performed using SPSS v22 (IBM inc., Chicago, USA). The descriptive characteristics included mean ± SD of all the categories. According to BFI-44, personality is considered a latent factor that includes traits such as extraversion, agreeableness, conscientiousness, neuroticism and openness to experience. Since this study was designed as a comparative analysis of personality characteristics among different levels of cricket players, MANOVA (Multivariate analysis of variance) was employed to compare the group means among both the batsmen and pace bowlers groups at 3 levels of participation: district, state, and national. $P < 0.05$ was considered statistically significant.

Results

The descriptive characteristics (mean ± standard deviation) of both the categories i.e. batsmen and pace bowlers at three different levels are presented in table 1. The results of multivariate tests performed on big five personality variables at different levels of pace bowlers and batsmen are presented in table 2. The equality of covariance matrices was assessed using the Box's M test which yielded statistical insignificance. This means that the covariance matrices were equal, which is an important assumption for the application of multivariate analysis. The error variances of all the big five personality variables were also equal for both pace bowlers and batsmen group as evaluated by Levene's test of homogeneity of error variances (Table 3).

Table 1. Descriptive statistics of big five personality variables among pace bowlers and batsmen at different levels

	Variable	Statistics	Pace Bowler			Batsmen		
			District	State	National	District	State	National
Big Five Personality Inventory	Openness	Mean	32.05	33.55	36.30	32.00	33.05	35.20
		SD*	2.70	3.78	3.48	6.17	4.31	4.20
	Extraversion	Mean	25.80	27.90	28.60	24.55	27.35	28.90
		SD*	3.43	4.95	2.78	3.43	3.38	4.40
	Agreeableness	Mean	29.40	30.70	34.10	29.20	27.35	31.05
		SD*	5.56	4.35	4.13	3.69	4.17	2.70
	Conscientiousness	Mean	31.20	32.40	33.95	29.00	28.80	32.25
		SD*	3.43	5.72	4.84	2.64	3.79	3.91
	Neuroticism	Mean	19.80	21.95	23.50	23.65	22.90	26.90
		SD*	3.36	4.70	5.53	4.31	4.39	4.10

*SD: Standard Deviation

Table 2. Multivariate statistics for Big Five Personality variables of Pace Bowlers and Batsmen at different levels

Group	Box's M Test		Wilk's λ			η_p^2	Power
	F	P value*	Value	F	P value*		
Pace Bowlers	1.104	0.317	0.543	3.782	**0.000**	0.263	0.994
Batsmen	1.268	0.149	0.502	4.362	**0.000**	0.292	0.998

F: F-statistics; η_p^2: Partial Eta Squared; *P-value in bold face indicates significance at 0.05 level of significance

Table 3. Univariate between-subject tests for big five personality variables among pace bowlers and batsmen

Dependent Variable	Group	Levene's Test		F	P value*	ηp2	Power
		F	P value				
Openness	Pace Bowlers	1.245	0.296	8.274	**0.001**	0.225	0.953
	Batsmen	0.841	0.436	2.148	0.126	0.070	0.422
Extraversion	Pace Bowlers	2.442	0.096	2.896	0.063	0.092	0.544
	Batsmen	1.339	0.270	6.864	**0.002**	0.194	0.908
Agreeableness	Pace Bowlers	1.841	0.168	5.284	**0.008**	0.156	0.816
	Batsmen	2.450	0.095	5.354	**0.007**	0.158	0.822
Conscientiousness	Pace Bowlers	2.915	0.062	1.681	0.195	0.056	0.340
	Batsmen	1.791	0.176	6.153	**0.004**	0.178	0.874
Neuroticism	Pace Bowlers	2.566	0.086	3.239	0.047	0.102	0.595
	Batsmen	0.247	0.782	4.964	0.010	0.148	0.790

F: F-statistics; η_p^2: Partial Eta Squared; *Bonferroni correction to the p-value. Corrected p-value=0.05/5; P-value in bold faces indicates significance at 0.01 level of significance

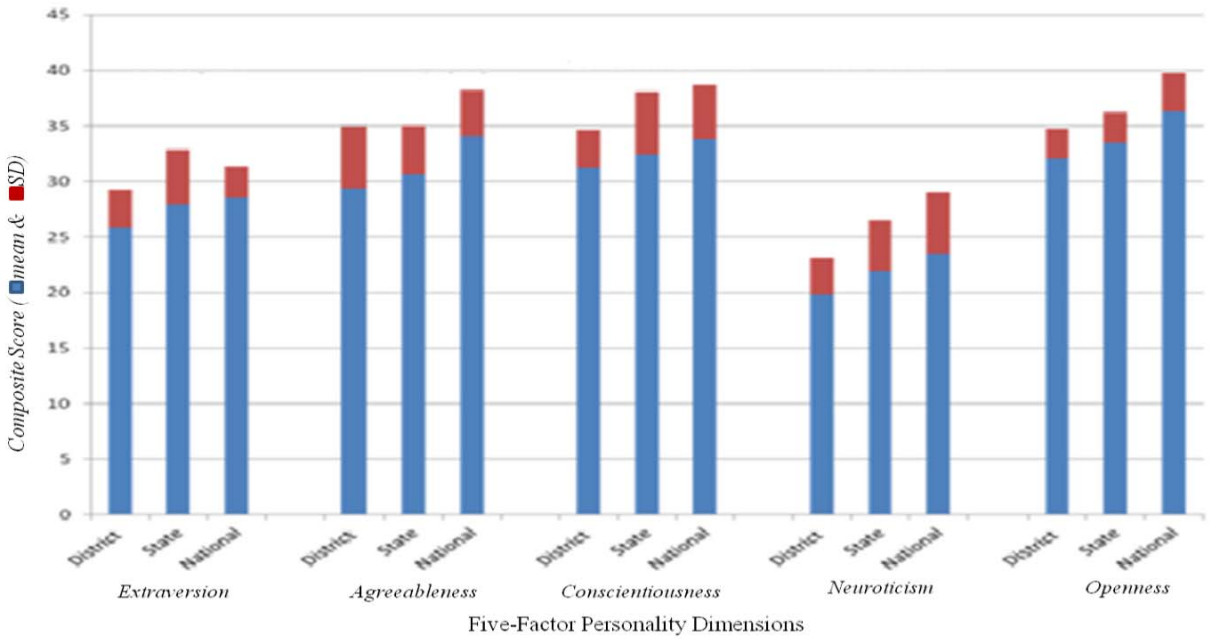

Fig. 1. Graphical representation of various psychological dimensions of Pace bowlers

The one-way MANOVA test was statistically significant for pace bowlers ($F_{(10,106)}$ =3.782; $p < 0.05$; Wilk's $\lambda = 0.543$; partial $\eta^2 = 0.263$; Table 2) indicating that the pace bowlers at district, state, and national levels had differences in big five personality variables. Similarly, one-way MANOVA test for batsmen resulted in statistical significance ($F_{(10,106)} = 4.362$; $p < 0.05$; Wilk's $\lambda = 0.502$; partial $\eta^2 = 0.292$; Table 2) and it meant that batsmen at district, state, and national levels had differences in big five personality variables. Univariate between-subject tests were employed to determine those big five personality variables that produced significant differences among pace bowlers and batsmen at different levels.

Openness: In openness, there was significant difference among district, state, and national level pace bowlers ($F_{(2,57)} = 8.274$, $p < 0.01$, partial $\eta^2 = 0.225$; Table 3). Post-Hoc comparison suggested that national level pace bowlers scored high in openness as compared to district level (mean difference = 4.25; $p < 0.05$; 95% CI: 2.128-6.372; Table 4; Figure 1) and state level (mean difference = 2.75; $p < 0.05$; 95% CI: 0.628-4.872; Table 4) pace bowlers. No significant difference was observed between district and state level

Table 4. Post-Hoc pairwise comparisons for Pace bowlers and batsmen at different levels

Variable	Level (I)	Level (J)	MD	P value*	95% C.I.
Pace Bowlers					
Openness	District	State	-1.50	.162	0.662-3.622
		National	-4.25	.000	2.128-6.372
	State	National	-2.75	.012	0.628-4.872
Extraversion	District	State	-2.10	.088	0.325-4.525
		National	-2.80	.024	0.375-5.225
	State	National	-0.70	.565	1.725-3.125
Agreeableness	District	State	-1.30	.388	1.690-4.290
		National	-4.70	.003	1.710-7.690
	State	National	-3.40	.027	0.410-6.390
Conscientiousness	District	State	-1.20	.428	1.811-4.211
		National	-2.75	.073	0.261-5.761
	State	National	-1.55	.307	1.461-4.561
Neuroticism	District	State	-2.15	.146	0.774-5.074
		National	-3.70	.014	0.776-6.624
	State	National	-1.55	.293	1.374-4.474
Batsmen					
Openness	District	State	-1.050	.507	2.102-4.202
		National	-3.200	.047	0.048-6.352
	State	National	-2.150	.177	1.002-5.302
Extraversion	District	State	-2.800	.022	0.417-5.183
		National	-4.350	.001	1.967-6.733
	State	National	-1.550	.198	0.833-3.933
Agreeableness	District	State	1.850	.107	0.414-4.114
		National	1.850	.107	0.414-4.114
	State	National	-3.700	.002	1.436-5.964
Conscientiousness	District	State	.200	.857	2.011-2.411
		National	-3.250	.005	1.039-5.461
	State	National	-3.450	.003	1.239-5.661
Neuroticism	District	State	.750	.581	1.952-3.452
		National	-3.250	.019	0.548-5.952
	State	National	-4.000	.004	1.298-6.702

MD = Mean Difference; CI = Confidence Interval; *P-values in bold face indicate statistical significance at 0.05 level of significance

pace bowlers. But among batsmen, univariate test yielded insignificant results ($F_{(2,57)} = 2.148$, $p > 0.01$, partial $\eta^2 = 0.07$; Table 3) suggesting that the batsmen at different levels were indifferent although pairwise comparison showed difference between national vs. district level batsmen (mean difference = 3.20; $p < 0.05$; 95% CI: 0.048-6.352; Table 3; Figure 1).

Extraversion: In extraversion, pace bowlers were found indifferent among district, state, and national level ($F_{(2,57)} = 2.896$, $p > 0.01$, partial $\eta^2 = 0.092$; Table 3; Figure 1). But batsmen at different levels differed significantly ($F_{(2,57)} = 6.864$, $p < 0.01$, partial $\eta^2 = 0.194$; Table 3). Post-Hoc comparison suggested significant difference between district vs. state level (mean difference = 2.80; $p < 0.05$; 95% CI: 0.417-5.183; Table 4) and between district vs. national level (mean difference = 4.350; $p < 0.05$; 95% CI: 1.967-6.733; Table 4; Figure 2). There was no difference between state vs. national level batsmen on extraversion (Table 3).

Agreeableness: Significant difference among district, state, and national level pace bowlers was observed on agreeableness ($F_{(2,57)} = 5.284$, $p < 0.01$, partial $\eta^2 = 0.156$; Table 3). Post-Hoc comparison suggested that national level pace bowlers scored high on agreeableness as compared to district level (mean difference = 4.70; $p < 0.05$; 95% CI: 1.710-7.690; Table 4) and state level (mean difference = 3.40; $p < 0.05$; 95% CI: 0.410-6.390; Table 4) pace bowlers (Figure 1). No significant difference was observed between district and state level pace bowlers. Similarly, batsmen at different levels also differed significantly ($F_{(2,57)} = 5.354$, $p < 0.01$, partial $\eta^2 = 0.158$; Table 3) on agreeableness. Post-hoc comparison among batsmen yielded significant difference between national vs. state level batsmen (mean difference = 3.70; $p < 0.05$; 95% CI: 1.436-5.964; Table 4; Figure 2). Batsmen at district vs. national and district vs. state levels showed no difference (Table 4).

Conscientiousness: In conscientiousness, no statistically significant difference was observed among district, state, and

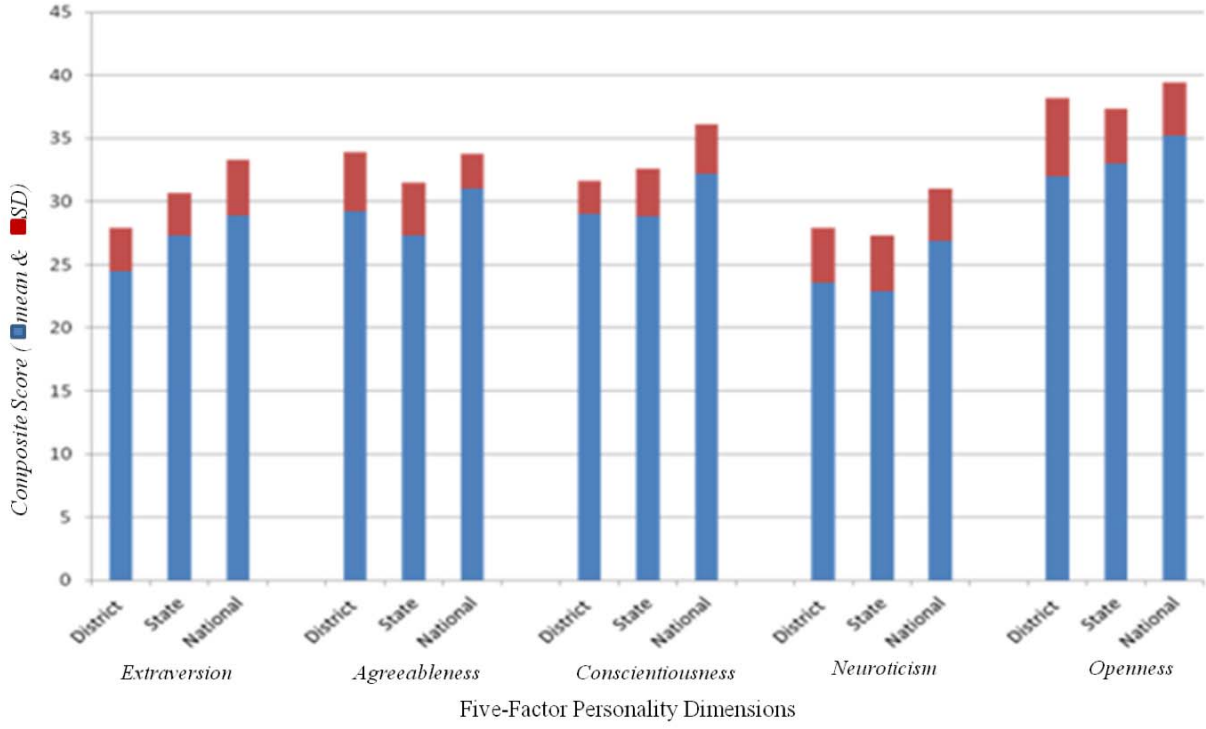

Fig. 2. Graphical representation of various psychological dimensions of batsmen.

national level pace bowlers ($F_{(2,57)}$ = 1.681, p > 0.01, partial η^2 = 0.056; Table 3; Figure 1). But batsmen at different levels differed significantly ($F_{(2,57)}$ = 6.153, p < 0.01, partial η^2 = 0.178; Table 3). Post-Hoc comparison suggested significant difference between district vs. national level (mean difference = 3.25; p < 0.05; 95% CI: 1.039-5.461; Table 4; Figure 2) and between state vs. national level (mean difference = 3.450; p < 0.05; 95% CI: 1.239-5.661; Table 4; Figure 2). There was no difference between district vs. state level batsmen (Table 4).

Neuroticism: Again, pace bowlers did not differ significantly in univariate between-subject test on neuroticism ($F_{(2,57)}$ = 3.239, p > 0.01, partial η^2 = 0.102; Table 3; Figure 1). Although very close to being significant, but batsmen also did not differ significantly ($F_{(2,57)}$ = 4.964, p > 0.01, partial η^2 = 0.148; Table 3) at different levels (Figure 2).

Discussion

Behavioral researchers attribute the inter-individual differences in performance among athletes to their underlying personality characteristics (Mosalaei et al., 2014; Sternberg, 2019). During competitions, athletes inevitably expose the psychological core of their personality and this psychological core drives their athletic behavior (Mosalaei et al., 2014; Weinberg & Gould, 2011). Allen et al. (2011) stated that the five-factor model of personality can help distinguish various levels of athletic involvement (Allen et al., 2011). Therefore it was hypothesized that cricket players at different levels of participation (district, state, national) possess distinct personality traits as per Five Factor Model (FFM) of personality. Big Five Personality Inventory (BFI-44) was utilized to assess the personality of cricket players at different levels.

The results of present study suggested a significant difference in dependent variables (Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness) among pace bowlers and batsmen at different levels. Specifically, the big five personality traits explained 45.7% and 49.8% of the variance between district, state, and national level pace bowlers and batsmen respectively (Wilk's λ; Table 2). National level pace bowlers scored high in openness. Openness is characterized by imagination, knowledge seeking curiosity, risk-taking attitude, unconventionality, and creativity (George & Zhou, 2001; John & Srivastava, 1999). Apart from skill set, the cricket players at national level are generally older and would have trained for more years as compared to lower competition level cricket players, and hence they tend to show improvisation in basic cricketing skills (Baker et al., 2007; Schorer & Baker, 2009). As they have had more exposure to stressful match situations, they tend to develop better coping skills (Tok, 2011).

Pace bowlers are real workhorses who consistently sprint and explode during bowling and in-between their spells generally field at the boundary lines (Petersen et al., 2010, 2011; Vickery et al., 2018). As the competitive levels increase, the physiological and psychological demands also surge high. Also, the pace bowlers tend to sustain musculoskeletal injuries, hence they engage in rehabilitation program apart from regular training. This may affect their social behavior inside and outside the stadia. Although loquacious, they are often perceived as shy, self-centered, and drained athletes. On the other hand, with an increase in competitive levels, batsmen tend to be profoundly chirpy, vocal, sociable, and cheerful (Mosalaei et al., 2014; Stricker et al., 2019; Trninić et al., 2016) as suggested by our findings on extraversion among batsmen (Table 4).

National-level batsmen exhibited greater conscientiousness as compared to district or state level (Table 3). Although not significant statistically, national-level pace bowlers showed greater conscientiousness as compared to district level (p=0.073; table 4). Cricket players are often driven by multidimensional perfectionism: perfectionistic strivings, and perfectionistic concerns (Hill et al., 2010), thus always striving for ideal stroke-playing, delivering ideal ball, tactical prowess and have fear of committing mistakes. And Waleriańczyk & Stolarski (2021) suggested that athletes having perfectionistic strivings tend to score high in conscientiousness and those having perfectionistic concern correlate negatively with emotional stability (Waleriańczyk & Stolarski, 2021). Also, perfectionistic strivings have an association with other dimensions of big five personality too. Openness follows positive correlation with perfectionistic striving whereas agreeableness and extraversion have inconsistent association. Neuroticism has been mostly negatively correlated to perfectionistic strivings (Stricker et al., 2019).

Cricket being a team game always demands optimism, liveliness, energy, cooperation, and camaraderie (Nia & Ali Besharat, 2010) and hence national level pace bowlers and batsmen exhibited high agreeableness as reported by the results of present study. Also, agreeableness and conscientiousness have been associated with age of athletes too. Thus national players being significantly older tend to show greater agreeableness and conscientiousness as compared to district or state players (Trninić et al., 2016). Although pace bowlers and batsmen at different levels did not differ significantly on neuroticism (Table 4), post-hoc analysis revealed national-level pace bowlers and batsmen being less neurotic as compared to district and state players (Table 4). Lower neuroticism is associated with higher achievement levels, coachability, motor fitness, and overall "team-man" concept (Trninić et al., 2016). Team game athletes experience low neuroticism because they tend to share responsibility and report greater emotional stability as compared to individual games athletes.

Conclusions

The present study is considered a novel attempt to characterize personality traits of cricket players at different levels of competition based on the dimensions of Five Factor Model (FFM). The study indicates that national level pace bowlers exhibited greater agreeableness and openness whereas national level batsmen showed greater agreeableness, openness, extraversion, and conscientiousness as compared to inferior levels of participation. Since the game of cricket demands multi-factorial approach to fully elucidate the concept of "Form", other facets of personality such as focus, mental toughness, self-belief, optimism etc. should also be explored in an attempt to optimize the salient inherent and trainable traits that should be focused in talent identification and coaching in cricket.

Although this study presents delightful findings, small sample size is considered a potential limitation. Also, age of the players was not recorded and analyzed, although the age category for this study was 18-25 years. The findings of this study must be interpreted in the light of these limitations because age and hence maturation brings significant improvements in skill acquisition and skilful players exhibit greater self-confidence, resilience, focus, and coping skills.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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ВПЛИВ ОСОБИСТІСНИХ ХАРАКТЕРИСТИК НА РІВЕНЬ ДОСЯГНЕНЬ ГРАВЦІВ В КРИКЕТ: ДОСЛІДЖЕННЯ П'ЯТИФАКТОРНОЇ МОДЕЛІ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 4 табл., 2 рис. 26 джерел.

Мета дослідження. Крикет вважається ментальною грою серед спортсменів елітного рівня. Специфічні риси особистості характерні для професійних спортсменів і спортсменів з високим потенціалом. Попередні дослідження психологічних характеристик гравців в крикет показали, що більш досвідчені гравці в крикет послідовніше й ефективніше справляються зі своїми емоціями і тиском. Тому метою даного дослідження був аналіз особистісних якостей гравців в крикет на національному, державному та районному рівнях за допомогою п'ятифакторної моделі.

Матеріали та методи. У дослідженні прийняли 120 чоловіків (60 гравців з битою і 60 боулерів), набраних в академіях крикету / тренувальних центрах / місцях проведення змагань в Індії. Опитувальник великої п'ятірки (BFI-44) використовувався для вимірювання параметрів особистості. Відмінності між особистісними змінними на різних

рівнях змагань у гравців з битою і боулерів проаналізовані за допомогою одностороннього MANOVA.

Результати. Боулери національного рівня отримали високі бали по відкритості (національний і районний, середня різниця (MD) = 4,25, p < 0,05; національний і штатний, MD = 2,75, p <0,05) і дружелюбності (національний або районний, MD = 4,70, p < 0,05; національний проти штату, MD = 3,40, p < 0,05). Так само гравці з битою національного рівня отримали високі бали по екстраверсії (національний проти округу; MD = 4,350; p < 0,05), поступливості (національний проти штату; MD = 3,70; p < 0,05) і сумлінності (національний проти округу, MD = 3,25, p < 0,05; національний проти штату, MD = 3,450, p <0,05).

Висновки. Боулери національного рівня демонстрували більшу поступливість і відкритість, тоді як гравці з битою аналогічного рівня демонстрували більшу поступливість, відкритість, екстраверсію і сумлінність у порівнянні з більш низькими рівнями участі. Оскільки концепція «форми» вимагає багатофакторного підходу в грі в крикет, інші аспекти особистості, такі як зосередженість, психологічна стійкість, впевненість в собі, оптимізм тощо, так само повинні бути досліджені для ефективного виявлення талантів і підвищення ефективності тренування в крикеті.

Ключові слова: особистість, велика п'ятірка, бетсмени, боулери, BFI-44.

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ORIGINAL SCIENTIFIC ARTICLE

PREREQUISITES FOR THE DEVELOPMENT OF PREVENTIVE MEASURES AGAINST OFFICE SYNDROME AMONG WOMEN OF WORKING AGE

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Abstract

The purpose of the article is to study prerequisites for the development of preventive measures against office syndrome among women of working age.

Material and methods. The research involved 52 female office employees 21 to 57 years old.

Results. The extended clustering of the original data using EM method with the performance of V-fold crosschecking has shown that female office employees are clearly divided into two clusters depending on the manifestation of office syndrome. Despite our assumptions, their division does not depend on age or length of service in the office, but on the manifestation of office syndrome and behavioral characteristics in the work process. Women assigned to different clusters are characterized by statistically significant ($p < 0.05$) differences between the level of pain in the joints and spine. The research has found that among female office employees with increased musculoskeletal pain, there are statistically significantly ($p<0.05$) more women with significant overweight and spinal diseases. They are less likely to take active breaks when working at a computer and a larger percentage of them use information technology for entertainment purposes outside the office for 3-4 hours a day. However, a smaller percentage of them work with a PC for more than 7 hours a day. Women with predominant musculoskeletal pain differ in their lifestyle and point to fundamentally different reasons that stop them from taking measures to prevent the risk of occupational diseases. In particular, among female office employees with no office syndrome, a statistically significant ($p<0.05$) larger share does not need to expand knowledge about the organization of health care in the office and among them the share of those who lead a passive lifestyle predominates.

Conclusions. Thus, these women are potentially at risk of developing office syndrome and, with the absence of preventive measures, are expected to move to the cluster of women with signs of office syndrome. The results of the research indicate the need for different approaches to planning health measures in the work environment, depending on the presence of office syndrome and the level of their responsible attitude to health in the work process.

Keywords: musculoskeletal pain, syndrome, posture, spine, prevention.

Introduction

The development of science, improvement of medical services and the emergence of new reproductive technologies have contributed to the spread among Ukrainian women of the European demographic trend of increasing birth age, including the first birth (Aksonova, 2019). Thus, according to the State Statistics Service of Ukraine, the average age of a mother at the birth of the first child was 25.9 years old (from 23.4 in Zakarpatska region to 29.2 in Kyiv). The desire to achieve career success, to succeed as a person, the lack of a flexible work schedule along with the reduction in the number of public institutions for children, as well as the social insecurity of young families are the reasons that often force women to delay childbearing to 30-35 years old or more. In turn, it creates a problem of ensuring the uncomplicated

course of pregnancy after 35 years (Zhabchenko et al., 2019). Therefore, in order to bear, give birth and then raise a healthy child, a woman must maintain her own health and take care of herself.

On the other hand, Ukraine is carrying out a pension reform, one of the steps of which is the rise of the retirement age, including for women (Haiduk, 2018). Increasing competition in the labor market, labor intensity and the need for continuous professional development require significant energy, physical, emotional, intellectual costs, and, consequently, good health.

It is well-known fact that the disease is easier to prevent than to cure. Therefore, experts have intensified their search for the most effective forms of supporting the health of women of working age (Kashuba et al., 2019, 2020). However, only a high level of self-determination of women in health care, i.e. a responsible attitude to maintaining their health, may allow realizing their work and personal potential and may guarantee a job in the labor market until retirement age.

In the information age, the share of people involved in mental work is growing steadily. Currently, many women work in the office. Until recently, office work was considered the most acceptable for women and did not involve any health risks. However, it is now confirmed that office workers, under the influence of adverse factors of the working environment, are prone to office syndrome, which experts understand as a number of disorders, including posture disorders, musculoskeletal pain, carpal tunnel syndrome, headaches, obesity, etc. (Savytska, 2020).

Taking into account the exceptional importance of health as a vital resource, in our opinion, the issues of maintaining the health of female office employees and formation of self-determining behavior in health have become unprecedentedly urgent and need to be addressed immediately.

The purpose of the research is to study prerequisites for the development of preventive measures against office syndrome among women of working age.

Material and methods

Study Participants

The research involved 52 female office employees 21 to 57 years old.

Study Organization

The study involved theoretical research methods, online surveys, assessment of the level of musculoskeletal pain using a visual-analog scale (VAS technique) (Tomilina, Byshevets, 2018; Kashuba, Stepanenko et al., 2020), statistical analysis using cluster (Britvikhin et al., 1994), frequency and comparative evaluation.

The survey, developed using Google Forms, was distributed via social networks and using the most popular messengers Viber and Telegram. It should be noted that the use of Google Forms made it possible to distribute the survey via social networks and messengers, to get the results of the survey in MS Excel spreadsheet and view statistical data analysis online, which greatly simplified the survey procedure and allowed to involve a wider range of people.

Statistical Analysis

The STATISTICA software package developed by StatSoft to perform statistical analysis was used for data processing.

The division of female office employees into subgroups was carried out using the module "Generalized EM and k-means cluster analysis", available in the module of cluster analysis of the software package STATISTICA. The research also used extended EM clustering (probability-based clustering). This allowed dividing the set of obtained data, which were both continuous and categorical variables, into clusters. The best solution to the task of clustering was provided by performing a V-fold crosscheck, which allowed automating the process of selecting the optimal number of clusters according to the observed data. In addition, the application of this module allowed determining the presence of statistically significant differences at a given level of significance between all indicators of female office employees assigned to different clusters.

The hypothesis H0 about the conformity of data to the normal distribution law was checked using the Shapiro-Wilk consistency criterion W (Kashuba, Tomilina et al., 2020). Since the statistical processing revealed that the samples formed from the studied indicators did not correspond to the normal distribution law, the average indicators of work experience, age and intensity of musculoskeletal pain are presented in the form of median and interquartile range Me (25; 75).

The comparative analysis between the level of pain in the spine and joints was performed using non-parametric Mann-Whitney test (Byshevets et al., 2019), and the comparative analysis between categorical variables – using the Pearson correlation coefficient and Fisher's angular criterion φ (Byshevets, Denysova et al., 2019a; Byshevets, Shynkaruk et al., 2019b).

The level of statistical significance was taken as $\alpha=0.05$ ($p<0.05$).

The value of p was rounded to the thousandth, and in the case when the value of p-level was less than 0.001, the value of p is given in the standard form.

Results

During the development of preventive measures against the risk of office syndrome among women of working age and the formation of a responsible attitude to health when working at a computer, the results of the survey of female office employees were subject to clustering. The preliminary analysis revealed female office employees are clearly divided into two clusters. Figure 1 shows the first cluster is formed by slightly older female office employees with less experience of a PC user, who have pain in the joints and spine, and the second – by younger women who have a bigger work experience, but are characterized by less pronounced musculoskeletal pain (Fig. 1).

The first cluster included 13 women with an average age of 46.5 (40.0; 49.5) and experience of a PC user 13.0 (7.5; 20.0) years. The second, more numerous cluster, consisted of 39 women with an average age of 40.0 (38.0; 42.0) and experience of a PC user 17.0 (14.0; 20.0) years. The statistical processing of the research results has shown that women

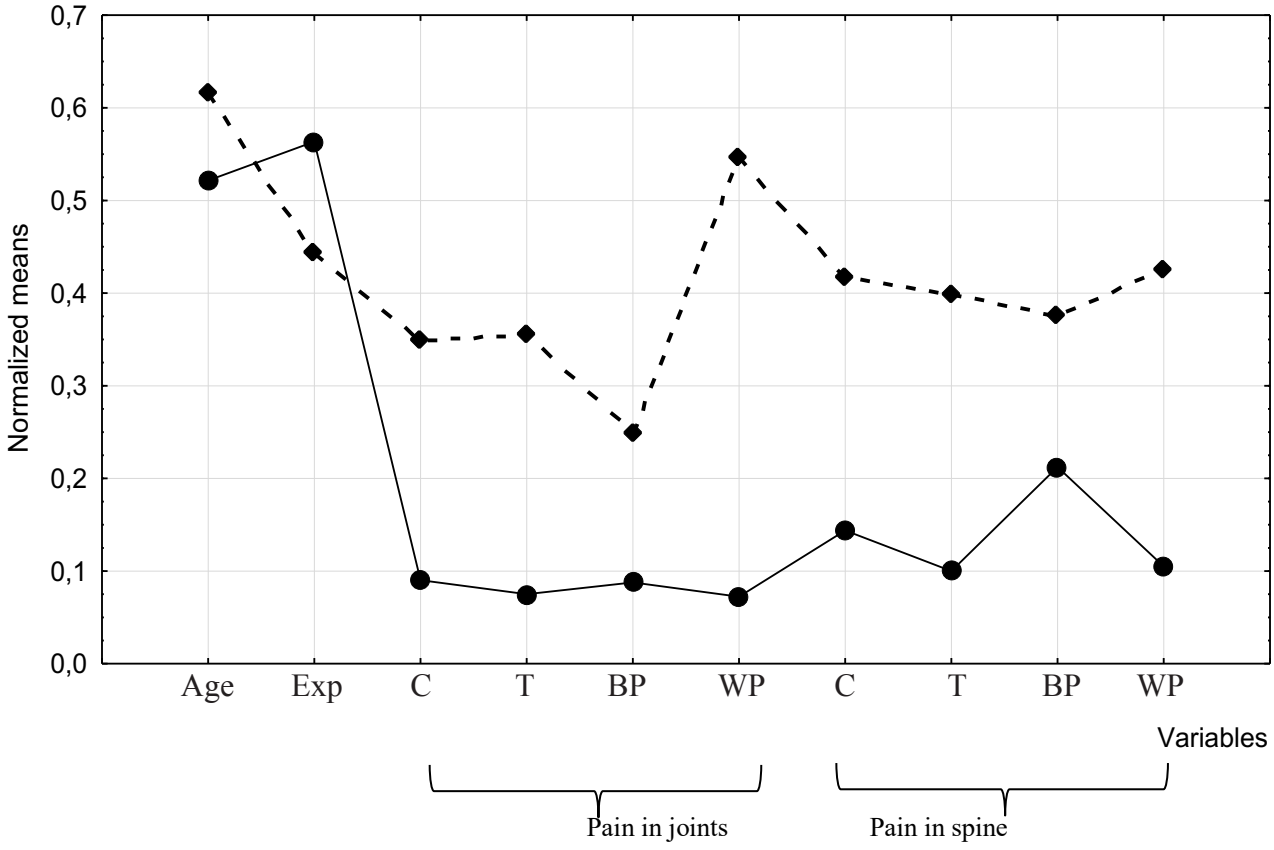

Fig. 1. Graph of means for continuous variables: Cluster 1; Cluster 2; where C – current pain level; T – typical level; BP – pain level in the best period; **WP –** pain level in the worst period

Table 1. Comparative analysis

N	Indicators		Average values						ANOVA for continuous variables					
			Cluster 1, n=13			Cluster 2, n=39			Between SS	df	Within SS	df	F	p value
			Me	25%	75%	Me	25%	75%						
1	Age, years		46.5	40.0	49.5	40.0	38.0	42.0	106.19	1	2214.64	50	2.40	0.127
2	Work experience, years		13.0	7.5	20.0	17.0	14.0	20.0	75.42	1	1540.64	50	2.45	0.124
3	Pain in joints, score	Current	1.5	1.0	2.0	0.0	0.0	1.0	15.60	1	28.15	50	27.71	$3 \cdot 10^{-6}$
		Typical	2.0	1.5	3.5	1.0	0.0	1.0	46.04	1	59.27	50	38.84	<0.05
		Best period	1.0	0.0	1.0	0.0	0.0	1.0	3.90	1	23.10	50	8.44	0.006
		Worst period	4.0	2.5	8.0	1.0	0.0	1.0	168.04	1	112.02	50	75.01	<0.05
4	Pain in spine, score	Current	1.0	0.5	3.0	1.0	0.0	1.0	11.00	1	36.44	50	15.09	$3.0 \cdot 10^{-4}$
		Typical	3.0	1.0	5.5	1.0	0.0	1.0	66.46	1	120.52	50	27.58	$3.11 \cdot 10^{-6}$
		Best period	1.0	0.0	1.0	0.0	0.0	1.0	0.98	1	16.03	50	3.04	0.087
		Worst period	3.0	2.0	7.5	1.0	0.0	1.0	94.52	1	184.15	50	25.67	$5.92 \cdot 10^{-6}$

assigned to different clusters are characterized by statistically significant ($p<0.05$) differences between the level of pain in the joints and the level of pain in the spine except for the best period indicator (Table 1).

It should be stressed that, in contrast to the level of musculoskeletal pain, no statistically significant differences were found between the age and work experience of female office employees in different clusters ($p>0.05$).

The research has found that in addition to increased musculoskeletal pain, women belonging to cluster 1 have other statistically significant ($p<0.05$) manifestations of office syndrome, namely overweight, musculoskeletal system disorders. The share of women with spinal diseases is also bigger.

In addition, the research has established the presence of statistically significant ($p<0.05$) differences between the level of responsible attitude to the preservation of own health depending on the cluster. The study has revealed that female office employees differ in the following types of self-determination: control of the working posture of a PC user,

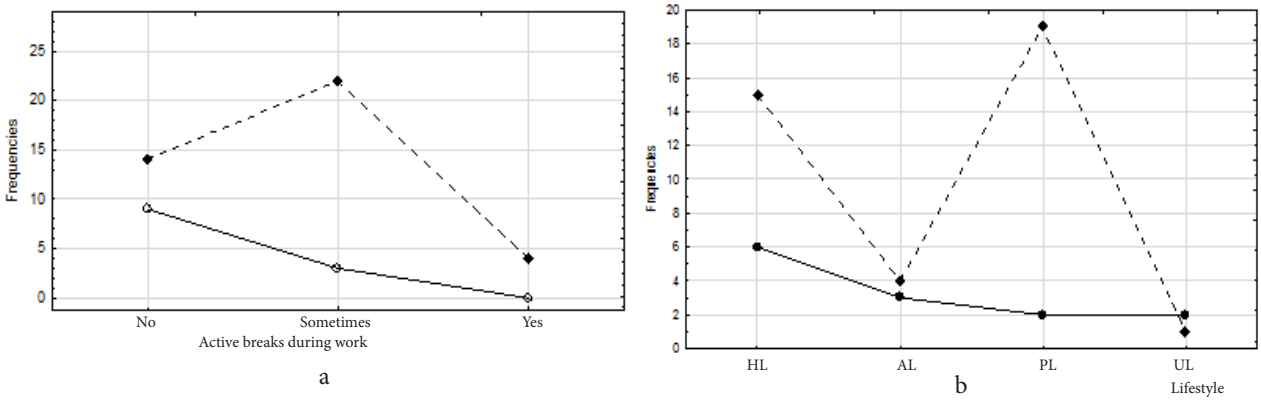

Fig. 2. Graphic analysis of women's answers to individual questions depending on the cluster, n=52: Cluster 1; Cluster 2; where HL – healthy lifestyle; AL – active lifestyle; PL – passive lifestyle; UL – unhealthy lifestyle

Table 2. Comparative analysis of the results of the survey of female office employees, n=52

N	Survey questions / Questions answered in the affirmative	Independence test for categorical variables					Cluster				p; df=1
		df	Chi-square	p value	G-square	p value	Cluster 1, n=13		Cluster 2, n=39		
							n	%	n	%	
1	Body weight / Presence of significant excess body weight	3	9.29	0.021	12.21	$6.7 \cdot 10^{-3}$	4	30.7	3	7.7	0.042
2	Duration of work with a PC / duration for more than 7 hours a day	4	14.56	0.005	16.66	0.002	3	23.1	28	71.8	0.003
3	Duration of use of IT for entertainment purposes / duration for 3-4 hours a day	3	6.41	0.093	5.53	0.137	4	30.8	2	5.1	0.021
4	Knowledge of ergonomically optimal posture	2	2.28	0.320	2.32	0.314	2	15.4	7	17.9	0.601
5	Posture care	2	2.86	0.239	3.14	0.208	4	30.8	9	23.1	0.415
6	Control of a working pose of a PC user	2	6.95	0.031	6.87	0.032	1	7.7	8	20.5	0.275
7	Systematic classes of health-improving motor activity / Systematic classes	2	4.85	0.089	4.68	0.096	3	23.1	8	20.5	0.562
8	Performing active breaks while working with a PC	2	4.86	0.088	5.71	0.058	4	30.8	25	64.1	0.038
9	Self-massage	2	1.37	0.504	1.44	0.488	2	15.4	5	12.8	0.568
10	Condition of the spine / No spine diseases	2	20.44	0.000	19.39	0.000	6	53.8	39	100	$2.9 \cdot 10^{-5}$
11	No joint pain	7	10.40	0.167	10.80	0.148	2	15.4	18	46.2	0.046
12	No pain in the spine	6	16.37	0.012	16.21	0.013	1	7.7	15	38.5	0.035
13	Used measures / Availability of the workplace taking into account ergonomic requirements	16	22.67	0.123	26.27	0.050	0	0	5	12.8	0.222
14	Level of the musculoskeletal system / High and good condition of the musculoskeletal system	3	3.82	0.281	3.65	0.302	3	23.1	16	41.0	0.205
15	Obstructive factors / Lack of knowledge and skills as interfering factors	11	22.45	0.021	24.34	0.011	1	7.7	14	35.9	0.049
16	Lifestyle / Dominating passive lifestyle	3	6.79	0.079	6.77	0.080	2	15.4	19	48.7	0.033
17	Need for knowledge regarding the organization of health care measures in the office / No need for knowledge or doubts about its need	3	4.25	0.235	6.62	0.085	0	0	10	25.64	0.040

Note: p – Fisher's exact criterion; p <0.05 – proved statistically significant differences between the shares of female office employees assigned to different clusters, which gave an affirmative answer

health-supporting physical activity, and performance of active breaks during the working day.

It should be noted that after assessing the differences between the distributions of female office employees assigned to different clusters according to the survey answers, the research focused on the study of those questions in which the distributions differed statistically significantly. In such cases, we performed a graphical analysis and assessed

the differences, after which we decided on combining the individual gradations of responses and reducing their number to two possible. For example, Figure 2a shows that among the female office employees included in cluster 2, there are significantly more those who always or from time to time take active breaks during the performance of professional duties compared to women who make up cluster 1. Therefore, by reducing the number of graduations, we combined the number of women who take or sometimes take breaks to perform mini-sets of exercises during the working day in the office. Similarly, a visual analysis of Figure 2b shows that the maximum differences between women depending on the cluster in answering the question "What lifestyle is typical for you" are observed in the answer "I lead a passive lifestyle". Thus, when reducing the number of gradations, we took into account the number of women who chose this answer.

Due to the similar considerations, further analysis of the answers of female office employees to the survey was performed. The results of statistical analysis are presented in the table (Table 2).

The research has found that a smaller percentage of female office employees in cluster 1 work with a PC for more than 7 hours a day. At the same time, in contrast to women in cluster 2, among respondents with increased musculoskeletal pain in the joints and spine, a higher percentage use IT for entertainment at least for 3-4 hours a day.

However, it should be noted that the proportion of female office employees who do not have reasons that prevent them from taking care of their health in the office, does not differ statistically significantly (p=0.568). Women without office syndrome are statistically significantly (p=0.049) dominated by those who do not have the knowledge and skills to organize activities to maintain health while working at a computer. At the same time, among them there is a significantly higher share of those who do not have the opportunity to systematically engage in health-improving motor activity (20.5% vs. 7.7%). Although no statistically significant (p=0.275) differences were found, it is possible to trace the tendency to increase the share of women (among employees without office syndrome) who believe that they do not have the opportunity to systematically engage in health-improving physical activity. It is obvious that in the current situation, there is a need to widely inform female office employees about the causes of office syndrome and the positive impact of a responsible attitude to own health both in the office and outside it.

Discussion

The modern type of employment is considered to be innovative, meaning the ability of employees to perform their duties in the conditions of constant introduction of technological innovations into the production process (Levchuk, 2017).

According to the State Labor Office, more than 50% of working population are office employees; most of them are women.

Despite the existing views, the work of female office employees is characterized by high intensity. Their health is affected by harmful factors, including the sedentary nature of work and the need to stay in the working position of a PC user for a long time, which lead to the development of office syndrome – a number of health disorders, such as musculoskeletal pain in the spine and joints, posture disorders, spinal diseases, obesity, headache (Savytska, 2020).

The transition to the information age was accompanied by the massive spread of computer technology among the population and a significant increase in sedentary motor activity in the structure of daily physical activity of various groups. It was caused by increased length of time spent in the working position of a PC user. As a result, the problem of increasing the level of responsible attitude to health when working with a computer continues to worsen. Scientists model the rational posture of a PC user in the "Human-Computer" system (Kashuba et al., 2007), study the dynamics of changes in muscle tone that are involved in maintaining working postures at work (Kashuba et al., 2008), assess the state of the bio-geometric profile of posture and working posture of a PC user (Byshevets, 2017; Byshevets et al., 2018; Hakman et al., 2020), develop technologies aimed at neutralizing the negative effects of work with a computer (Kashuba, Byshevets et al., 2019). However, most research in this area concerns the contingent of student youth (Kashuba, Andrieieva et al., 2021) and does not take into account the peculiarities of their behavior when working with a computer.

It should be noted that based on the research (Fomin & Fedorova, 1999), the self-determining behavior of female office employees in the field of health is considered to be behavior aimed at maintaining the potential of health in general and in the labor process in particular., Scientists consider diet, exercise, care for the regime, sleep and rest, and abandonment of bad habits (Fomin & Fedorova, 1999) to be indicators of self-determining human behavior in connection to health. In relation to female office employees, we considered the following forms of self-determination: active lifestyle, regular physical activity and control of a working posture. They all require adequate health measures. However, their effectiveness is directly proportional to the motivation of the contingent, the level of responsible attitude of female office employees to their own health, the reasons that prevent them from taking health measures while working at the computer, the level of awareness and so on. Health measures should include maintaining a correct working posture of a PC user, taking active breaks and self-massage in the work process, refusal of overtime work, minimizing the duration of the use of IT for entertainment purposes.

Within the prevention of the risks of occupational diseases of office workers, the issue of differentiation of female office employees into subgroups is now particularly relevant.

Analyzing the works related to the development of treatment or prevention measures, we noticed that scientists divide office employees by age, gender and length of working week. Thus, Savytska (2020), studying the clinical and neurological features of the manifestations of office syndrome among Ukrainian office employees, divided the study participants according to working conditions as follows: workers with working day up to 8 hours, with 8-hour working day and with irregular working hours. On the other hand, the author divided office employees by gender and

into the following age groups: 20-30, 31-40, 41-50 and 51-60 years old.

Taking into account the generally accepted age division of women and the experience of scientists in the comprehensive assessment of pathologies in the health of office workers, we suggested that the manifestations of office syndrome increase with age and/or with increasing length of work experience. However, the use of a modern method of EM clustering, which automates the process of selecting the optimal number of clusters according to the observed data, allowed determining that female office employees are divided into two clusters according to office syndrome manifestations and by self-determining health behaviors when working at a computer.

The first cluster consists of women with pronounced musculoskeletal pain in the spine and joints, diseases of the spine, a tendency to obesity. They are characterized by a reduced level of determinant behavior concerning health when working with a computer. At the same time, the tendency of women without office syndrome to work overtime against the background of reduced need to expand knowledge about the organization of health measures in the workplace creates a risk of developing office syndrome in the future.

Conclusions

In modern world, the problem of maintaining the health of women of working age is urgent because of the increase in the average age of motherhood on the one hand, and the consequences of pension reform on the other. Health is the most important resource in the working life of a person, and only the self-determining behavior of women concerning health care may allow them to remain competitive in the labor market until retirement age.

Under the influence of negative factors of the working environment, the risk of office syndrome among female office employees increases. Some manifestations of office syndrome are posture disorders, spinal diseases, musculoskeletal pain in the spine and joints. They are caused by static loads on the spine of employees during prolonged stay in the same position of a PC user, as well as by the dynamic loads occurring during repeated actions while working with the keyboard and computer mouse. In addition, obesity and cardiovascular disease caused by sedentary work are common among female office employees.

The research has found that female office employees are divided into groups regardless of age and work experience with a PC. This division is based on the manifestations of the office syndrome and their behavior at work; these factors determine their health. According to the obtained data, women in cluster 1, compared with other female office workers, have increased manifestations of office syndrome: they have pain localized in the joints and spine, musculoskeletal system disorders, overweight. At the same time, statistically significant ($p<0.05$) differences between the following types of self-determination have been revealed: overtime work, control of the working posture of a PC user and factors limiting the implementation of health measures in the labor process.

In addition, the research has shown that among women with manifestations of office syndrome, a statistically significant ($p=0.021$) proportion uses IT for entertainment purposes for 3-4 hours a day and a smaller proportion takes active breaks while working with a PC ($p=0.038$). However, among women without manifestations of office syndrome, a statistically significant ($p = 0.040$) smaller share is aware of the need for knowledge on the organization of measures aimed at maintaining health in the work process.

It is obvious that both overweight and musculoskeletal pain cause a decrease in physical performance of female office employees. These negative factors make it impossible to work overtime and may have a restrictive effect on women's performance of professional duties. On the other hand, women without office syndrome are more prone to passive lifestyles and do not realize the importance of knowledge about the organization of health measures in the office.

When developing preventive measures against the risk of office syndrome among women of working age, it should be taken into account that among women without office syndrome, a statistically significant ($p=0.049$) share does not have the knowledge and skills to organize measures to maintain health while working with a computer. This share is also characterized by a reduced need to expand this knowledge.

Further research is planned to develop measures aimed at forming a responsible attitude of female office workers to their health when working with a computer.

Conflict of interest

The authors declare that there is no conflict of interest that could be perceived as interfering with publication of the article.

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Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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ПЕРЕДУМОВИ РОЗРОБКИ ПРОФІЛАКТИЧНИХ ЗАХОДІВ, СПРЯМОВАНИХ НА ПОПЕРЕДЖЕННЯ РИЗИКУ РОЗВИТКУ ОФІСНОГО СИНДРОМУ В ПОПУЛЯЦІЇ ЖІНОК ПРАЦЕЗДАТНОГО ВІКУ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 3 рис., 33 джерела.

Мета дослідження – дослідити передумови розробки профілактичних заходів, спрямованих на попередження ризику виникнення проявів офісного синдрому в популяції жінок працездатного віку.

Матеріали і методи. У дослідженні прийняло участь 52 офісних працівниці віком від 21 до 57 років.

Результат. Розширена кластеризація вихідних даних методом ЕМ з виконанням V-кратної крос-перевірки показала, що популяція офісних працівниць чітко розподіляється на два кластери залежно від прояву офісного синдрому. Попри наші припущення, їхній розподіл відбувається не за віком або стажем роботи в офісі, а за проявом офісного синдрому й особливостями поведінки в трудовому процесі. Жінки, віднесені до різних кластерів, характеризуються статистично значущими ($p<0,05$) відмінностями між рівнем больових відчуттів у суглобах та відділах хребта. Установлено, що серед офісних працівниць із посиленими м'язово-скелетними болями, статистично значуще ($p<0,05$) більше жінок із суттєвою надлишковою масою тіла, захворюваннями хребта, вони рідше виконують активні перерви при роботі за комп'ютером, більший відсоток з них поза офісом 3-4 години на добу використовують інформаційні технології з розважальними цілями, однак менший їх відсоток працює за ПК понад 7 годин на добу. Жінки з переважаючими м'язово-скелетними болями відрізняються за способом життя й вказують на принципово інші причини, що заважають їм здійснювати профілактичні заходи, спрямовані на попередження ризику виникнення професійних захворювань. Зокрема серед офісних працівниць з відсутністю офісного синдрому статистично значуща ($p < 0,05$) більша частка не має потреби в розширеннях знань щодо організації заходів здоров'язбереження в офісі й серед них переважає частка таких, що ведуть пасивний спосіб життя. Отже, ці жінки потенційно знаходяться в групі ризику розвитку офісного синдрому й за умови відсутності профілактичних заходів очікувано перейдуть до кластеру жінок, що мають ознаки офісного синдрому.

Висновки. Отримані результати свідчать про необхідність різних підходів для планування здоров'язбережувальних заходів у трудовому середовищі залежно від наявності в працівниць офісного синдрому та рівня їх відповідального ставлення до здоров'я в трудовому процесі.

Ключові слова: скелетно-м'язовий біль, синдром, постава, хребет, профілактика.

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ORIGINAL SCIENTIFIC ARTICLE

MODERN APPROACHES TO ANALYSIS OF TECHNICAL AND TACTICAL ACTIONS OF SKILLED VOLLEYBALL PLAYERS

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Abstract

Purpose. To develop an algorithm of special analysis for improving the training process, based on the identification of indicators of technical and tactical actions in the competitive activity of skilled volleyball players.

Material and Methods. The study analyzed 2,688 technical and tactical indicators of the competitive activity of 56 players of national volleyball teams which played 6 games in the 2019 CEV Volleyball European Championship, taking into account the athletes' playing roles, based on the methods of analysis of the competitive activity, analysis of generalization of practical experience, and theoretical modeling.

Results. The study interpreted the total performance indicators of the competitive activity of skilled volleyball players, the indicators of technical and tactical activity in the competitive process, the ratio of performance indicators in skilled volleyball players in position zones.

Conclusions. The modified algorithm of special analysis of indicators of technical and tactical actions has the following structure: analysis of quantitative characteristics of team, group and individual actions in attack and defense; chronological analysis of the competitive activity development in sets; analysis of playing actions in various zones of the court; comparative analysis of quantitative indicators of technical and tactical actions of volleyball players who directly counteract in the match; analysis of critical moments of the game, which is directly related to organizing and holding a particular match; interpretation and qualitative analysis of indicators of technical and tactical actions in a particular match.

Based on the analysis of success and performance indicators of the competitive activity of Ukraine's national volleyball team in the qualifying tournament of the 2019 European Championship (group F), it can be said that the modified algorithm of special analysis of indicators of technical and tactical actions showed high efficiency.

Keywords: volleyball, technical and tactical actions, competitions, analysis, algorithm.

Introduction

Modern requirements for training skilled volleyball players are conditioned by strong competition in official international competitions – the Olympic Games, World and European Championships, World League and Euroleague. In the structure of factors that ensure the achievement of high sports results, the leading role belongs to the effectiveness of technical and tactical actions of skilled volleyball players in the competitive activity (Afonso et al., 2010; Marcelino et al., 2010). For the procedures of analyzing the effectiveness of technical and tactical actions in the competitive activity in volleyball, quantitative and qualitative indicators of the effectiveness of technical and tactical actions; taking into account the

playing specialization (role) of athletes; choosing a tactical orientation in the game against a particular opponent are of critical importance (Bergeles et al., 2009; Doroshenko et al., 2019). Based on the combined use of these components of the competitive activity, prerequisites are created for developing a procedure of special analysis of technical and tactical actions of skilled volleyball players. This will make it possible to identify the leading components of technical and tactical actions and promptly use the most effective means for correction of technical and tactical training, which indicates the relevance and timeliness of experimental studies on this issue.

Experts note that the procedure of special analysis requires a differentiated accounting of indicators of technical and tactical actions (individual, group, and team characteristics) (Cojocaru et al., 2018; Millán-Sánchez et al., 2018), variants of the competitive activity development in sets (dominant, recessive, variable, and combined) (Silva et al., 2016; Paulo et al., 2016), differentiation of attacking technical and tactical actions from the front or back line, and the direction of attacking technical and tactical actions, taking into account the tactical variants of players' positioning in the front line zones ("2", "3", "4") (Palao et al., 2004; Sotiris et al., 2009). Additionally, it is important to develop an algorithm of special analysis – a certain sequence of procedures that ensures a logical and rational interpretation of the results of special analysis of technical and tactical actions in the competitive activity of skilled volleyball players (Doroshenko, 2013).

Considering the complexity of analysis and interpretation of indicators of technical and tactical actions in the competitive activity of skilled volleyball players, specialists are naturally interested in the problem of special physical training, which is a factor that also determines the efficiency and effectiveness of competitive actions. A wide range of experimental studies is presented in this research area. In addition to attacking technical and tactical actions, it is important to use a group block with a certain number of blockers (2-3 athletes) and the effectiveness of this playing action. (Afonso et al., 2005; Millán-Sánchez et al., 2019). It was shown that a group block consisting of two athletes is the most effective. The study of isokinetic strength characteristics of the muscles of the lower limbs and their manifestations in training and competitive processes in female volleyball players gives grounds for creating specialized plyometric programs in order to make the most of female athletes' technical and tactical potential (Gjinovci et al., 2017; Jackson et al., 2017; Kabaciński et al., 2017). Additionally, experimental studies revealed the relationship between acoustic disorders and indicators of aerobic endurance of female volleyball players (Sienkiewicz-Dianzenza et al., 2015) and showed the mechanisms of possible correction, which helps optimize the training process. The assessment of the impact of physical development parameters on the level of motor coordination in female volleyball players at the stage of specialized basic training gave reason to believe that in the process of long-term training there is a need for targeted individual correction of motor abilities development, taking into account the sensitive periods of motor abilities development (Boichuk et al., 2018, 2021). Similar processes were recorded in experimental studies of the team of authors (Kumar et al., 2021; Zerf et al., 2019), which show that special exercises are an effective means of developing coordination abilities and contribute to the formation of specialized psychophysiological functions that ensure the effectiveness of the competitive activity in volleyball. Based on the study of special literature and the results of their own studies, researchers summarized the ways of improving the special physical training of highly-skilled volleyball players in the preparatory (Trajkovic et al., 2012) and competitive periods (Malikova et al., 2018) of the annual macrocycle and showed their role in achieving a steady effect for maximum fulfilment of female athletes' technical and tactical potential in the competitive process.

Studies showed a steady effect when using special training devices for developing technical skills in female volleyball players (Kovalchuk et al., 2019).

The study by Nikolaidis et al., 2015 examines the differences in anthropometry, somatotype, body composition, and physiological characteristics of female volleyball players according to the levels of competitive practice (regional, national and international). It was shown that female volleyball players with different qualifications have pronounced anthropometric and somatotypical differences. Taking into account these factors helps reduce sport traumatism and contributes to maximum integration of fitness indicators into the highest possible sports result (Migliorini et al., 2019; Natali et al., 2019).

Also of importance for effective implementation is the psychological aspect – experimental studies show the relationship between volleyball players' psychomotor abilities and the selected level of tactical tasks in the competitive activity, which indicates the dependence between the athlete's psychological characteristics and the implementation of his/her skills in the competitive activity (Singh et al., 2016). The study (Afrouzeh et al., 2013) determined the optimal time for learning the skills of basic technical and tactical actions in volleyball. Based on the generalization of data from special literature, we state that the problem of analysis of technical and tactical actions in the competitive activity of skilled volleyball players is complex. The most relevant directions for its solution are the selection of the most important indicators for analyzing the competitive activity effectiveness, as well as the development of an algorithm of special analysis and interpretation of indicators of technical and tactical actions. Despite the sufficient degree of development of the problematic issues that determine the efficiency and effectiveness of the competitive activity of skilled volleyball players, these scientific areas remain under discussion.

Hypothesis. Substantiation, development and testing of the procedure of special analysis of indicators of technical and tactical actions in the competitive activity of skilled volleyball players will help optimize the training process and competitive activity.

The purpose of the study: To develop an algorithm of special analysis for improving the training process, based on the identification of indicators of technical and tactical actions in the competitive activity of skilled volleyball players.

Material and methods

Study Participants

The study participants were 56 skilled volleyball players, members of national teams of Switzerland, Macedonia, Hungary, and Ukraine, which played 6 games in the

qualifying tournament of the 2019 CEV Volleyball European Championship – Men – Pool F. The study analyzed and interpreted 2,688 technical and tactical indicators of the competitive activity of highly-skilled volleyball players, taking into account the playing role of athletes.

Study Organization

According to the regulations of the 2019 CEV Volleyball European Championship – Men, the national volleyball team of Ukraine played 6 games with rivals in the Pool F group. The date, venue, rivals, and results of the competition are presented below: 1) Ukraine – Switzerland – 3:0 (15.08.2018, Zaporizhzhia, Ukraine); 2) Macedonia – Ukraine – 2:3 (18.08.2018, Skopje, Macedonia); 3) Ukraine – Hungary – 3:0 (22.08.2018, Zaporizhzhia, Ukraine); 4) Hungary – Ukraine – 1:3 (25.08.2018, Budapest, Hungary); 5) Ukraine – Macedonia – 3:1 (05.01.2019, Zaporizhzhia, Ukraine); 6) Switzerland – Ukraine – 2:3 (09.01.2019, Schönenwerd, Switzerland).

The indicators of technical and tactical actions in the competitive activity of volleyball players of the national team of Ukraine were obtained by specialists of the complex scientific group of the Volleyball Federation of Ukraine, using the "DataVolley 4 Professional" computer program. When preparing for the official games of the qualifying tournament "2019 CEV Volleyball European Championship, Men, Pool F", the algorithm of special analysis of indicators of technical and tactical actions proposed in the studies (Doroshenko, 2013) was used. It contains the following components:

- analysis of team schemes of the game: in attack, in defense;
- analysis of group interactions in attack, in defense;
- analysis of individual actions in attack, in defense;
- chronological analysis of the competitive activity development in sets (up to 8 points up to 16 points up to 25 points or until the end of the set);
- analysis of playing actions in various zones of the court: defense zone or back row, attack zone or front row;
- analysis of critical moments of the game, which is directly related to:
  a) a mindset for the game, a tactical plan of the game, individual tactical tasks for the game;
  b) the coach's personal qualities, professional knowledge, professional experience, and pedagogical skills;
  c) the current team composition, taking into account the level of technical and tactical skills and special physical fitness of players.

In addition, the structure of the algorithm of special analysis uses a differentiated accounting of individual, group, and team indicators of technical and tactical actions, the peculiarities of the formation of dynamic models of the competitive activity effectiveness in sets (dominant, recessive, variable, and combined), differentiation of attacking technical and tactical actions (front or back line of attack) and their direction, taking into account the tactical variants of players' positioning in zones "2", "3", "4".

Methods of research. Analysis of scientific-methodological and special literature, Internet data, analysis and generalization of practical experience of coaches of Ukraine's national volleyball team, analysis and interpretation of indicators of technical and tactical actions in the competitive activity of skilled volleyball players, theoretical modeling.

Statistical Analysis

Experimental studies used the following methods of mathematical processing of the obtained results: calculation of the arithmetic mean, error of the arithmetic mean, standard deviation, confidence interval, coefficient of variation, modes and medians.

Statistical processing of indicators of technical and tactical actions in the competitive activity of skilled volleyball players was carried out by specialists of the Department of Physical Rehabilitation, Sports Medicine, Physical Education and Health of Zaporozhzhia State Medical University, using the "SPSS-12" computer program.

The general efficiency of indicators of technical and tactical actions of skilled volleyball players in the competitive activity was determined by the formula (1):

$$E = \frac{Ne}{N} \bullet 100, \% \quad (1),$$

where E is the effectiveness of technical and tactical actions of skilled volleyball players in the competitive activity, %; N is the total indicator of technical and tactical actions, n; Ne is the indicator of technical and tactical actions, as a result of which the team won a point.

With the help of methods of analysis of the competitive activity, analysis of generalization of practical experience, and theoretical modeling, 2,688 technical and tactical indicators of the competitive activity of highly-skilled volleyball players were analyzed and interpreted, taking into account the playing role of athletes. To process the obtained results of the competitive activity, the authors of the study conducted a special analysis of the effectiveness of technical and tactical indicators of the competitive activity of highly-skilled volleyball players. To interpret the results obtained, the study applied the method of theoretical modeling, which provided the basis for the formation of an algorithm for preparing national volleyball teams.

Results

Table 1 shows the total performance indicators of the competitive activity of skilled volleyball players, which were recorded by specialists of the complex scientific group of the national team of Ukraine in the qualifying games of the 2019 European Volleyball Championship.

Table 2 shows the indicators of team technical and tactical actions in the competitive activity of volleyball players in the qualifying tournament of the 2019 European Championship (group F). The indicators of the national team of Ukraine in the games with the national teams of Macedonia, Switzerland, and Hungary were taken as a basis. The quantitative indicators of technical and tactical actions and their ratio in the competitive activity were determined: "kill on reception" and "attack on dig" by the ratio of errors, blocks, efficiency, and the total points scored.

The ratio of performance indicators in skilled volleyball players in position zones in the qualifying tournament of the 2019 European Championship (group F) is given in Table 3. In the structure of special analysis of the effectiveness of

Table 1. Performance indicators of volleyball players' competitive activity in the qualifying tournament of the 2019 European Championship (group F), n=12

Team, place	Performance indicators								
	games			sets			points in sets		
	"W"	"L"	points	"W"	"L"	"W : L"	"W"	"L"	"W : L"
1. Ukraine	6 (2)	0 (0)	16	18	6	3.000	572	512	1.117
2. Macedonia	3 (2)	3 (2)	9	14	13	1.077	595	594	1.002
3. Switzerland	2 (2)	4 (3)	7	12	16	0.750	581	600	0.968
4. Hungary	1 (1)	5 (2)	4	8	17	0.471	534	576	0.927

Note. "W" – won; "L" – lost; "W : L" – "won-lost" ratio; n – number of games

Table 2. Indicators of team technical and tactical actions in the competitive activity of volleyball players in the qualifying tournament of the 2019 European Championship (group F), n=12

Game, result	Indicators of team technical and tactical actions							
UA - SUI 3 : 0	kill on reception							
	1st attack after positive reception				1st attack after negative reception			
	err, n_1	blo, n_1	pts, %	tot, n_1	err, n_1	blo, n_1	pts, %	tot, n_1
	2 : 4	0 : 4	74 : 52	19 : 29	2 : 2	1 : 3	63 : 17	19 : 23
	attack on dig							
	err, n_1		blo, n_1		pts, %		tot, n_1	
	2 : 0		2 : 2		53 : 39		30 : 23	
MAC - UA 2 : 3	kill on reception							
	1st attack after positive reception				1st attack after negative reception			
	err, n_1	blo, n_1	pts, %	tot, n_1	err, n_1	blo, n_1	pts, %	tot, n_1
	2 : 5	5 : 5	53 : 53	34 : 47	5 : 6	2 : 4	29 : 43	41 : 30
	attack on dig							
	err, n_1		blo, n_1		pts, %		tot, n_1	
	1 : 4		7 : 1		39 : 57		38 : 49	
UA - HUN 3 : 0	kill on reception							
	1st attack after positive reception				1st attack after negative reception			
	err, n_1	blo, n_1	pts, %	tot, n_1	err, n	blo, n_1	pts, %	tot, n_1
	1 : 2	0 : 3	73 : 55	22 : 20	0 : 3	0 : 1	52 : 61	21 : 28
	attack on dig							
	err, n		blo, n		pts, %		tot, n	
	2 : 1		1 : 3		61 : 42		31 : 26	
HUN - UA 1 : 3	kill on reception							
	1st attack after positive reception				1st attack after negative reception			
	err, n_1	blo, n_1	pts, %	tot, n_1	err, n	blo, n_1	pts, %	tot, n_1
	0 : 4	3 : 1	61 : 56	28 : 34	5 : 6	3 : 1	38 : 45	34 : 33
	attack on dig							
	err, n_1		blo, n_1		pts, %		tot, n_1	
	5 : 1		3 : 2		56 : 50		39 : 32	
UA - MAC 3 : 1	kill on reception							
	1st attack after positive reception				1st attack after negative reception			
	err, n_1	blo, n_1	pts, %	tot, n_1	err, n_1	blo, n_1	pts, %	tot, n_1
	1 : 2	2 : 5	58 : 57	38 : 30	4 : 4	3 : 2	43 : 50	28 : 32
	attack on dig							
	err, n_1		blo, n_1		pts, %		tot, n_1	
	4 : 2		2 : 5		51 : 37		37 : 35	
SUI - UA 2 : 3	kill on reception							
	1st attack after positive reception				1st attack after negative reception			
	err, n_1	blo, n_1	pts, %	tot, n_1	err, n_1	blo, n_1	pts, %	tot, n_1
	3 : 3	5 : 4	47 : 58	45 : 40	3 : 5	1 : 7	52 : 28	31 : 32
	attack on dig							
	err, n_1		blo, n_1		pts, %		tot, n_1	
	6 : 1		5 : 2		38 : 62		39 : 29	

Note. n – number of games; n_1– number of technical and tactical actions; err– errors; blo – block; pts– points; tot– total

Table 3. Performance ratio in skilled volleyball players in position zones in the qualifying tournament of the 2019 European Championship (group F), n=12

Game, result	Indicators of team technical and tactical actions in players' position zones, n_1					
UA - SUI 3 : 0	"1"	"2"	"3"	"4"	"5"	"6"
	+14 : -2	+5 : -4	0 : -1	+5 : -10	0 : -1	0 : -3
	ratio of performance indicators, n_1					
	reception	points SO	R / P SO	serve	points BP	S / P BP
	43 : 63	28 : 23	1.54 : 2.74	74 : 53	28 : 9	2.64 : 5.89
MAC - UA 2 : 3	"1"	"2"	"3"	"4"	"5"	"6"
	-8 : -9	+4 : +8	+1 : +4	+1 : +3	+2 : +3	-5 : +4
	ratio of performance indicators, n_1					
	reception	points SO	R / P SO	serve	points BP	S / P BP
	91 : 94	37 : 47	2.46 : 2	106 : 112	27 : 41	3.93 : 2.73
UA - HUN 3 : 0	"1"	"2"	"3"	"4"	"5"	"6"
	+6 : -4	+2 : -5	+5 : -3	+3 : -1	0 : -2	+2 : -3
	ratio of performance indicators, n_1					
	reception	points SO	R / P SO	serve	points BP	S / P BP
	51 : 63	38 : 33	1.34 : 1.91	75 : 61	22 : 9	3.41 : 6.78
HUN - UA 1 : 3	"1"	"2"	"3"	"4"	"5"	"6"
	+4 : +3	-2 : +4	-8 : 0	+7 : 0	-3 : -1	0 : -2
	ratio of performance indicators, n_1					
	reception	points SO	R / P SO	serve	points BP	S / P BP
	79 : 81	36 : 40	2.19 : 2.02	96 : 97	25 : 32	3.84 : 3.03
UA - MAC 3 : 1	"1"	"2"	"3"	"4"	"5"	"6"
	-2 : -5	+5 : -4	+7 : +3	+1 : -1	+5 : -4	-3 : +3
	ratio of performance indicators, n_1					
	reception	points SO	R / P SO	serve	points BP	S / P BP
	78 : 80	44 : 38	1.77 : 2.11	100 : 94	33 : 21	3.03 : 4.48
SUI – UA 2 : 3	"1"	"2"	"3"	"4"	"5"	"6"
	+7 : -2	-6 : +1	-2 : -1	+7 : +4	-1 : +2	-3 : -2
	ratio of performance indicators, n_1					
	reception	points SO	R / P SO	serve	points BP	S / P BP
	86 : 83	44 : 41	1.95 : 2.02	108 : 107	28 : 27	3.86 : 3.96

Note. n – number of games; n_1 – number of technical and tactical actions; points SO – points scored on the opponent's serve; points BP – points scored on the serve

technical and tactical actions of skilled volleyball players, the ratio of indicators of technical and tactical actions in different zones of the court is the dominant factor. This is due to the peculiarities of the competitive activity in volleyball and the official rules of competitions – "positioning and transitions of players".

Table 4 shows the indicators of attacking technical and tactical actions in the competitive activity of skilled volleyball players in the qualifying tournament of the 2019 European Championship (group F). The data are given taking into account the playing specialization (role) of athletes who perform more than 80% of the team's attacking technical and tactical actions – "opposite", "outside-spiker" and "middle-blocker".

Discussion

In our opinion, the indicators of technical and tactical actions in the competitive activity of skilled volleyball players, given in Tables 2-4, have a significant difference from similar studies (Afonso et al., 2010; Bergeles et al., 2009; Kovalchuk A. al., 2019) – analytical approaches are based not on the quantitative and qualitative indicators of technical and tactical actions of skilled volleyball players, but on their ratio in a particular match. This makes it possible to form the foundations of an algorithm of special analysis of indicators of skilled volleyball players' technical and tactical actions in a particular match, taking into account a comparative analysis of characteristics of athletes with a certain role ("opposite", "outside-spiker", and "middle-blocker"), certain positions of players (zones "1" – "6"). Also of importance is the selection of indicators of technical and tactical actions, which are used in the procedures of special analysis. For most modern researchers, a complex use of quantitative and qualitative indicators of the effectiveness of technical and tactical actions of skilled volleyball players is a common practice (Cojocaru et al., 2018; Sotiris et al., 2009) – quantitative characteristics of technical and tactical actions in attack, in defense, when blocking, serving are complemented by qualitative characteristics of

Table 4. Indicators of attacking technical and tactical actions in the competitive activity of skilled volleyball players in the qualifying tournament of the 2019 European Championship (group F), n=12

Match	Indicators of attacking TTA		
UA – SUI – 3:0	total, n_1	pts, n_1	%
opposite	12 : 15	7 : 5	58.33 : 33.33
outside-spiker	40 : 47	23 : 18	57.5 : 38.30
middle-blocker	15 : 11	11 : 4	73.33 : 36.36
MAC – UA – 2:3	total, n_1	pts, n_1	%
opposite	49 : 42	23 : 24	46.94 : 57.14
outside-spiker	51 : 55	18 : 27	35.29 : 49.09
middle-blocker	9 : 27	4 : 15	44.44 : 55.55
UA – HUN – 3:0	total, n_1	pts, n_1	%
opposite	24 : 22	14 : 10	58.33 : 45.45
outside-spiker	32 : 36	17 : 18	53.13 : 50
middle-blocker	17 : 9	14 : 5	82.35 : 55.55
HUN – UA – 1:3	total, n_1	pts, n_1	%
opposite	33 : 32	17 : 17	51.51 : 53.13
outside-spiker	41 : 43	18 : 22	43.90 : 51.16
middle-blocker	24 : 22	16 : 11	66.67 : 50
UA – MAC – 3:1	total, n_1	pts, n_1	%
opposite	34 : 53	19 : 25	55.88 : 47.17
outside-spiker	50 : 37	21 : 17	42 : 45.95
middle-blocker	19 : 7	11 : 4	57.89 : 57.14
SUI – UA – 2:3	total, n_1	pts, n_1	%
opposite	21 : 28	9 : 16	42.86 : 57.14
outside-spiker	71 : 45	20 : 18	28.17 : 40.00
middle-blocker	21 : 16	12 : 9	57.14 : 56.25

Note. n – number of games; n_1 – number of technical and tactical actions.

their effectiveness. In studies on the analysis of technical and tactical actions of skilled athletes, the authors use this approach in the structure of one of the research methods – analysis of competitive activity (Afrouzeh et al., 2013; Millán-Sánchez et al., 2019). However, in our opinion, the analysis of competitive activity, in this case, is an integral component of the long-term training management system. Its structure also includes such components as planning, programming, modeling, forecasting, control, and correction of the training process indicators. One of the main provisions of the theory of athletes' training management is the statement that when modeling the training and competitive processes, it is inappropriate to use calculated indicators (in this case, qualitative characteristics of volleyball players' technical and tactical actions). A complex use of quantitative and qualitative indicators of the competitive activity in the procedures of special analysis of indicators of technical and tactical actions of skilled volleyball players can lead to serious distortions of results. Naturally, subsequent procedures of interpreting the indicators of technical and tactical actions can also have significant distortions. This provision should be taken into account by researchers of this issue. In our opinion, this statement is true not only for volleyball, but also for other team sports – basketball, handball, football, etc.

The next aspect of optimal analysis of indicators of technical and tactical actions in the competitive activity of skilled volleyball players is the problem of standardization when using quantitative indicators. We are talking about the use of various forms in the structure of special analysis, namely, maximal indicators, minimal sufficient indicators, average indicators, data ranges (min-max). In modern research, when analyzing the indicators of technical and tactical actions in the competitive activity, it is also common to use the principle of determining leading indicators. For example, in the process of special analysis and interpretation of indicators of technical and tactical actions of a volleyball player with the "opposite" role, the most important are the indicators of attacking technical and tactical actions during attacks from zones "2" and "1". Other indicators of technical and tactical actions in the competitive activity of volleyball players with the "opposite" role may be close to minimal sufficient values. This example characterizes the relationships between individual, group, and team aspects of athletic fitness of skilled volleyball players based on the playing role and tactical variants of the competitive activity.

This approach to algorithmization of the procedures of special analysis of indicators of skilled volleyball players' technical and tactical actions also enables the use of comparative characteristics during athletes' direct opposition in the competitive activity. For example, the effectiveness of attacking technical and tactical actions of the player of team "A" (zone "4", role "outside-spiker") and the effectiveness of blocking of the player of team "B" (zone "2", role "opposite").

In addition, in the process of experimental research, we identified four main models of the competitive activity chronological development in sets: dominant, recessive, and variable. Certain combinations of the chronological models in a particular set allow us to single out the fourth model of the competitive activity chronological development – a combined one.

The dominant model of the competitive activity chronological development in the set is characterized by a constant 3-point or more advantage over the opponent.

The recessive model of the competitive activity chronological development, on the contrary, is characterized by a constant lag behind the opposing team in terms of the number of points scored (3 points or more).

The variable model of the competitive activity chronological development is characterized by frequent changes in the leadership of teams in terms of the number of points scored with approximately equal values: + 1 or +2.

Conclusions

Based on the results of experimental studies and analysis of scientific and methodological literature, we state the following:

1. The modified algorithm of special analysis of indicators of technical and tactical actions has the following structure:

- analysis of quantitative characteristics of team, group and individual actions in attack and defense;
- chronological analysis of the competitive activity development in sets;
- analysis of playing actions in various zones of the court;
- comparative analysis of quantitative indicators of technical and tactical actions of volleyball players who directly counteract in the game;
- analysis of critical moments of the game, which is directly related to organizing and holding a particular match;
- interpretation and qualitative analysis of indicators of technical and tactical actions in a particular match.

2. Based on the analysis of success and performance indicators of the competitive activity of Ukraine's national volleyball team in the qualifying tournament of the 2019 European Championship (group F), it can be said that the modified algorithm of special analysis of indicators of technical and tactical actions showed high efficiency.

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Conflict of interest

The authors state no conflict of interest.

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СУЧАСНІ ПІДХОДИ ДО АНАЛІЗУ ТЕХНІКО-ТАКТИЧНИХ ДІЙ КВАЛІФІКОВАНИХ ВОЛЕЙБОЛІСТІВ

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Реферат. Стаття: 9 с., 3 рис., 33 джерела.

Мета дослідження – на основі визначення показників техніко-тактичних дій в змагальному процесі кваліфікованих волейболістів розробити алгоритм спеціального аналізу для вдосконалення тренувального процесу.

Матеріал і методи. Проаналізовані з урахуванням ігрового амплуа спортсменів на підставі методів аналізу змагальної діяльності, аналізу узагальнення практичного досвіду і теоретичного моделювання 2688 техніко-тактичних показників змагальної діяльності 56 гравців національних збірних команд з волейболу, які провели 6 ігор в рамках чемпіонату Європи з волейболу 2019.

Результати. Інтерпретовані підсумкові показники результативності змагальної діяльності кваліфікованих волейболістів, показники техніко-тактичної діяльності

в змагальному процесі, співвідношення показників результативності у кваліфікованих волейболістів в зонах розміщення.

Висновки. Модифікований алгоритм спеціального аналізу показників техніко-тактичних дій має наступну структуру: аналіз кількісних характеристик виконання командних, групових та індивідуальних дій в атаці і захисті; хронологічний аналіз розвитку змагального процесу в сетах; аналіз ігрових дій в різних зонах майданчика; порівняльний аналіз кількісних показників техніко-тактичних дій волейболістів, які безпосередньо протидіють в матчі; аналіз критичних моментів гри, який безпосередньо пов'язаний з організацією та проведенням конкретного матчу; інтерпретація і якісний аналіз показників техніко-тактичних дій в конкретному матчі.

На підставі аналізу показників успішності і результативності змагального процесу національної збірної команди України з волейболу у відбірковому турнірі чемпіонату Європи 2019 року (група F), можна констатувати, що модифікований алгоритм спеціального аналізу показників техніко-тактичних дій показав високу ефективність.

Ключові слова: волейбол, техніко-тактичні дії, змагання, аналіз, алгоритм.

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ORIGINAL SCIENTIFIC ARTICLE

THE EFFECT OF SQUAT TRAINING AND LEG LENGTH IN INCREASING THE LEG POWER OF VOLLEYBALL EXTRACURRICULAR PARTICIPANTS

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Abstract

The study purpose. This study aims to see: (1) The difference in the effect of barbell squat and resistance band squat exercises on the increase in leg power. (2) The difference in influence between players who have high leg height and low leg length on the increase in leg power. (3) The interaction of barbell squat and resistance band squat exercises with leg length (high and low) to increase the power of volleyball extracurricular participants.

Materials and Methods. This is an experimental research using a 2 × 2 factorial design. The population in this study were 38 volleyball extracurricular participants at SMA Negeri 1 Sedayu. The sample in this study may be 20 people. Instruments used for measuring: a tape measure for the length of the legs and a vertical jump for the power of the legs. The data analysis technique used was two-way ANOVA.

Results. The result showed that (1) There was a significant effect between barbell squat and resistance band squat exercises on the increase in the power of volleyball extracurricular participants, with an F value of 65.789 and a significance value of p = 0.000 (<0.05). The squat group has a higher resistance band (good) compared to the barbell squat group with an average difference of 2.5. (2) There was a significant difference in the effect of players who have high leg height and low leg length on the increase in leg power of volleyball extracurricular participants, it is proven that the F value is 38.000 and the significance value is p = 0.000 (<0.05). Players who have high leg length are higher (good) compared to players who have low leg length with an average difference of 1.90. (3) There was a significant interaction between barbell squat and resistance band squat and leg length (high and low) on the leg power increase of volleyball extracurricular members, with an F value of 88.256 and a significance of p = 0.000 (<0.05).

Conclusions. There was a significant difference in the effect of barbell squats and resistance band squats on increasing leg power, there was a significant difference in the effect between players who have high leg length and low leg length on the increase in leg power, and There is a significant interaction between barbell squats and squat resistance bands and leg length (high and low) on the increase in leg power of volleyball extracurricular participants.

Keywords: barbell squats, resistance band squats, leg power, leg length.

Introduction

The physiological character of volleyball is determined by the specific offensive and defensive performance of the players such as jumps to spike, leaps in different directions or sprints to the ball at distances up to 10 m (Sarabia et al., 2017). Kumar, Goswami, and Kumar (2016) added that "While spiking & blocking a player has to jump vertically in order to make contact with the ball from maximum height". Leg muscle power is the ability of a person to exert maximum strength and speed to overcome resistance or load (Zemková et al., 2017). Another opinion according to Bompa and Haff (2019) "Power is the result of two abilities; maximum speed and strength in the shortest possible time". Based on both opinions, high jumping can be achieved by doing exercises related to power or explosive power.

It was explained that one of the components in volleyball is power. Suresh and Perinbaraj (2016) states that "explosive power (muscular power) is a person's ability to use the maximum strength that is deployed in the shortest possible time". Power is a combination of strength and speed or the maximum exertion of muscle force with maximum speed, strong and fast abilities are needed, especially for actions

that require maximum power capabilities such as smashing movements (Wirth et al., 2016).

Based on the results of observations on volleyball extracurricular participants at SMA Negeri 1 Sedayu, it shows that the exercises applied by the coaches are less varied. The coach just emphasizes technical practice and continues with the game. As stated by Bompa and Haff (2019) that "suggested that a lack of training variation can result in what is termed monotonous program overtraining". Another gap found is the low jump of players when doing smash or blocking. The latest data when performing the leg power test with the vertical jump test showed that the average jump height of the players was 30.8 cm. These results when converted into the table of Physical Fitness Tests for Indonesians aged 16-19 years are in the poor category. Volleyball players, if they have good power legs, it will be more effective and efficient in performing techniques, especially smash and block (Challoumas & Artemiou 2018).

Therefore, it is necessary to apply the right training method to increase power. Many studies use the plyometric training method to increase power, but weight training can also be used to increase athlete's power. The results of Brown et al. (Aghajani et al. 2014) showed "examined the effect of two plyometric training with weightlifting programs on aesthetic jumping ability among men at university. Squats are a very simple movement. This movement can start from a standing position and then squat and return to the standing position as before. Bryanton et al. (2018) revealed that to perform squat movements must have the right basic strength, for athletes or players who have basic strength and poor flexibility, it is recommended to perform squat movements without using weights first.

Csapo (2016) explains weight training is a good enough training method to build muscle than other methods, building muscle strength is very important for non-athletes and athletes from various sports, training hard to strengthen muscles means also keeping from injury while doing sports. In order to avoid injury when doing weight training, there needs to be a systematic training program that can show the amount of weight that must be done at the time of training. Several forms of exercise to develop power, including weight training/barbells (12-16 RM) or strength training (8-12 RM) and continued with speed training (Wallace, Winchester, & McGuigan, 2006).

In the field there are still many trainers who do not know the form of power exercises using rubber resistance bands. Radu, Făgăraş, and Graur (2015) argue that the combination of resistance band exercises is very effective in improving the height of the jump and the strength of the legs, increasing speed, agility. In addition, exercises using resistence bands can also increase joint strength and can be used for aerobic exercises. Based on the background that has been stated above, the researchers are interested in conducting a study entitled "The Effect of Barbell Squat Exercises and Squat Resistance Bands and Leg Length on Increasing Leg Power of Volleyball Extracurricular Participants at SMA Negeri 1 Sedayu".

This study aims to see: (1) The difference in the effect of barbell squat and resistance band squat exercises on the increase in leg power. (2) The difference in influence between players who have high leg height and low leg length on the increase in leg power. (3) The interaction of barbell squat and resistance band squat exercises with leg length (high and low) to increase the power of volleyball extracurricular participants.

Materials and Methods

Study Participants

This type of research is an experiment using a factorial design of 2 × 2. Sugiyono (2015) states that factorial is an action on one or more variables that are manipulated simultaneously in order to study the effect of each variable on the dependent variable or the effect caused by the interaction between several variables. This experimental study used two groups that received different treatments, namely barbell squats and resistance band squats. The population in this study was volleyball extracurricular participants at SMA Negeri 1 Sedayu which amounted to 38 people. Siyoto & Sodik (2015) state that the sample is part of the number and characteristics possessed by the population, or a small part of the population members taken according to certain procedures so that they can represent the population. Total population 38 players in the leg length test. This test is used to determine the leg length of the player. After the leg length data is collected, an analysis is then performed to identify the group of players with high and low legs using the overall test score of the length of the legs owned by the player by ranking.

Study Organization

Based on the ranking, 27% of the upper group and 27% of the lower group of test results were determined (Dearing, 2019). Thus the grouping of samples taken from players who have high legs as much as 27% and players who have low legs as much as 27% of the data that has been ranked. Based on this, 10 people have high legs and 10 people have low legs. Then from each of these data, they were divided into two groups by ordinal pairing and it was found that 5 people with tall legs were treated with barbell squats and resistance band squats. The same treatment is also performed for groups of players who have low legs. The division of groups in this way will be more objective for all research subjects. This is based on equal opportunity for all objects to be included in each group. After being divided into four groups, each group of high and low legs performs pretest using vertical jump test instrument before treatment.

Statistical Analysis

The variables in this study consisted of two independent manipulative variables, namely barbell squats and resistance band squats, while the attributive independent variable was leg length. Then the dependent variable is leg power.

The barbell squat exercise is an exercise method with the form of movement starting from a standing position then squatting and returning to a standing position as before by being given a weight in the form of a barbell with a predetermined weight.

Squat resistance band exercise, which is an exercise in the form of movement starting from a standing position then squatting and returning to a standing position as before by being given a resistance band with the same size of

Table 1. Pretest and Posttest Data on Leg Power

No	High Leg Group					
	Squat Barbell (A1B1)			Squat Resistance Band (A2B1)		
	Pretest	Posttest	Difference	Pretest	Posttest	Difference
1	32	33	1	32	38	6
2	31	31	0	32	38	6
3	31	32	1	30	35	5
4	30	31	1	30	38	8
5	29	30	1	29	35	6
Mean	30.6	31.4	0.8	30.6	36.8	6.2
	Percentage		2.1%	Percentage		20.26%
No	Low Leg Group					
	Squat Barbell (A1B2)			Squat Resistance Band (A2B2)		
	Pretest	Posttest	Difference	Pretest	Posttest	Difference
1	26	27	1	26	27	1
2	25	27	2	25	26	1
3	23	25	2	22	24	2
4	20	22	2	20	22	2
5	18	20	2	17	18	1
Mean	22.4	24.2	1.8	22	23.4	1.4
	Percentage		8.04%	Percentage		6.36%

Table 2. Descriptive Statistics of Pretest and Posttest of Leg Power

Group	Minimum	Maximum	Mean	Std. Deviation
Pretest A1B1	29.00	32.00	30.60	1.14
Posttest A1B1	30.00	33.00	31.40	1.14
Pretest A2B1	29.00	32.00	30.60	1.34
Posttest A2B1	35.00	38.00	36.80	1.64
Pretest A1B2	18.00	26.00	22.40	3.36
Posttest A1B2	20.00	27.00	24.20	3.11
Pretest A2B2	17.00	26.00	22.00	3.67
Posttest A2B2	18.00	27.00	23.40	3.58

elasticity. The use of rubber resistance bands for treatment is always weighed at each training session, so each session before the treatment, the elasticity of the resistance band has been measured. For treatment model must be different from the length of elasticity rubber resistance band, because there is a heavier load to use it is the experimental group (testi).

Leg length is the presence of a leg measured from the groin to the sole of the foot and measured using a meter in centimeters.

Leg muscle power is the ability of the leg muscles to exert maximum strength in a very fast time and measured using vertical jump test with centimeters.

Results

The data from this study are in the form of pretest and posttest leg power data. The research process will take place in three stages. The first stage is to do a pretest to get initial data on the assessment of leg length and leg power on June 29, 2020. The second phase of this research activity is to conduct treatment, this research lasts for 2 months, from July 1, 2020 to August 8, 2020. The implementation of the treatment will last for 6 weeks with a frequency of 3 times a week. The data of pretest and posttest power legs are presented in Table 1 as follows.

Descriptive statistics of pretest and posttest leg power are presented in Table 2 as follows.

When displayed in the form of a diagram, the leg power data is presented in Figure 1 as follows:

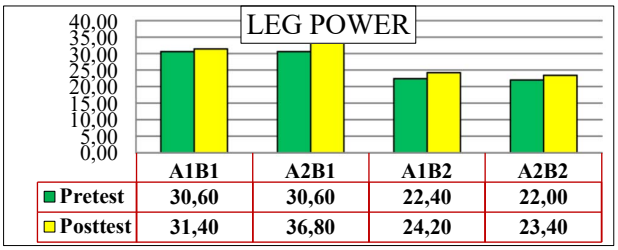

Figure 1. Pretest and Posttest Legs Power Chart Diagram

Information:

A1B1: Athletes trained using the barbell squat exercise method with high leg length

A2B1: Athletes trained using the squat resistance band exercise method with high leg length

A1B2: Athletes trained using the barbell squat exercise method with low leg length

A2B2: Athletes trained using the squat resistance band exercise method with low leg length

Based on the graph above, it shows that the leg power of the A1B1 group has an average prestest of 30.60 cm and has increased at the posttest of 31.40 cm, the A2B1 group has an average prestest of 30.60 cm and has increased at the posttest of 36.80 cm, the A1B2 group has an average prestest of 22.40 cm and has increased at the posttest of 24.20 cm, the A2B2 group has an average prestest of 22.00 cm and has increased at the posttest of 23.40 cm.

Prerequisite Test Results

Normality Test

Test normality data in this study used Shapiro-Wilk method. The results of the data normality test carried out in each group were analyzed using the SPSS version 20.0 software program for windows with a significance level of 5% or 0.05. The summary is presented in Table 3 as follows.

Table 3. Summary of Normality Test Results

Group	p	Significance	Description
Pretest A1B1	0.814	0.05	**Normal**
Posttest A1B1	0.814		Normal
Pretest A2B1	0.201		Normal
Posttest A2B1	0.206		Normal
Pretest A1B2	0.677		Normal
Posttest A1B2	0.332		Normal
Pretest A2B2	0.787		Normal
Posttest A2B2	0.685		Normal

Based on the statistical analysis of the normality test that has been carried out using the Shapiro-Wilk test in Table 3 above, it shows that all the pretest and posttest data on leg power were obtained from the results of the normality test of the data, the significance value of p > 0.05, which means the data is normally distributed. The complete calculation results are presented in appendix 6 on page 166.

Homogeneity Test

Homogeneity test is conducted to test the equation of some samples i.e. homogeneous or not. Homogeneity test is intended to test the similarity of variants between pretest and posttest. The homogeneity test in this study was the Levene Test. Homogeneity test results are presented in Table 4 as follows.

Table 4. Summary of Homogeneity Test Results

F	df1	df2	Sig.
1.009	3	16	0.414

Based on statistical analysis of homogeneity test that has been conducted using Levene Test Wilk in Table 4 above the calculation results obtained a significance value of 0.414 0.05. This means that the data group has a homogeneous variant. Thus the population has the same variance or is homogeneous.

Hypothesis Test Results

The testing of the research hypothesis was conducted based on the results of data analysis and interpretation of two-way ANOVA analysis (two-way ANOVA). The order of hypothesis test results is adjusted to the hypothesis formulated in chapter II, as follows.

The Hypothesis of the Difference in the Effect of Barbell Squats and Resistance Band Squats on Increasing Leg Power

The first hypothesis states "There is a significant difference in influence between barbell squat exercises and squat resistance bands against the increased power of volleyball extracurricular participants at SMA Negeri 1 Sedayu". Based on the results of the analysis obtained data in Table 5 as follows.

Table 5. ANOVA Test Results between Barbell Squat Exercises and Squat Resistance Bands on Increasing Leg Power

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Group_Practice	31.250	1	31.250	65.789	0.000

From the results of the ANOVA test in Table 5 above, it can be seen that the significance value of p is 0.000 and the F value is 65.789. Because the significance value of p is 0.000 < 0.05, it means that H0 is rejected. Thus there are significant differences in influence. Based on the results of the analysis, the squat resistance band exercise group was 3.80 higher (good) compared to the barbell squat exercise group of 1.30 with a posttest average difference of 2.5. This means that the research hypothesis which states that "There is a significant difference in the effect of barbell squats and resistance band squats on increasing leg power in volleyball extracurricular participants at SMA Negeri 1 Sedayu", has been proven.

The Hypothesis of the Difference in the Effect Between Players who have High Leg Length and Low Leg Length on Increasing Leg Power

The second hypothesis states "There is a significant difference in the effect between players who have high leg length and low leg length on increasing leg power in volleyball extracurricular participants at SMA Negeri 1 Sedayu". The calculation result is presented in Table 6 as follows.

Table 6. ANOVA Test Results Differences in Players with High and Low Leg Length on Increasing Leg Power

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Leg_Length	18.050	1	18.050	38.000	0.000

From the results of the ANOVA test in Table 6 above, it can be seen that the significance value of p is 0.000 and the F value is 38.000. Because the significance value of p is 0.000 <0.05, it means that H_0 is rejected. Based on this, it means that there is a significant difference in influence. Based on the results of the analysis, players who had a high leg length of 3.50 were higher (good) compared to players who had a low leg length of 1.60 with a posttest average difference of 1.90. This means that the research hypothesis which states that «There is a significant difference in the effect between players with high leg length and low leg length on increasing leg power in volleyball extracurricular participants at SMA Negeri 1 Sedayu» has been proven.

Interaction Between Barbell Squats and Resistance Band Squats and Leg Length (High and Low) on Increasing Leg Power

The third hypothesis states "There is a significant interaction between barbell squats and squat resistance bands and leg length (high and low) on increasing the leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu". The calculation results are presented in Table 7 as follows.

From the results of the ANOVA test in Table 7 above, it can be seen that the significance value of p is 0.000 and the F value is 88.526. Because the significance value of p is 0.000 <0.05, it means that H_0 is rejected. Based on this, it

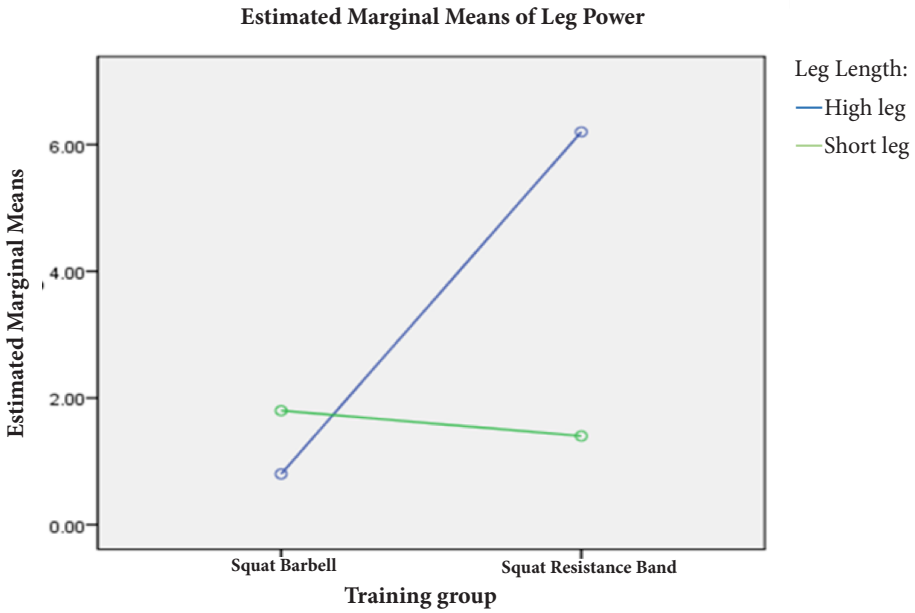

Fig. 2. Interaction Results between Barbell Squat Exercises and Squat Resistance Bands and Leg Length (High and Low) on Increasing Leg Power

Table 7. ANOVA Test Results Interaction between Barbell Squat Exercises and Squat Resistance Bands and Leg Length (High and Low) on Increasing Leg Power

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Exercise_Group* Leg_Length	42.050	1	42.050	88.526	0.000

Table 8. Summary of Post Hoc Test Results

Group	Interaction	Mean Difference	Std. Error	Sig.
A1B1	A2B1	-5.4000*	.43589	.000
	A1B2	-1.0000	.43589	.141
	A2B2	-.6000	.43589	.531
A2B1	A1B1	5.4000*	.43589	.000
	A1B2	4.4000*	.43589	.000
	A2B2	4.8000*	.43589	.000
A1B2	A1B1	1.0000	.43589	.141
	A2B1	-4.4000*	.43589	.000
	A2B2	.4000	.43589	.796
A2B2	A1B1	.6000	.43589	.531
	A2B1	-4.8000*	.43589	.000
	A1B2	-.4000	.43589	.796

means that the hypothesis which states "There is a significant interaction between barbell squats and squat resistance bands and leg length (high and low) on increasing the leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu" has been proven.

The graph of the interaction results between barbell squats and squat resistance bands and leg length (high and low) on increasing leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu can be seen in Figure 2 as follows.

After being tested there was an interaction between squat barbell and squat resistance band exercises and leg length (high and low) to increase the power of volleyball extracurricular participants at SMA Negeri 1 Sedayu, it is necessary to conduct further tests using Tukey test. Further test results can be found in Table 8 below:

Based on Table 8 tukey test calculation results on asterisk marks (*) show that pairs that have significantly different interactions or pairs are: (1) A1B1-A2B1, (2) A2B1-A1B2, (3) A2B1-A2B2, while other pairs are stated to have no differences in influence are: (1) A1B1-A1B2, (2) A1B1-A2B2, and (3) A2B2-A1B2.

Discussion

The Difference in the Effect of Barbell Squats and Resistance Band Squats on Increasing Leg Power

Based on the test, it is known that there is a significant difference in the effect of barbell squats and resistance band squats on increasing leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu. The squat resistance band exercise group was higher (good) compared to the barbell squat exercise group in increasing leg power. A study from Yoon et al. (2017) explain that the use of elastic bands provides a significant increase in the level of cognitive function, physical function, and muscle strength. Research from Chowdhary, Bhowmik, & Mahapatra (2015) shows that exercise using elastic bands has increased muscle activation and become an effective method for building muscle hypertrophy in low-activity adults. With the described characteristics of elastic bands, this tool is suitable for use as an alternative to strength training for the general public, athletes, people with disabilities (Dhar & Agarwal, 2015), the elderly (Nyberg et al. 2014), children (Şahin, Aslan, & Demir, 2016) even people who are healing muscles (Skals et al., 2018) and have even recently been modified and applied

to larger functions. The use of alternative tools can make the process of training athletes with special needs easier and certainly become safer and more friendly.

As stated by Shoepe et al. (2011) that "In recent years, one of these that has gained widespread acceptance in training programs throughout the world is the combination of elastic bands (EB) added to free weight (FW) exercises". Exercise using resistance bands is an alternative to weight training using rubber or elastic cables as resistance (Kim et al., 2015). Resistance bands have different lengths and levels of elasticity so the resistance weights are also different. Before using this resistance band should be ensured in advance the condition of elastic rubber so that it doesn not break at the time of use, because if it breaks, it will be able to endanger safety. In addition, it must also be ensured that the pivot point where the resistance bands are attached must be strong, so that exercises can be done comfortably and safely (Nasrulloh & Wicaksono, 2020).

Resistance training is also known as strength training or weight training which is often used as an effective training method to develop muscle fitness (Ozsu, 2018). Based on the results of the study (Loturco, et al. 2014) concluded that the resistance training model to increase agility, speed and explosive power of the leg muscles uses exercises as smith press, seated press, squat, lying dumbbell leg cruel, leg extension, leg press, standing barbell curls, lying barble extensions and sit ups have an effect on increasing agility, speed and explosive power of the leg muscles. Meanwhile, research conducted by Biçher et al. (2015) concluded that resistance training models for speed enhancement using leg extension exercises, leg curls, leg press and seated calf raises have an effect on speed improvement.

The energy system for resistance training produces changes in anaerobic capacity, an increase in the phosphagen system (ATP-PC), and the lactic acid system (glycolysis), (Fox, in Sakti & Irmansyah, 2016). Anaerobic is the amount of energy released by cellular metabolic processes without involving oxygen (Çakmakçı, Selçuk, & Çakmakçı, 2017). Anaerobic is arguably a rapid muscle fiber energy system that does not require oxygen (O2). The principles of weight training include frequency, intensity, duration, type, progressively increasing load, individual, specific, adaptation and recovery, (Nasrulloh, Prasetyo, & Apriyanto, 2018). According to Chen, Zhang, and Meng (2018) resistance training is an exercise program that causes muscles to contract against external loads in the hope of increasing endurance, strength, muscle mass. Resistance exercises are an ideal partner for plyometric exercises as they help prepare the muscles for the rapid loading impact of plyometric exercises. In resistance exercises, athletes work to develop an eccentric phase of muscle contraction by first losing body or weight and then overcoming weight using concentric contractions.

Milić, Grgantov, & Stipkov (2016), where a combination of resistance band exercises is very effectively used to increase the height of the jump and the strength of the legs, increase speed, agility. According to Coker (Oldenburg, 2015), that exercise can cause muscles to become responsive to loads, enlargement of muscle fibers, an increase in the number of capillaries, an increase in the number and size of mitochondria, and an increase in contractile proteins. The same opinion is said by Lamb (Oldenburg, 2015) stating that exercise can affect muscle hypertrophy, mitochondrial size, increase myofibril and sacoplasmic size, increase ATP-PC concentration and glycolysis enzymes. With the occurrence of muscle hypertrophy and improvement of the nervous system, as well as increased contractile protein, it will cause increased muscle strength. As stated by Bompa and Buzzichelli (2015) that muscle strength is affected by cross-sectional latitude or diameter of muscles especially myosin filament diameter, rapid muscle fiber recruitment ability and muscle synchronization in motion action.

The Difference in the Effect between Players who have High Leg Length and Low Leg Length on Increasing Leg Power

The results of the analysis showed that there was a significant difference in the effect of players with high leg length and low leg length on increasing leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu. Players who have high leg length are higher (good) compared to players who have low leg length to increase leg power. These results are strengthened in the research of Sardiman, Hidayah, and Soekardi (2017) that there is a difference in the effect between students who have leg length on increasing jump power abilities with a significant value of 0.00. Tanos et al., (2016) added that basically someone who has long legs will reach a longer jump distance compared to people who have short legs, because long legs can perform better leg swings when doing longer leg-range movements upon landing.

The results of research conducted on elite volleyball players showed that there was an effect of body weight, calf length, maximum ankle circumference, and leg length on vertical jumps (Martinez, 2017). People who have long legs can certainly make better jumps than people with short legs, meaning that they are in the same situation. As stated by Pasau (Ridwan, 2018) that people who have high physique and large average physical abilities such as strength, speed, heart-lung endurance, muscle endurance and others, more better than people who are small and short.

The Interaction between Barbell Squats and Resistance Band Squats and Leg Length (High and Low) on Increasing Leg Power

Based on the results that have been stated in the results of this study that there is a significant interaction between barbell squats and resistance band squats and leg length (high and low) on increasing leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu. The results showed that the squat resistance band exercise group was a more effective method for players with high leg length and the barbell squat exercise group was more effective for players with low leg length. The resulting interaction is that the group of athletes who have a height above average are more suitable if given resistance band exercises with tools, while the group of athletes who have a height below average is more suitable if given resistance band exercises without tools.

From the results of this form of interaction it appears that the main factors of the study in the form of two factors showed significant interactions. In the results of this study, the interaction means that in each cell or group there is a difference in the influence of each paired group. The pairs that have interactions or partners that are significantly different are as follows:

- The group of athletes who were trained using the squat resistance band exercise method with high leg length

was better than the athlete trained using the barbell squat exercise method with high leg length, with $p < 0.05$.
- The group of athletes who were trained using the squat resistance band exercise method with high leg length was better than the group of athletes trained using the barbell squat exercise method with low leg length, with $p < 0.05$.
- The group of athletes who were trained using the squat resistance band exercise method with high leg lengths was better than the group of athletes trained using the squat resistance band training method with low leg length, with $p < 0.05$.

Conclusions

Based on the results of the research and the results of the data analysis that has been carried out, the following conclusions are obtained:

1. There is a significant difference in the effect of barbell squats and resistance band squats on increasing leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu. The squat resistance band exercise group was higher (good) compared to the barbell squat exercise group on increasing leg power.
2. There is a significant difference in the effect between players who have high leg length and low leg length on the increase in leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu. Players who have high leg length are higher (good) compared to players who have low leg length to increase leg power.
3. There is a significant interaction between barbell squats and squat resistance bands and leg length (high and low) on the increase in leg power of volleyball extracurricular participants at SMA Negeri 1 Sedayu. The pairs that have interactions or partners that are significantly different are as follows:
   - The group of athletes who were trained using the squat resistance band exercise method with high leg length was better than the athlete trained using the barbell squat exercise method with high leg length, with $p < 0.05$.
   - The group of athletes who were trained using the squat resistance band exercise method with high leg length was better than the group of athletes trained using the barbell squat exercise method with low leg length, with $p < 0.05$.
   - The group of athletes who were trained using the squat resistance band exercise method with high leg lengths was better than the group of athletes trained using the squat resistance band training method with low leg length, with $p < 0.05$.

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

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ВПЛИВ ТРЕНУВАННЯ ТА ДОВЖИНИ НІГ НА ЗБІЛЬШЕННЯ СИЛИ НІГ УЧАСНИКІВ ПОЗАШКІЛЬНИХ ЗАНЯТЬ З ВОЛЕЙБОЛУ

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Реферат. Стаття: 9 с., 8 табл., 2 рис., 38 джерел.

Мета дослідження. Це дослідження має на меті визначити: (1) різницю у впливі присідань зі штангою і вправ з обтяженнями на збільшення сили ніг; (2) різницю у впливі на збільшення сили ніг у гравців з більшою і меншою довжиною ніг; (3) взаємодію присідань зі штангою і присідань з опором зі стрічкою в залежності від довжини ніг для збільшення сили ніг учасників волейбольної позаурочної програми.

Матеріали та методи. Це експериментальне дослідження з використанням факторної схеми 2 × 2. У дослідженні взяли участь 38 волейболістів, які брали участь в позакласній програмі SMA Negeri 1 Sedayu. Вибірка в цьому дослідженні становила 20 осіб. Вимірювання довжини ніг здійснювалося за допомогою рулетки. Сила ніг вимірювалася за допомогою вертикального стрибка. Для обробки даних використовувався метод двохфакторного дисперсійного аналізу.

Результати. Результати показали, що (1) між присіданнями зі штангою і вправами з опором зі стрічкою спостерігається значна різниця у впливі на збільшення сили ніг, значення F = 65,789 та значення достовірності p = 0,000 (<0,05). Група присідань з опором зі стрічкою має більш високий діапазон опору (добре) в порівнянні з групою присідань зі штангою з середньою різницею 2,5. (2) Спостерігалася значна різниця у впливі у гравців з різною довжиною ніг на збільшення сили ніг учасників позакласних занять з волейболу, доведено, що значення F становить 38,000, а значення достовірності p = 0,000 (<0,05). Гравці з більшою довжиною ніг в порівнянні з гравцями з меншою довжиною ніг мають вище (добре) результат із середньою різницею 1,90. (3) Спостерігалася значна взаємодія між присіданням зі штангою і присіданням з опором зі стрічкою і довжиною ніг на збільшення сили ніг, значення F = 88,256, p = 0,000 (<0,05).

Висновки. Спостерігалася значна різниця у впливі присідань зі штангою і присідань з опором зі стрічкою на збільшення сили ніг, була значна різниця у впливі між гравцями з більшою довжиною ніг і меншою довжиною ніг на збільшення сили ніг. Спостерігалася значуща взаємодія між присіданнями зі штангою і присіданнями з опором зі стрічкою і довжиною ніг на збільшення сили ніг учасників позаурочної програми з волейболу.

Ключові слова: присідання зі штангою, присідання з еспандером, сила ніг, довжина ніг.

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ORIGINAL SCIENTIFIC ARTICLE

SURFACE ELECTROMYOGRAPHY BASED CORE MUSCLE FATIGUE ANALYSIS DURING REPETITIVE PLANK USING MULTIVARIATE DIMENSIONALITY REDUCTION METHODS IN BOYS AGED 12-14

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Abstract

The aims of the study were: 1. To analyse the discriminative power of neuromuscular components for classifying the pre and post muscle fatigued states. 2. To examine whether the modification of neural recruitment strategies become more/less heterogeneous due to fatigue. 3. To research the effect of Erector Spinae (ES) muscle activity collectively with Rectus Abdominis (RA) and External Oblique (EO) muscle activity to identify the reduced spine stability during fatiguing Plank.

Material and methods. Twelve boys (age – 12-14 years, height 148.75 ± 10 cm, body mass 38.9 ± 7.9 kg) participated in the study. Multivariate Discriminant Analysis (DA) and Principal Component Analysis (PCA) were applied to identify the changes in the pattern of the electromyographic signals during muscle fatigue. In DA the Wilks' lambda, p-value, canonical correlation, classification percentage and structure matrix were used. To evaluate the component validity the standard limit for Kaiser-Meyer-Olkin (KMO) was set at ≥0.529 and the p-value of Bartlett's test was ≤0.001. The eigenvalues ≥1 were used to determine the number of Principal Components (PCs). The satisfactory percentage of non-redundant residuals were set at ≤50% with standard value >0.05. The absolute value of average communality ($\bar{x}$ h^2) and component loadings were set at ≥0.6, ≥0.4 respectively.

Results. Standardized canonical discriminant analysis showed that pre and post fatigued conditions were significantly different (p = 0.000, Wilks' lambda = 0.297, $\chi^2 = 24.914$, $df = 3$). The structure matrix showed that the parameter that correlated highly with the discriminant function was ES ARV (0.514). The results showed that the classification accuracy was 95.8% between fatigued conditions. In PCA the KMO values were reduced [$0.547_{\text{Pre fatigue}}$ vs. $0.264_{\text{Post fatigue}}$]; the value of Bartlett's sphericity test was in pre $\chi^2 = 90.72$ (p = 0.000) and post fatigue $\chi^2 = 85.32$ (p = 0.000); The Promax criterion with Kaiser Normalization was applied because the component rotation was non-orthogonal [Component Correlation Matrix (r_{CCM}) = $0.520_{\text{Pre fatigue}} > 0.3_{\text{Absolute}} < 0.357_{\text{Post fatigue}}$]. In pre fatigue two PCs (cumulative s^2 – 80.159%) and post fatigue three PCs (cumulative s^2 – 83.845%) had eigenvalues ≥1. The $\bar{x}$ h^2 increased [$0.802_{\text{Pre fatigue}}$ vs. $0.838_{\text{Post fatigue}}$] and the percentage of nonredundant residuals reduced [$50\%_{\text{Pre fatigue}}$ vs. $44\%_{\text{Post fatigue}}$] from pre to post fatigue.

Conclusions. The variability and heterogeneity increase in the myoelectric signals due to fatigue. The co-activity of antagonist ES muscle is significantly sensitive to identify the deteriorating spine stability during the fatiguing Plank. Highly correlated motor unit recruitment strategies between ES and RA, providing supportive evidence to the concept of shared agonist-antagonist motoneuron pool or "Common Drive" phenomenon during fatigue.

Keywords: Myoelectric Signals, Heterogeneity, Agonist-Antagonist Co-Contraction, Discriminant analysis, Principal Component Analysis.

Introduction

The physiological mechanism of "Muscle Fatigue" is critically diverse and difficult to understand (Merletti & Farina, 2016). The inherent characteristics of sEMG signals are complicated, often generate inconsistent multivariate pattern during muscle fatigue. For example, the rapid and additional recruitment of the motor unit pool is a well-established phenomenon, with a more homogeneous distribution of the amplitudes. The sEMG amplitude

increases due to the increased motor unit synchronization, but Staudenmann et al. (2014) stated that the increase in sEMG amplitude has resulted from decreased not increased synchronization and homogeneity in muscle activity during submaximal isometric fatiguing contraction.

Numerous studies have reported conflicting results based on ES sEMG co-activity during Plank. Schoenfeld et al. (2014) concluded that the ES muscle activity was not significant from a co-contraction perspective for trunk stability during the Plank. While Lee et al. (2015) reported that the synchronous co-activity of antagonist lumbar ES muscle was significantly more sensitive even more than agonist RA muscle in identifying the reduced spine stability while performing the fatiguing Plank. Synchronous agonist-antagonist co-activity has not been reported consistently in previous literature. Duchateau et al. (2014) stated that researchers often reveal doubts about the validity of true antagonist sEMG due to its negligible activation level. Stokes et al. (2003) also reported that sEMG electrodes are non-reliable for analyzing lumbar ES muscle activity. But conversely Mullany et al. (2002) found a significant correlation between the normalized agonist and antagonist sEMG during muscle fatigue. Furthermore, Chen et al. (1998) also reported that sEMG activity of ES muscle showed significant discriminating power to classify low back pain patients from non-symptomatic subjects.

Alteration of Low-frequency band is considered the most important indicator of muscle fatigue, because of its spatio-temporal low-pass filtering effect. Furthermore, the low-frequency of the neural drive can provide information about the isometric force fluctuations. We previously reported that the increased phenomenon of sEMG parameters of heterogeneous muscle group were not visible equally, even manifested reduction or no significant changes were noticed, specifically for the low-frequency band activity. Using the univariate statistical technique to analyze the non-normalized sEMG activity in the previous study further makes it uncertain about the true nature of fatigue induced muscle activity and noise, specifically for antagonist ES muscle based on its non-significant and low Inter-class correlation values (Samanta & Mukherjee, 2021). It required further research, which could provide a clear understanding of the control mechanism of agonist-antagonist muscle co-activity during fatigue in pediatric subjects, therefore we extended our previous study.

Previous studies have found that multivariate statistics provide exceptionally accurate results for studying the pattern of motor development of school children (Ivashchenko, 2020). The sEMG signal waveform shows non-uniform changes during isometric fatiguing contraction, makes it critically challenging to extract 'Muscle Fatigue' efficiently from a single index through conventional Univariate analysis (Samanta, & Mukherjee, 2021; Staudenmann, van Dieën, Stegeman, & Enoka, 2014). The "Fatigue Vector" comprises of different features, therefore the multivariate dimensionality reduction methods may represent it appropriately as it also consists of multifaceted sEMG signal manifestations, particularly the homogeneous combination of time-domain and frequency-domain features to estimate variability (Rogers & MacIsaac, 2011), which requires to search for a change point with time during muscle fatigue (Merletti & Farina, 2016).

Discriminant analysis (DA) is a multivariate statistical technique used to classify groups (two or more) of observations based on linear combinations of selected parameters, measured on each experimental unit, and find the contribution of each parameter in separating the groups. DA and PCA are both used to reduce the dimensionality and noise level of sEMG data. DA provides better classification accuracy between groups by maximizing the ratio of between and within-group variance (Ivashchenko, Nosko, Bartik, & Makanin, 2020).

The PCA is a statistical technique that performs orthogonal linear transformation of the correlated variables into a set of uncorrelated scalar variables, which are named PCs. This multiple features extraction model use to reduce the dimensionality of complex sEMG data may provide a decent overview using different sEMG signal parameters in fatigue. The potential advantage of unbiased PCA application is to reduce the effects of high-dimensional, multivariate fatigue induced sEMG signal vectors and transform them into a low-dimensional space to ease the interpretation of data (notwithstanding of muscle fiber architecture, or even with the presence of volume conduction and noise contamination) (Boonstra, Daffertshofer, Van, van-der-Vlugt, & Beek, 2007)

Hypotheses: The authors of this present study tested a set of hypotheses, and those were:

DA: $\mathbf{H_0}$ = The Time to task fail (T_{lim}) and myoelectric parameters have no significant discriminative power associated with the pre and post-fatigued conditions. Box's M tests the $\mathbf{H_0}$ that the covariance matrices do not differ between conditions (Roy & Oddsson, 1998).

PCA: Bartlett's test of sphericity tests the hypothesis that the correlation matrix comes from a population where the parameters are independent (Identity Matrix). A statistically significant p (≤0.001) value of Bartlett's sphericity test confirms the $\mathbf{H_0}$ hypothesis that the pairwise correlations among parameters are equal to 0. Rejecting the independent hypothesis also confirmed the adequacy of PCA (Watkins, 2021). Some other specific outcomes were also expected to ensure the validity of the PCA: 1. significant correlation might exist among different sEMG signal parameters and the magnitude of correlation might also alter or decrease due to fatigue (Staudenmann et al., 2014). 2. Fewer components explain a considerable percentage of the cumulative variance (s^2) ≥80%, which might change from pre to post fatigued states (Naik, Selvan, Gobbo, Acharyya, Nguyen, 2016). The explained s^2 by the 1st PC represents one of the multivariate Fatigue indices that might decrease from pre to post fatigue (Cowleya & Gates, 2017). 3. The weighted loading selected the label for each component as per the predominant characteristics of sEMG parameters of the EO, RA and ES muscle at the loading position therefore loading weight might change from pre to post fatigued states (Naik, Selvan, Gobbo, Acharyya, & Nguyen, 2016).

Objectives: Analyzing the myoelectric activity of global axial skeleton stabilizing muscles is crucial for a better understanding of lumbopelvic stability as weakness of these muscles significantly contributes to the progression of low back pain (Lee, Kang, & Shin, 2015). To our best information about existing literature on sEMG based muscle fatigue assessment, there are no studies that enable sports experts to evaluate myoelectric manifestation of core muscle fatigue

by using multivariate DA and PCA in children during exhaustive plank test. The aims of this present study were: 1. To analyse the discriminative power of neuromuscular components for classifying the pre and post muscle fatigued states. 2. To examine whether the modification of neural recruitment strategies become more or less heterogeneous due to isometric fatigue. 3. We further aimed to research the effect of antagonist ES activity collectively with agonist RA and synergist EO muscle activity to identify the reduced spine stability while performing a fatiguing Plank.

Materials and methods

Study participants

Previous studies reported that less than 12 subjects are sufficient for sEMG based muscle fatigue assessment using multivariate statistical methods (Farina, Negro, Gizzi, & Falla, 2012; Ortega, Besier, Byblow, & McMorland, 2018; Rogers & MacIsaac, 2011; Staudenmann et al., 2014). Therefore a total of 12 school-going boys aged between 12 to 14 years (height 148.75 ± 10 cm; mass 38.9 ± 7.9 kg) were included in the study. They were selected randomly from Ramkrishna Vidya Mandir Ashrama School-Sharada Balgram (RKVM), Gwalior (M.P.), India. The study was approved previously by the Departmental Research Ethics Board of Lakshmibai National Institute of Physical Education-Gwalior (Reg. No. PH2010-114, Ref. No.-HOD/Ex.Phy./26/2018-19) and conducted following the ethical principles for human research proposed in the Helsinki Declaration. After comprehensive verbal and written explanations of the study, the RKVM school principal signed the written informed consent form. No Neuro/Myo pathological disorders and postural spinal deformities were reported during data collection. Only the dominant right handed subjects were included in this study (Samanta & Mukherjee, 2021).

Study organization

The sEMG signals were recorded using ENCEPHALAN – MPA Autonomous Patient Transceiver-Recorder ABP-10 (Medicom MTD Ltd., Russia). The "REHACOR" and "MEDICOM" software (British Standard-Reg. No. DE/CA37/POL044A4) was used for sEMG signal processing and raw data analysis. The Bipolar (20 mm inter-electrode space) EMG/ECG Surface electrodes (Ag/AgCl sensors) were placed on EO, RA, ES muscle and the ground electrode was placed over the midline of the lumbosacral bony landmark. The sEMG linear envelope and Power Spectral Density (PSD) was calculated using Welch and Bartlett's averaged modified periodogram (Non-parametric) method with 1024 sample analysis, 50% overlapping windows to avoid aliasing effect (Nyquist's theorem). In the power spectral density, the sEMG frequency cut-off or the band-pass filter was 10-512 Hz. The Common Mode Rejection Ratio (CMRR) was 120 dB and noise was < 1.4 μV (Lee, Kang, & Shin, 2015; Ortega, Besier, Byblow, & McMorland, 2018; Samanta & Mukherjee, 2021)

It is diffificult to understand specific motor unit behavior singularly from amplitude or frequency changes alone, therefore both the features extraction domain were used to assess muscle fatigue efficiently during isometric contraction. Therefore, the T_{lim} [Sec.], Average Rectified Value (ARV) [μV], sEMG SD [μV], Total Spectral Power (TSP) [μV^2] and Normalized Low frequency band (10-70 Hz.) (N.LF) [%] were used for fatigue analysis. Furthermore, to study the sEMG patter changes during muscle fatigue using DA and PCA, it is important to select the non-identical parameters. sEMG signals provide several complex neurophysiological information about the electrical activity of contracting muscle: 1. sEMG Amplitude: Neural drive, motor-unit recruitment/threshold, firing/discharge rate modulation or rate coding, muscle activation timing, indirect information about force generation and sharing. 2. sEMG Spectral Power and Frequency: Muscle fiber conduction velocity and motor unit synchronization (McManus et al. 2021).

Detail descriptions about fatiguing Plank were given by our previous study (Samanta & Mukherjee, 2021). Briefing, those children performed Surya Namaskara (5 times) for worming up purpose, then took rest for 5 minutes. Three times repetitive fatiguing (until exhaustion) Plank [pre-fatigue (1st Plank) and post fatigue (3rd Plank)] was performed with 3 mins. interval in between every Plank.

Statistical analysis

IBM SPSS software for Windows 8.1, version 20.0, (IBM Corp., Armonk, NY, USA) was used for data analysis and Microsoft PowerPoint 2013 for graphical representations.

Stepwise DA was conducted to determine whether the classification was significant between pre and post fatigued states, and to assess the extent of the contribution of the sEMG signals parameters and task time, the classification is scored. The assumptions of DA are the probability density distributions are multivariate normal (Fig. 1), and equal within-group covariance matrices (Table 1). However, DA is robust to violation of these assumptions (Verma, 2013). The criterion used for the discriminant function was Wilk's Lambda (the deviations within each condition concerning the total deviations) with corresponding p-value, canonical correlation, and classification percentage were noted. The Structure Matrix shows pooled within-groups correlations between discriminating parameters and standardized canonical discriminant function parameters were ordered by the absolute size of correlation within the function. Discriminant scores were standardized scores with $\bar{x} = 0$ (combined groups $\bar{x}$ on the discriminant score on that function) and s = 1. In DA the acceptable classification accuracy rate was set at ≥95% with the classification error rate ≤5%. (Iermakov, Ivashchenko, Khudolii, Chernenko, Veremeenko, & Zelenskyi, 2021; Ivashchenko, Nosko, Bartik, & Makanin, 2020).

Model for Discriminant Analysis: i. 12 (participants) × 1 (Plank 1-Pre fatigue task) × 3 (EO, RA, ES muscles) × 4 (sEMG Parameters-ARV [μV], EMG SD [μV], N.LF [%], and TSP [μV2]) × Tlim (Sec.), ii. 12 (participants) × 1 (Plank 3-Post fatigue task) × 3 (EO, RA, ES muscles) × 3 (sEMG Parameters-ARV [μV], EMG SD [μV], N.LF [%], and TSP [μV2]) × T_{lim} (Sec.). We used only Log_{10}-transformed data for DA.

In the PCA, the value of Bartlett's test of sphericity was set at $p \leq 0.001$ (Broen et al., 2015). The KMO compares the extent of observed correlation to the degree of partial correlation (r) and the value of KMO ≥0.529 was considered

acceptable (Broen et al., 2015; Kaiser & Rice, 1974). The eigenvalues (λ_i) ≥1 [$\lambda_i = s_i^2/(n-1)$] were used to determine the number of PCs. The total s^2 equaled the total number of parameters and each parameter had the s^2 of 1. Therefore λ_i <1 were not allowable and considered as non-functional components within the system. The acceptable value for the component loadings was set at ≥0.40 (Broen et al., 2015; Watkins, 2021). The smallest number of components that explained ≥80% of the total s^2 was considered satisfactory (Naik, Selvan, Gobbo, Acharyya, & Nguyen, 2016). The value of 'r', ≥0.80=very strong, ≥0.70=comparably strong, 0.5-0.6's=moderate, 0.3-0.4 modest and r<0.3 were considered as a non-reliable indicator in the correlation matrix. The satisfactory percentage of nonredundant residuals were set at ≤50% with a standard value greater than 0.05. The absolute value for the r_{CCM} was set for Promax (oblique rotation) ≥0.3> Varimax (orthogonal rotation solution) (Watkins, 2021). The percentage of non-redundant residuals and r_{CCM} was applied to see the correlations between the components. The criteria for rotation was that the parameters have high loading on a few first PCs and low loading on the rest of the components. The communality (h^2 – squared multiple correlation) was the proportion of s^2 of one parameter, assigned to the standard components shared with other parameters. The acceptable value for $\bar{x}$ h^2 was set at ≥0.6, which further indicated the appropriateness of PCA (Broen et al. 2015). The p value of ≤ 0.05 was considered significant for the correlation matrix.

The PCA are optimal decorrelation strategy for Gaussian distributed data. Further to reduce the dimensionality of multivariate sEMG parameters normalization/variance stabilizing transformation procedure is required. High variability in the non-normalized sEMG data could adversely affect the multilevel interpretation, therefore at first, Log_{10}-transformation, followed by Fisher's Z transformation was applied for all the pre and post fatigue sEMG parameters for rescaling and stabilizing the s^2 ($\bar{x}$ = 0, s^2 = 1) before conducting PCA (Broen et al., 2015; Ivanenko, Poppele, & Lacquaniti, 2004; Gajewski & Viitasalo, 1994). Model for PCA Analysis: The sEMG parameters of all participants and conditions combined into a single signal vector yielding four different high-dimensional signal vectors: i. 12 (participants) × 1 (Plank 1-Pre fatigue task) × 3 (EO, RA, ES muscles) × 3 (sEMG Parameters-ARV [μV], N.LF [%], and TSP [μV^2]), ii. 12 (participants) × 1 (Plank 3-Post fatigue task) × 3 (EO, RA, ES muscles) × 3 (sEMG Parameters-ARV [μV], N.LF [%], and TSP [μV^2]). In the correlation matrices, the linear and partial correlations (r) among a set of interrelated parameters are called latent parameters in PCA analysis (Rogers & MacIsaac, 2011).

Results

Tables

Table 1. Test of Assumptions for Discriminant Analysis

Fatigued State	Log Determinant		
Pre Fatigue	-13.314	Box's M	13.823
Post Fatigue	-14.903	F	1.960
Pooled Within Condition	-13.480	Sig.	0.068

Box's M tests null hypothesis of equal population covariance matrices.

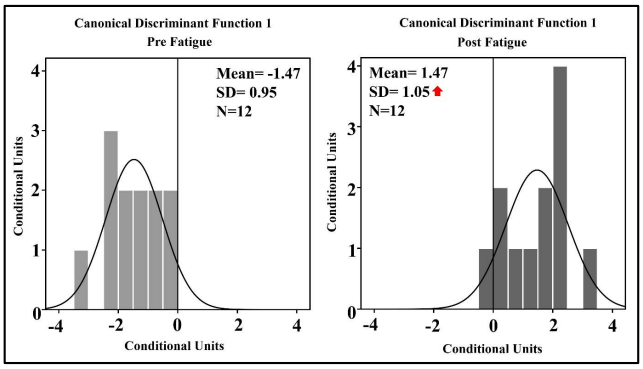


Fig. 1.: Canonical discriminant functions. Graphic representation of classification results of the pre and post fatigued conditions: ⬆ – increased variability due to fatigue.

Table 2. Canonical discriminant function. Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	2.371	100.0	100.0	.839

Table 3. Canonical discriminant function. Wilks' Lambda

Test of Function	Wilks' Lambda	Chi-square	df	Sig.
1	0.297	24.914	3	.000

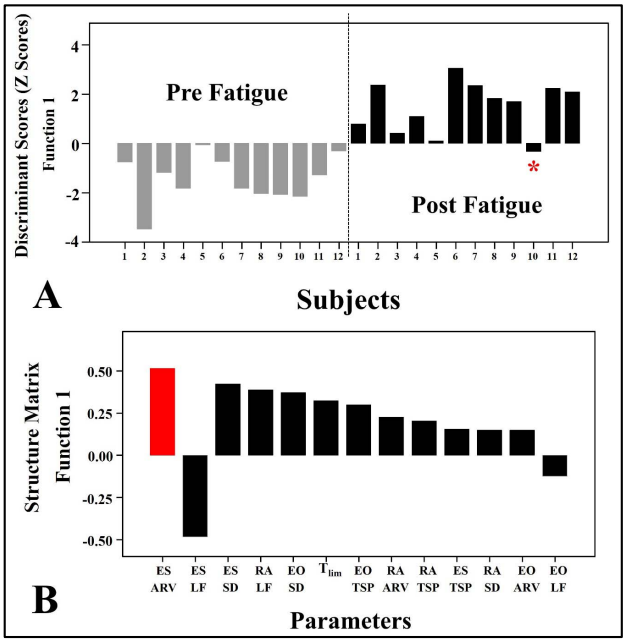


Fig. 2. A. Fisher linear discriminant function scores (Z scores), significantly discriminate the pre and post-fatigued states. Negative Z scores specify pre-fatigued, and positive Z scores indicate post-fatigued condition. The Z score with * sign in the post-fatigued condition represents false-positive classification. B. Structure Matrix plot indicates that using sEMG to assess the recruitment patterns of ES muscle (ARV) (Red bar) is necessary during fatiguing plank as it shows highest discriminating power to classify the pre and post fatigued conditions.

Table 4. Classification results

		Fatigued State	Predicted Group Membership		
		Pre Fatigue	Post Fatigue	Total	
Original	Count	Pre Fatigue	12	0	12
		Post Fatigue	1	11	12
	%	Pre Fatigue	100.0	0	100.0
		Post Fatigue	8.3	91.7	100.0

95.8% of original grouped cases correctly classified.

Table 5. The correlation matrices of different sEMG parameters of EO, RA, ES muscle in pre and post fatigued states. The upper matrix consists of pre fatigue sEMG correlation values and the lower matrix consists of post fatigue sEMG correlation values.

In.	Parameters†	Pre Fatigue								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	EO-ARV (μV)	—	-0.645*	0.871**	0.75**	-0.666**	0.601*	0.708**	-0.599*	0.374
2	EO-LF (%)	-0.526*	—	-0.635*	-0.636*	0.49	-0.679**	-0.476	0.515*	-0.473
3	EO-TSP (μV^2)	0.693**	-0.346	—	0.624*	-0.475	0.595*	0.746**	-0.8**	0.622*
4	RA-ARV (μV)	0.566*	-0.516*	0.277	—	-0.87**	0.9**	0.616*	-0.313	0.207
5	RA-LF (%)	-0.291	0.293	0.072	-0.563*	—	-0.791**	-0.345	0.221	-0.014
6	RA-TSP (μV^2)	0.355	-0.35	0.439	0.802**	-0.389	—	0.371	-0.331	0.145
7	ES-ARV (μV)	0.63*	-0.382	0.448	0.866**	-0.218	0.737**	—	-0.621*	0.626*
8	ES-LF (%)	0.425	-0.398	0.328	-0.156	-0.132	-0.239	-0.143	—	-0.531*
9	ES-TSP (μV^2)	-0.82**	0.439	-0.409	-0.268	0.257	0.025	-0.261	-0.76**	—
		Post Fatigue								

Note: The sEMG parameters are Normalized through Variance Stabilizing Transformation [Log10-transformation followed by Fisher's z transformation ($\bar{x} = 0$, $s^2 = 1$)] †, $p \leq 0.01$**, $p \leq 0.05$*. Multicollinearity in Italics. In the Correlation matrix the Normalized low frequency mostly showed negative relationship Time amplitude domain (ARV) and Total Spectral Power (TSP). The relationship between sEMG parameters were reduced mostly from pre to post fatigue, with the absolute value ~0.52 at 0.05 significance level.

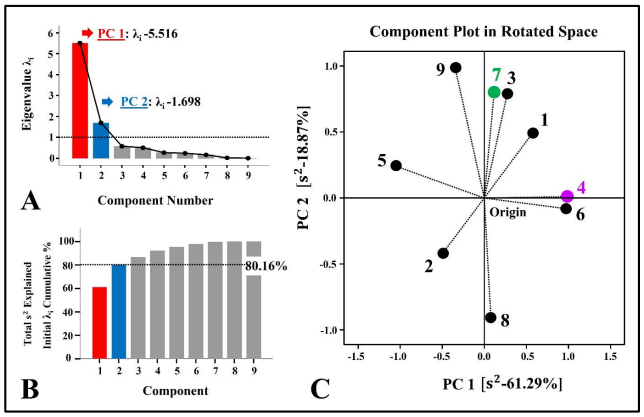
KMO test of sampling adequacy with an absolute value of >0.529 (criterion range between 0-1). The pre fatigue KMO value was 0.547 (>0.529), but the post fatigue KMO value was 0.264 (<0.529). The Bartlett's sphericity test was $\chi^2 = 90.72$ (p = 0.000, df = 36) in pre fatigue and $\chi^2 = 85.32$ (p = 0.000, df = 36) in post fatigued state, indicated the correlation matrix was not an identity matrix hence rejected the H_0 that correlation matrix was a diagonal matrix.

The absolute value of component loading cutoff was set at ≥0.4 (weighted components) with the corresponding h^2,

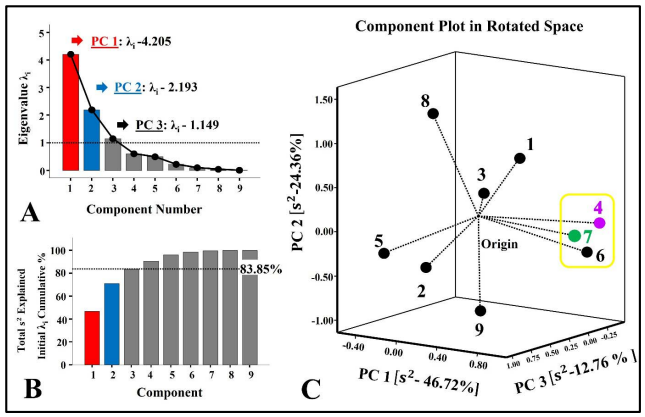
Table 6. The rotated component pattern Quantitative Structure matrices (Pre and Post fatigue) after Promax rotation with Kaiser Normalization.

Pre Fatigue				**Post Fatigue**				
Rotated Component Loadings				**Rotated Component Loadings**				
	1	**2**	**h^2**		**1**	**2**	**3**	**h^2**
RA-ARV*	**.968**	**.510**	.937	ES-ARV§	**.926**	.307	.024	.862
RA-TSP*	**.926**	**.422**	.863	RA-ARV§	**.918**	.282	-.374	.957
RA-LF	**-.914**	-.301	.876	RA-TSP	**.885**	.093	-.133	.845
EO-ARV*	.803	**.765**	.811	ES-TSP	-.255	**-.930**	.020	.884
EO-LF*	**-.707**	**-.671**	.627	EO-ARV	**.670**	**.856**	.108	.889
EO-TSP*	**.676**	**.921**	.902	ES-LF	-.129	**.819**	.026	.881
ES-ARV*	**.527**	**.852**	.735	EO-TSP*	.579	.628	.563	.830
ES-LF	-.385	**-.847**	.722	EO-LF	**-.504**	**-.621**	.205	.534
ES-TSP	.165	**.807**	.741	RA-LF	-.360	-.233	**.845**	.862
$r_{CCM} = 0.520$†			$\bar{x} = 0.802$	$r_{CCM} = 0.357$†				$\bar{x} = 0.838$

Note: h^2 – Communality. $\bar{x}$ – Mean communality. Predominant sEMG of muscles and Complex Component Loading*. Absolute Component Correlation Matrix value between PCs†. Component loading ≥0.4 are bolded and arranged in hierarchical order. RA and ES ARV shows highest weighted loading in the 1st PC in post fatigue §. In the "Fatigue Vectors" extraction the negative loading for either delayed alteration or lack of neuromuscular fatigue representation.



1. Pre Fatigue



2. Post Fatigue

Fig. 3. 1. EO ARV (μV), 2. EO N.LF (%) 3. EO TSP (μV2); 4. RA ARV (μV), 5. RA N.LF (%) 6. RA TSP (μV2); 7. ES ARV (μV), 8. ES N.LF (%) 9. ES TSP (μV^2). The λi ≥1 were used to determine the number of PCs with corresponding explained s2 [Fig. 3 (1) and Fig. 3 (2) A] and Cumulative s^2 [Fig. 3 (1) and Fig. 3 (2) B]. In pre fatigue PCA plot the horizontal (X-Axis) and vertical axis (Y-Axis) represents the 1st and 2nd PC respectively [Fig. 3 (1) C]. In post fatigue the PCA plot shows the three-dimensional vector space, hence 1st (X-Axis), 2nd (Y-Axis) and 3rd (Z-Axis) PC [Fig. 3 (2) C]. The agonist (RA ARV) is denoted with a purple circle and the antagonist (ES ARV) with a green circle. The yellow rectangular line denotes the highest loading weight in 1st PC and concurrent agonist-antagonist co-activity in the post fatigued state. The nine black dots denote the scaled PC scores, which were drawn from the variance stabilized values of sEMG parameters from EO, RA and ES muscle in pre and post fatigue. The straight black dotted line segments emerge from the origin. The Promax rotation with Kaiser Normalization applied for the rotated component pattern structure matrices [Fig. 3 (1) C and Fig. 3 (2) C].

lower values than the acceptable values both in pre and post fatigued states would be considered as non-functional and futile. The EO had salient loading on two PCs in pre fatigued state and three PCs in post fatigued state called the Complex Component Loading. Different sEMG signal domain (time amplitude, frequency and spectral power) generated by EO muscle played a predominant role during fatiguing Plank. ES ARV showed highest weighted loading in the 1st PC in post fatigue which changed from pre fatigued state weighted loading.

The satisfactory percentage (≤50%) of non-redundant residuals were calculated to assess the PCA model validity. The pre fatigue showed 18 (50%) nonredundant residuals and post fatigue showed 16 (44%) nonredundant residuals with absolute value greater than 0.05.

Discussion

The changes in the previously mentioned multidimensional neurophysiological factors were responsible for the temporal alteration of the magnitude, variability and rate modulation properties of myoelectric signals during fatigue (McManus et al. 2021). Several other complex physiological reasons might also involved: The ATP depletion, inorganic Pi, lactate, and reactive oxygen species production; the depleted Ca^{2+} concentration in myofilaments and reduced sarcoplasmic reticulum Ca^{2+} release channels (SR-Ca^{2+} RC/RYR1) sensitivity; the K^+ accumulation and Na^+ depletion in extracellular space in the muscle (Allen & Westerblad, 2001; Samanta & Mukherjee, 2021).

During static fatiguing contractions, the nociceptive input decreases the discharge rate of the active motor units by activating small-diameter afferents in muscle, further influencing the descending drive. In the neuronal level, the presynaptic Ia input inhibited through non-uniform excitation of Group III/IV nociceptive afferents further changed motor neuronal activity by modifying the variability in the descending neural drive and adopted a temporal reorganization strategy to reduces muscle fiber overload during fatiguing Plank (Dideriksen, Holobar, & Falla, 2016; Falla, & Farina, 2008; Farina, Leclerc, Arendt, Buttelli, & Madeleine, 2008). The increased variability in the sEMG signal (Table 6, Fig. 1, Fig. 3) might indicate the disablement of the CNS's ability to control the synaptic input efficiently. In summary, altered electric properties of the membrane, recruitment/derecruitment, firing rate in the diversely distributed motor unit types with different diameters and intramuscular pressure redistribution might affect the rate of metabolic clearance during fatigue (Farina, Leclerc, Arendt, Buttelli, & Madeleine, 2008). All of these phenomenon might alter the characteristics of the sEMG based fatigue factors and significantly discriminate the pre and post-fatigued conditions (Table 2, 3, 4; Fig. 2) (Farina, Negro, Gizzi, & Falla, 2012; Roy & Oddsson, 1998).

In the PCA model, the changes in correlation matrices (Table 5) and KMO value ($0.547_{\text{Pre fatigue}}$ vs. $0.264_{\text{Post fatigue}}$) was observed. Although some 'r' value increased between sEMG parameters [e.g. the correlation between RA ARV (μV) and ES ARV (μV) increased as rpre fatigue 0.616 ($p < 0.05$) vs. rpost fatigue 0.866 ($p < 0.01$)] (Mullany, O'Malley, St Clair Gibson, & Vaughan, 2002) but reduced mostly, with a reduction from the $r_{\text{pre fatigue}} = 0.520$ to $r_{\text{post fatigue}} = 0.357$ was observed (Table 5, 6). Therefore it was concluded that the variability and heterogeneity in temporal sEMG distribution increased during isometric fatiguing contractions (Staudenmann et al. 2014; Rogers & MacIsaac, 2011). The heterogeneity resulted from several complex physiological factors: Increased α-γ motoneuronal coactivity. Further changes in motoneuronal activities were controlled by the afferent inputs from peripheral receptors [muscle spindles, Golgi tendon organs, afferent neurons with small diameter (III and IV)] (Ortega, Besier, Byblow, & McMorland, 2018).

This afferent input further caused the discharge rate to be deteriorating progressively. The conduction velocity in muscle fiber action potential and the strength of common input related to the motor unit synchronization reduced gradually with additional recruitment of larger motor units or rate coding. However, several inconsistent results have reported by the previous literature regarding the increase in motor unit discharge rate and synchronization during submaximal isometric fatiguing contraction (Samanta & Mukherjee, 2021; Staudenmann et al. 2014). This non-uniformly increased sEMG amplitude might have resulted from the coordination or load sharing phenomenon of synergists during fatigue (Rogers & MacIsaac, 2011).

The previous study reported that in multivariate PCA the absolute value for 'r' between the Conduction Velocity with Average Rectified Value and the Mean Power Frequency was ≥0.52, within ±0.52, ≤-0.52 ($p \leq 0.05$) (Table 5) (Kiryu, Takahashi, & Ogawa 1997). Mild Multicollinearity might not affect the findings of PCA as only one 'r' value was 0.9 (Table 5) (Verma, 2013; Watkins, 2021). In the dominant distribution, the substantial λi had a meaningful correlation with other λ_i (≥1). But the small λ_i (<1) showed multidirectional distribution, therefore the certainty of the relationship was relatively weak. The probability of Type I error might also increase with the number of extracted components in the post fatigued state (Fig. 3). Although in PCA the Varimax orthogonal rotation technique used most often (Ivashchenko, Prykhodko, & Cieslicka, 2018) but Temporal Promax (Pre fatigue r_{CCM} = 0.520 to Post fatigue r_{CCM} = 0.357, kappa = 4) proposed a significantly accurate rotation strategy for PCA in this present study. The obliqueness is more likely than orthogonality in electrophysiological data (Dien, 2010; Watkins, 2021). In summary, re-arrangement of the sEMG parameters with the changing magnitude of the correlation among them (Table 5) and temporal redistribution of muscle activities/sEMG parameters (Table 6, Fig. 3) were observed between the pre and post fatigued states.

Each PC considered as a "Fatigue Vector" (Merletti, & Farina, 2016). The two PCs in pre fatigue [Cumulative s2 80.159%] increased to three PCs in post fatigue [Cumulative s^2 83.845%]. The explained s^2 (%) of 1st PC reduced from pre to post fatigue (61.287% vs. 46.72%) and the 2nd PC's explained s^2 (%) inflated from pre to post fatigued states (18.872% vs. 24.363%). This similar s^2 alteration tendency of the non-uniformly functional fatigue vectors was also reported by Cowleya et al. (2017). The fatiguing muscles showed unique electrical activity as the hierarchical functional components loading order (≥0.4) changed and reorganized the sEMG parameters (Table 6). Higher shear stress and torsional loading on the spine (intervertebral joint) might be imposed by EO as different sEMG parameters of this muscle had the Complex Component Loading (CCL) pattern in the PCA model (Table 6) while other superficial muscles (RA and ES) acted as a neutralizer/stabilizer while performing the fatiguing Plank (Ivanenko, Poppele, & Lacquaniti, 2004; Lee, Kang, & Shin, 2015). Efficient synergistic activity and agonist-antagonist co-activity were controlled by Central (CNS)/ Peripheral Nervous System (PNS) might reduce the metabolic burden, neuromuscular in-stabilization and alter loading pattern to protect the spine by optimizing force distribution. The CNS and PNS redistributed the muscle activation by afferent signals with preferential innervation through the supraspinal descending motoneuronal drive (Barroso et al. 2014) which might alter the weighted distribution (Table 6, Fig. 3).

The acceptability of the PCA model was improved significantly (KMO value= $0.547_{\text{Pre fatigue}} > 0.529_{\text{Absolute}}$) in the pre fatigued state when the sEMG parameters of antagonist ES muscle included jointly with agonist RA and synergist EO muscle sEMG. We also observed that despite negligible activity, the ES muscle (ARV) showed highest discriminating power to classify the pre and post fatigued conditions (Fig. 2) (Chen, Chiou, Lee, Lee, & Chen, 1998) and sensitive enough with RA and EO to identify the reduced spinal stability (KMO value= $0.547_{\text{Pre fatigue}}$ vs. $0.264_{\text{Post fatigue}}$) or nociceptive/ pain induced impaired posture maintenance in children while performing the fatiguing Plank (Lee, Kang, & Shin, 2015). The percentage of non-redundant residuals reduced (50% Pre fatigue vs. 44% post fatigue) and the $\bar{x}$ h^2 increased ($\bar{x}$ h^2 Pre fatigue=0.802 vs. $\bar{x}$ h^2 Post fatigue=0.838), we further observed that the $\bar{x}$ h^2 was significantly higher from the acceptable value of 0.6 both in pre and post fatigued states (Table 6), therefore it was concluded that the validity of PCA model was satisfactory (Broen et al. 2015). We further observed that after the Kaiser Normalization applied for Promax rotation solution, both the ES ARV (μV) (antagonist) and RA ARV (μV) (agonist) showed highest loading weight with 0.926 (h^2 = 0.862) and 0.918 (h^2 = 0.957) respectively in the post fatigued state, which changed from the pre fatigue weighted loading 0.527 (h^2 = 0.735) and 0.968 (h^2 = 0.937) respectively in the 1st PC (Table 6, Fig. 3). This parallel increased RA-ES ARV (μV) might indicate the "Common Drive" phenomenon, controlling the agonist-antagonist moto-neuronal pool and adopted similar motor unit recruitment strategies for both the RA and ES muscle. In addition with synergistic muscle, either parallel increase or constant coactivation by agonist-antagonist helped to attenuate the declined force capacity, delayed early onset of fatigue or increased time to task capacity (Samanta & Mukherjee, 2021). During fatiguing contraction, the force capacity of agonist muscle reduces, which further increases the net excitatory input to the moto-neuronal pool and recruits additional motor units. The "Common Drive" of agonist-antagonist muscles disproportionately increased the co-activity of antagonist muscle to compensate for the deteriorating joint stability during fatigue (Fig. 2, 3). Which further controlled by either supraspinal descending drive or differentiated motor neuronal pool. The altered excitability of motor neuronal pool in the antagonist muscle conventionally perceived with a substitute spinal pathway of disynaptic reciprocal inhibition from afferents of muscle spindle to the motor neurons (Duchateau & Baudry, 2014; Mullany, O'Malley, St Clair Gibson, & Vaughan, 2002).

The CCL pattern of EO, and RA-ES common drive phenomenon (Table 6, Fig. 3) could be understand extensively by their complex anatomical features. The EO maintains the lumbar spine stability through the hydraulic amplifier effect. The fused epimysial fasciae of EO and Latissimus Dorsi are extended to the posterior layer of the Thoracolumbar Fascia (TLF). Therefore, the EO fascia could transmit the tension from the EO muscle to the posterior layer of the TLF. The myofascial connections between TLF and EO, ES, RA muscles are accomplished through the aponeurosis

and fascia, which might explain the synchronized activity between ES and RA (Fan, 2018).

Further Recommendation: The multivariate statistical methods such as PCA/DA are not accepted widely in sports research due to high methodological complexity for selecting parameters and interpreting the results. The sEMG signal waveform cannot provide a valid conclusion about 'Muscle Fatigue' if we use a single parameter for a heterogeneous muscle group. In sports training, the DA and PCA is a reliable analytical tool for categorizing subjects using a set of sEMG parameters. The productivity of a training program could also be estimated by the changes in parameters of interest in a subject (Czaplicki, Śliwa, Szyszka, & Sadowski, 2017; Ivashchenko, Khudolii, Iermakov, Prykhodko, & Cieslicka, 2018). Strength and endurance training obtain opposite adaptations in motor unit discharge rates but have an indistinguishable effect on muscle fiber conduction velocity. We have a limited understanding of these training effects on heterogeneous muscle activity during fatiguing contraction. Both DA and Singular Value Decomposition/ Matrix Factorization method used with PCA may anticipate a robust computational configuration to understand different training effects efficiently on muscle fatigue (Vila-Chã, Falla, & Farina, 2010). Furthermore increase sample size, items/parameters could provide a significantly accurate and reliable multivariate fatigue model.

Limitations

Using non-maximum voluntary isometric contraction (MVIC) based non-normalized sEMG data with cautions for interpretation in a study dealing with the pediatric population is advisable due to ethical reasons (McManus et al., 2021; Samanta & Mukherjee, 2021). We also would like to address some of the other points listed below: 1. The MVIC induced sEMG amplitude normalization has some methodological limitations (e.g. 21.61% error in MVIC sEMG amplitude value which can be a potential threat to the validity and reliability of MVIC induced sEMG data, as it also depends on subject's fatigue, posture and non-cooperativeness) (Araujo, Duarte, & Amadio, 2000). 2. The previous study also reported that normalization of different sEMG parameters increase the chance to lose necessary information about neural recruitment strategies. 3. The sEMG amplitude normalization is also not suitable to understand neural drive mechanisms between muscles (Martinez, Negro, Falla, De-Nunzio, & Farina, 2018). 4. The electromagnetic interferences, crosstalk/volume conduction and artifacts by surrounding muscles might affect sEMG findings. 5. We used both PCA and DA individually in providing a better sEMG patterns alteration based multivariate fatigue model to impart a reliable solution to the insufficient sample size, high dimensionality and high redundancy problems (Prasad & Bruce, 2008).

Conclusions

Multivariate sEMG signals undergo systematic changes with increasing magnitude and variability (phase shift) during submaximal isometric fatiguing contraction, and these changes are relatively difficult to detect with conventional Univariate analysis. A better understanding only possible by applying the multivariate DA and PCA based on the fatiguing sEMG signal. PCA analysis revealed that the heterogeneity and variability of sEMG distribution increased, specifically from the muscles with higher geometrical diversity and a wide range of fiber type distribution during fatiguing contraction. During fatigue contraction, the distribution of muscle activity altered by CNS/PNS control, which further changed the magnitude of the correlation function among the sEMG parameters. Efficient synergistic activation, agonist-antagonist coactivation modulated by the nervous system, further reduced metabolic burden, neuromuscular in-stabilization and unwanted loading patterns on trunk structure to protect it, by optimizing force distribution and reorganized the fatigue induced load on different muscles. This efficient load sharing phenomenon of the muscles mediated by the nervous system during fatigue compensate for the fatigue induced force loss. Despite limitations, the ES muscle is highly sensitive even more than RA and EO muscle to identify the reduced spine stability while performing the fatiguing Plank. Highly correlated motor unit recruitment strategies between ES and RA, providing supportive evidence to the concept of shared agonist-antagonist motoneuron pool or "Common Drive" phenomenon during fatigue.

Conflict of interest

The authors state that there is no conflict of interest.

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АНАЛІЗ СТОМЛЮВАНОСТІ ОСНОВНИХ М'ЯЗІВ НА ОСНОВІ ПОВЕРХНЕВОЇ ЕЛЕКТРОМІОГРАФІЇ ПІД ЧАС ПОВТОРЕННЯ ПЛАНКИ З ВИКОРИСТАННЯМ МЕТОДІВ БАГАТОВИМІРНОГО ЗМЕНШЕННЯ У ХЛОПЧИКІВ 12-14 РОКІВ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 3 рис., 6 табл., 42 джерела.

Мета дослідження: 1. Аналіз розрізняльної здатності нервово-м'язових компонентів для класифікації станів до і після м'язового стомлення. 2. Вивчити, чи стає модифікація стратегій рекрутування нейронів більш / менш гетерогенної через втому. 3. Вивчити вплив активності м'язів Erector Spinae (ES) разом з активністю м'язів Rectus Abdominis (RA) і External Oblique (EO), щоб визначити зниження стабільності хребта під час виснажливої планки.

Матеріал і методи. У дослідженні взяли участь 12 хлопчиків (вік 12-14 років, зріст 148,75 ± 10 см, маса тіла 38,9 ± 7,9 кг). Багатоваріантний дискримінантний аналіз (DA) і аналіз головних компонентів (PCA) застосовувалися для виявлення змін в характері електроміографічних сигналів під час м'язової втоми. В DA використовувалися Лямбда Уїлкса, значення p, канонічна кореляція, відсоток класифікації і матриця структури. Для оцінки достовірності компонент стандартна межа для Кайзера-Мейера-Олкіна (KMO) була встановлена на рівні ≥0,529, а значення p тесту Бартлетта було ≤0,001. Власні значення ≥1 використовувалися для визначення кількості головних компонент (ПК). Задовільний відсоток ненадлишкових залишків був встановлений на рівні ≤50% при стандартному значенні >0,05. Абсолютне значення середньої спільності ($\bar{x}$ h^2) і навантаження компонентів були встановлені на рівні ≥0,6, ≥0,4 відповідно.

Результати. Стандартизований канонічний дискримінантний аналіз показав, що стан до і після втоми значно різнився (p = 0,000, Лямбда Уїлкса = 0,297, χ^2 = 24,914, df = 3). Матриця структури показала, що параметром, який тісно корелював з дискримінантною функцією, був ES ARV (0,514). Результати показали, що точність класифікації між станами стомлення склала 95,8%. У PCA значення KMO були знижені [0,547 $_{\text{до стомлення}}$ проти 0,264 $_{\text{після втоми}}$]; значення критерію сферичності Бартлетта було до χ^2 = 90,72 (p = 0,000) і після втоми χ^2 = 85,32 (p = 0,000). Був застосований критерій Promax з нормалізацією Кайзера, оскільки

обертання компонент було неортогонально [матриця кореляції компонентів (r_{CCM}) = 0,520 $_{\text{Попереднє стомлення}}$> 0,3 $_{\text{Абсолютна}}$ <0,357 $_{\text{Втома після закінчення}}$]. У двох ПК до стомлення (кумулятивне s^2 – 80,159%) і після втоми три ПК (кумулятивне s^2 – 83,845%) власні значення ≥1. $\bar{X}$ h^2 збільшилася [0,802 $_{\text{до стомлення}}$ проти 0,838 $_{\text{після втоми}}$], а відсоток ненадлишкових залишків знизився [50% $_{\text{до стомлення}}$ проти 44% $_{\text{після втоми}}$].

Висновки. Через стомлення збільшується варіабельність і неоднорідність міоелектричних сигналів. Спільна активність ES-м'язи-антагоністи дуже чутлива для визначення погіршення стабільності хребта під час стомлюючої планки. Стратегії рекрутування моторних одиниць з високим ступенем кореляції між ES і RA підтверджує докази концепції загального пулу мотонейронів агоністів-антагоністів або феномена «Common Drive» під час стомлення.

Ключові слова: міоелектричні сигнали, неоднорідність, скорочуваність агоністів і антагоністів, дискримінантний аналіз, аналіз головних компонент.

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ORIGINAL SCIENTIFIC ARTICLE

THE EFFECT OF KNOWLEDGE LEVEL (IQ) AND PHYSICAL CONDITIONS (POWER, FLEXIBILITY AND COORDINATION) ON SMASH TECHNIQUE LEARNING SKILL IN SEPAK TAKRAW

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Abstract

Athlete's knowledge level (IQ) is needed to increase smash technique learning skill in sepak takraw. Besides, physical conditions which consist of power, flexibility and coordination, are also determined athlete's accomplishment in learning smash technique in sepak takraw.

The study purpose. The aim of this research was to discover the direct influence between knowledge level (IQ) and physical conditions (power, flexibility and coordination) on smash technique learning skill in sepak takraw.

Materials and Methods. The method used in this research was quantitative. Path analysis was conducted to analyze the result. As many as 50 athletes of sepak takraw from capital city of Jakarta were taken as population. Those athletes were also taken as sample by using total sampling. The sample was the athletes who joined the regional and national championship.

Results. Based on the research it was obtained: 1) knowledge level (IQ) affects smash technique learning skill in sepak takraw directly as many as 0.982; 2) physical conditions (power, flexibility and coordination) affect smash technique learning skill in sepak takraw directly as many as 0.845; and 3) overall, knowledge level (IQ) and physical condition (power, flexibility and coordination) affect smash technique learning skill in sepak takraw directly as many as 0.703.

Conclusion. Therefore, it could be concluded that knowledge level (IQ) and physical conditions (power, flexibility and coordination) affect smash technique learning skill in sepak takraw on the athletes of capital city of Jakarta.

Keywords: Knowledge Level (IQ), Physical Condition, Smash Technique, Sepak Takraw.

Introduction

Sport education is one of sport science fields which supports someone to reach his desired achievement. The development of sport education is divided into three kinds namely educational sport, recreational sport and sporting achievement. Educational sport is engaged physical education as a part of continuous and well-organized education process in order to obtain knowledge, personality, health and physical fitness. Recreational sport is kind of sport which conducted by people using their hobby and ability based on their condition and society's cultural value aimed to attain their health, fitness and happiness. Sporting achievement is kind of sport which guiding and developing athlete

gradually and continuously through competition to obtain achievement using sport technology and science. This is in line with Indonesian Law No 3 Year 2005 about Indonesian Republic National Sport System in Paragraph 1 Verse 13 which stated, "Sporting achievement is sport which build up and develop the athlete as planned in sustainably and step by step way supporting by sport technology and science." In implementing sporting achievement, there are also social values applied such as high value of sportsmanship. One of sporting achievement branches is sepak takraw.

Hermawan, Asmawi, and Tangkudung (2019) mentioned sepak takraw was a game played in rectangle field with flat surface (both in indoor and outdoor place) as long as it is free from obstacle. This game is started with service conducted by tekong (skipper) toward opponent's area. Then, the opponent plays the ball using leg or the other body parts except hands and touches the ball no more than three times. There are so many factors supporting the play of sepak takraw. The most important factors are the mastery of individual technique in playing sepak takraw and teamwork. The more perfect each player mastering the technique, the more good the quality of game. To keep the game played well, the player must master the basic technique very well.

Padli et al. (2019) divided the ability in sepak takraw into two parts namely the individual basic technique and the ability in mastering the game. The individual basic technique consists of sepak sila, sepak cungkil, sepak badek, sepak cross, blocking, heading, using chest and shoulder. Zarei & Ramkissoon (2021) mentioned the ability in mastering the game consists of service, give bait, smash and block. In order to get big score and win the game, the player must master smash technique very well. Smash is the player's effort in attacking opponent's area. Smash is dynamic and varied movement to get point. In doing smash, the player need optimal physical skill so that his smash technique can be more directed, faster and more accurate.

Hamid et al. (2015) stated that in performing smash, the athlete must have a complex series of movement which is supported by good physical condition component. The power of leg muscles is needed to perform good physical condition. According to Ribeiro et al. (2020) power is the product of two abilities: strength and speed. It is also known as the ability to apply the highest force in the shortest time. Unlike power lifting, in which the athlete expresses (maximum) strength without time limitation, athletes in all other sports face time constraints in applying as much force as possible. According to Hager et al. (2020) the explosive power of leg muscles was someone's leg muscles ability to jump as high as possible (explosive). If the athlete of sepak takraw has a very high jump, it would make him easier to perform good smash. Hence, in order to perform good and directed smash, the athlete must have a very good explosive power of leg muscles. Besides, to conduct good smash, the athlete needs the body flexibility.

Flexibility is an important component in human body to perform the movement as wide as possible. Therefore the stretching exercise is a necessary part in preparing further sport. The exercise in increasing muscle's flexibility is applied to avoid the injury and hypertension (miogelisis). Besides, this exercise is conducted after the power exercise program to prevent muscle contracture. In general, this effect is associated with stretching prevention to shortening muscles (Kolumbet, Natroshvili, & Chernovsky, 2018).

Nugroho et al. (2021) stated flexibility of the human body refers to the range of movement in a joint or series of joints. Quality of life is enhanced by improving and maintaining a good range of motion in the joints. Loss of flexibility can be a predisposing factor for physical issues such as pain syndromes or balance disorders. Many factors are taken into account when establishing the flexibility of a particular human body: joint structure, ligaments, tendons, muscles, skin, tissue injury, fat tissue, body temperature, age and gender, all influence an individual's range of movements.

In accordance with the result of research journal written by Nasrulloh et al. (2021) the acute effects of static stretching on torque production were dependent on the individual's flexibility; the greater the flexibility, the lower and shorter the torque decreases. In addition, stretch-induced torque reduction recovered faster in individuals with high flexibility. So, the static stretching in torque producing depends on the individual's flexibility. When the athlete performs the huge flexibility, he experiences his torque slighter and his flexibility becomes shorter. Besides, the reduction of torque is induced faster in high flexibility athlete.

Ehlert (2020) on text book Acsm's Foundation of strength training and conditioning described flexibility is the ability of a joint to move freely its ROM. Enhanced joint flexibility can reduce injury risk, improve muscle balance and function, increase performance, improve posture, and reduce the incidence of low back pain. The best ways to increase flexibility is to perform exercises in a full ROM and engage in a proper stretching program, preferably at the end of a workout when the muscles are thoroughly warmed up. Hence, the flexibility must be trained. The characteristics of flexibility are stretching the joints and extending a muscles group. There are four types of stretching according to Rahman & Islam (2020) namely static, dynamic, proprioceptive neuromuscular facilitation (PNF) and ballistic.

Based on the theory above, the flexibility of hip joints in this research is viewed as an important aspect. The flexibility in performing smash could be described as the ability in conducting kicking which requiring hip joints movement as wide as possible without experiencing injury. The development of flexibility could be increased by static stretching, dynamic stretching, ballistic stretching and proprioceptive neuromuscular facilitation (PNF). In performing smash, not only power and flexibility but also good coordination between eyes and legs support the athlete to carry out smash technique. This coordination is required to ensure the athlete's leg touches the ball properly which is appropriate with the basic technique of sepak takraw.

Coordination is someone's ability to combine some movement elements into one series of conformable movement and suitable to the aim. Coordination is useful for carrying out tactic and developing mental readiness (Bolotin & Bakayev, 2018). When the athlete has good coordination, his movement efficiency would be arranged nicely. He would not feel over exhausted so that he would be able to avoid injury.

Hughes (2019) stated these findings suggest males and females adopt similar intra-limb coordination strategies when landing, however, females exhibit greater variability in coordination which may indicate greater adaptation in

coordination patterns in an attempt to mitigate the effects of fatigue or compensate for gender differences in landing kinematics and kinetics identified in previous research.

Le et al. (2020) concluded that coordination is the ability to commit various movement in certain difficulties quickly, accurately and efficiently. Therefore, coordination states the conformable relation as a main factor happened in one movement. The reduction of coordination in daily activity starts occurring to those people over 40 years old. This condition is caused by the decrease of sensory perception and motoric response which undergoing the changes of morphology and biochemistry.

Coordination is really necessary to be mastered by the athlete of sepak takraw because when the athlete wants to perform passing, he would not see the ball. His leg must touch the ball while his eyes looking at the target. The leg-eyes coordination has an important role in sepak takraw. This ability is needed to control and play the ball after triggering by certain stimulus for example when the ball comes from opponent's attack. By carrying out good leg-eyes coordination the player masters the game and he is able to play the ball perfectly.

Therefore, *the study purpose* was to discover the direct influence between knowledge level (IQ) and physical conditions (power, flexibility and coordination) on smash technique learning skill in sepak takraw.

Materials and methods

Study participants

The population of this research was 50 athletes of sepak takraw from DKI Jakarta-Indonesia. The population was also taken as sample using total sampling (Thomson et al., 2020).

Study organization

This research involved two independent variables and one dependent variable. The independent variables consisted of knowledge level (IQ) and physical conditions (power, flexibility and coordination). To test knowledge level (IQ), this research used questionnaire that has been validated by expert namely Prof. Dr. Nadiro, Prof. Dr. dr. James Tangkudung, and Prof. Dr. Wawan S, Suherman.

To test the power, this research used Vertical Jump, the test has been commonly used for measuring the power (Montalvo & Dorgo, 2019). To test the flexiblity, this research used Wall Side Split Test. This test has been approved and validated by the expert namely Prof. Dr. Firmansyah Dlis, M.Pd, Prof. Dr. Moch. Asmawi, M.Pd, Dr. Johansyah Lubis, M.Pd, Dr. Iman Sulaiman, M.Pd, and Dr. Raffly Henjilito, M.Pd. This test has been registered to Directorate General of Intellectual Property, Indonesia. To test the coordination, this research used Eyes-feet Coordination test. This test has been approved and validated by the expert namely Prof. Dr. Firmansyah Dlis, M.Pd, Dr. Johansyah Lubis, M.Pd, Dr. Widiastuti, M.Pd, Dr. Raffly Henjilito M.Pd, and Dr. Zulkifli, M.Pd. This test has been registered to Directorate General of Intellectual Property, Indonesia. The detail of these tests can be easy seen in the table below (tabl. 1).

To describe on how to do the vertical jump, flexibility and Eyes-Feet Coordination Test, please refer to the figure below:

Fig. 1. Vertical jump test

Table 1. Test detail

Item	Test	Unit	Procedure
Knowledge level (IQ)	Questionnaire	-	Answer the question
Power	Vertical Jump	Centimeter (CM)	The person stands side on to a wall and reaches up with the hand closest to the wall. Keeping the feet flat on the ground, the point of the fingertips is marked or recorded. This is called the standing reach. The person puts chalk on their finger tips to mark the wall at the height of their jump. The person then stands away from the wall, and jumps vertically as high as possible using both arms and legs to assist in projecting the body upwards. Attempt to touch the wall at the highest point of the jump. The difference in distance between the standing reach height and the jump height is the score. The best of three attempts is recorded.
Flexibility	Wall Side Split	Centimeter (CM)	The person sits with a split facing the wall. Open your legs as wide as you can to form a position as wide as possible. Hands may hold on to the floor to maintain balance. In such a position measure with flexomeasures or a ruler, zero on the wall. Read the difference from the wall to the crotch. Do 2 repetitions.
Coordination	Eyes-Feet Coordination Test	Times/Minute	The person stands behind the boundary line. The person was instructed to carry out the test with the chosen foot by bouncing the ball against the wall and controlled for 60 seconds. Prior to the implementation of the test, the testes were given the opportunity to try to adapt them to the test. The test is considered successful if the kicked ball hits the target, the bouncing ball can be picked up, and bounced back to the wall. The person may not rock and catch a ball that bounces in front of the boundary line.

Fig. 2. Flexibility test

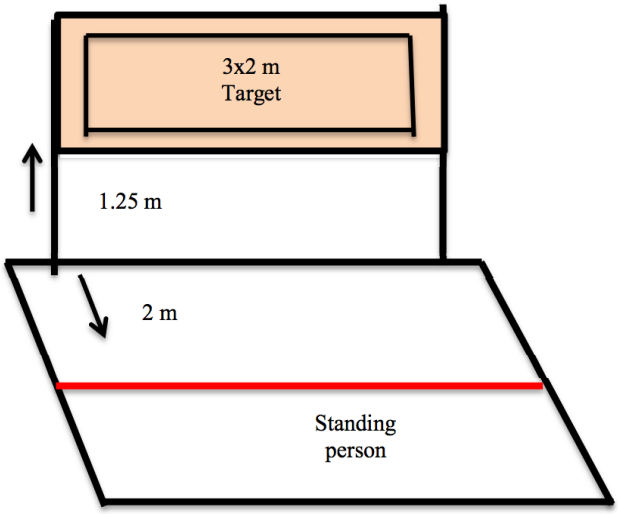

Fig. 3. Eyes-Feet Coordination Test

Meanwhile the dependent variable was smash technique learning skill in sepak takraw. The constellation model of the research method could be seen in following figure:

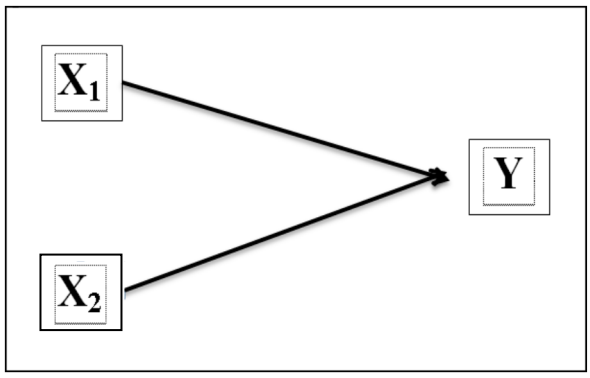

Fig. 4. The constellation of causal between variables X1, X2 and Y

Statistical analysis

The method used in this research is quantitative approach using measuring and test method. The Anova path analysis was carried out to conduct the analysis technique. The path analysis studied and analyzed the relation between each research variable by measuring the direct influence in dependent variable (Y) and independent variable (X_1 and X_2).

Results

The result of statistical analysis indicated that the hypothesis model-1 and model-2: knowledge level, physical condition (power, flexibility and coordination) affected on smash learning skill in sepak takraw simultaneously.

The structure of model-1

Fig. 5. The structural hypothesis of model-1

The result of significance testing is in following table:

Table 2. Model-1 Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.185a	.065	.001	9.765

a. Predictors: (Constant), Knowledge Level (IQ)

Based on the coefficient of determination for model-1 (R^2) as many as 0.065. It means as many as 6.5% of the knowledge level (IQ) variability is able to describe by smash technique learning skill in sepak takraw. Therefore, $\varepsilon = \sqrt{1} - R^2 = \sqrt{1} - 0.065 = 0.935$.

Table 3. Model-1ANOVA[b]

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	182.001	1	90.061	1.061	.061[b]
	Residual	2245.120	50	89.543		
	Total	2199.000	49			

a. Dependent Variable: knowledge level (IQ)
b. Predictors: (Constant), smash technique learning skill in sepak takraw

According to the result of analysis from the table above, it was obtained 1, Fo = 1.001; db1 = 1 db2= 50, p-value = 0.061< 0.05. It means H_0 is rejected. Hence, the knowledge level (IQ) affects smash learning skill technique in sepak takraw simultaneously.

The positive influence could be seen in following output:

Table 4. Model-1Coefficients[a]

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	69.377	9.959		6.277	.071
	Knowledge level (IQ)	.195	.195	.195	1.010	.061

a. Dependent Variable: smash technique learning skill in sepak takraw

By using knowledge level (IQ), it was obtained the path coefficient which is seen in standardized coefficient (Beta) column. The tested hypothesis was:

The formula of hypothesis model-1:

$H_0 : \rho x_1 y \leq 0$

$H_1 : \rho x_1 y > 0$

Based on the table coefficient, it was gained data consecutively: ρx_1x_2= -0.195; t_0 = 1.010, p-value = 0.061 < 0.05. It means H_0 is rejected. On the other words knowledge level (IQ) affects smash learning skill technique in sepak takraw positively.

The structure of model-2

The hypothesis of model-2: physical condition (power, flexibility and coordination) affects smash technique learning skill in sepak takraw simultaneously.

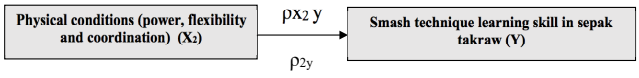

Fig. 6. The structural hypothesis of model-2

The result of significance testing is in following table:

Table 5. Model-2 Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.385[a]	.155	.200	7.821

a. Predictors: (Constant), physical conditions (power, flexibility & coordination)

Based on the coefficient of determination for model-2 (R2) as many as 0.155. It means as many as 15.5% of the smash technique learning skill in sepak takraw variability is able to describe by physical conditions (power, flexibility and coordination). Therefore, $\varepsilon = \sqrt{1 - R^2} = \sqrt{1 - 0.155} = 0.845$.

Table 6. Model-2ANOVA[b]

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	620.004	2	370.087	4.626	.099[b]
	Residual	2240.720	49	80.000		
	Total	2810.244	48			

a. Dependent Variable: smash technique learning skill in sepak takraw

b. Predictors: (Constant), physical conditions (power, flexibility & coordination)

According to the result of analysis from the table above, it was obtained 1, Fo = 4.626; db1 = 2 db2= 49, p-value = 0.099< 0.05. It means H_0 is rejected. Hence, the physical conditions (power, flexibility and coordination) affects smash learning skill technique in sepak takraw simultaneously.

The positive influence could be seen in following output:

Table 7. Model-2 Coefficients[a]

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	50.627	13.132		3.855	.001
	Physical conditions (power, flexibility & coordination)	.334	.155	.334	1.975	.099
		.322	.155	.321	1.901	.078

a. Dependent Variable: smash technique learning skill in sepak takraw

By using backward method, it was obtained the path coefficient which is seen in standardized coefficient (Beta) column. The tested hypothesis was:

The formula of hypothesis model-2:

H0 : $\rho x2y \leq 0$

H1 : $\rho x2y > 0$

Based on the table coefficient, it was gained data consecutively: ρx_1x_2 = - ρx_1x_2 = -0,155; t_0 = 1,975, p-value = 0.099 < 0.05. It means H_0 is rejected. On the other words physical conditions (power, flexibility and coordination) affects smash learning skill technique in sepak takraw positively.

The structure of model-3

The hypothesis of model-3: knowledge level (IQ) and physical conditions (power, flexibility and coordination) affect smash technique learning skill in sepak takraw simultaneously.

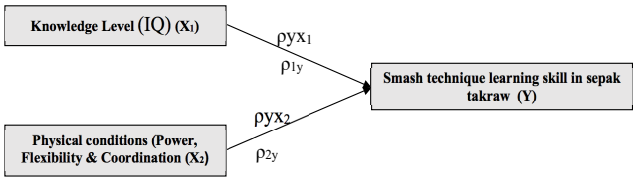

Fig. 7. The structural hypothesis of model-3

The result of significance testing is in following table:

Table 8. Model-3 Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.711[a]	.505	.448	6.328

a. Predictors: (Constant), knowledge level (IQ), physical condition (power, flexibility and coordination)

Based on the coefficient of determination for model-3 (R^2) as many as 0.505. It means as many as 50.5% of the smash technique learning skill in sepak takraw variability is able to describe by knowledge level (IQ) and physical conditions (power, flexibility and coordination). Therefore, $e = \sqrt{1 - R^2} = \sqrt{1 - 0.505} = 0.703$.

Table 9. Model-3 ANOVA[b]

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1063.823	3	354.608	8.854	.000[b]
	Residual	1041.262	26	40.049		
	Total	2105.085	29			

a. Dependent Variable: smash technique learning skill in sepak takraw

b. Predictors: (Constant), knowledge level (IQ), physical condition (Power, Flexibility & Coordination)

According to the result of analysis from the table above, it was obtained 1, Fo = 8.854; db1 = 3 db2= 26, p-value = 0.000 < 0.05. It means H_0 is rejected. Hence, the knowledge level (IQ) and physical conditions (power, flexibility and coordination) affects smash learning skill technique in sepak takraw simultaneously.

Discussion

This research discover the direct influence of knowledge level (IQ) and physical conditon (power, flexibility and

coordination) towards smash technique learning skill in Sepak Takraw. It can be shown that the result of this reseach was obtained 1, Fo = 8.854; db1 = 3 db2= 26, p-value = 0.000< 0.05. It means H_0 is rejected. Hence, the knowledge level (IQ) and physical conditions (power, flexibility and coordination) affects smash learning skill technique in sepak takraw simultaneously. Therefore, beside having good physical condition, an athlete needs to have good knomledge level (IQ) to maximize the peak performance.

Relevant research previously conducted by Hidayat et al. (2020) Dominant Physical Factors Determining Takraw Playing Skills. This study aims to determine the dominant physical factors that can support the skills of playing sepak takraw which consist of serving, passing and smash. The results of this study are the dominant factor that influences service skills is coordination with a correlation value of 0.937, in baiting skills the dominant factor that affects is coordination with a correlation value of 0.933, and the dominant factor that affects smash skills is strength with a correlation value of 0.603.

Another relevant research previously by Ramadhan and Bulqini (2018) with the title Receive Analysis in the Final Sepak Takraw Match. This study aims to determine the relationship between Kinesthetic Perception and Sila Kicks in the Sepak Takraw Game. The results showed that there was a relationship between kinesthetic perception and the skill of Sila kicks in the strong category of sepak takraw, which was indicated by (r^2) = 60.90%. The better the student's kinesthetic perception, the higher the ability of its sila kicks. The conclusion is that there is a close relationship between kinesthetic perception and sila kicks in the game of sepak takraw.

The most recent previous and relevant research is Wahyudi, Budiman, and Saepudin (2018). With the title Application of the TGT Type Cooperative Learning Model in the Learning of the Takraw-Oriented Big Ball Game to Improve Cooperation and Playing Skills. The purpose of this study was to determine the impact of the application of the TGT type cooperative model on playing skills and cooperation in takraw-oriented big ball learning. The results of the analysis of playing skills showed an increase in the percentage from the initial observation (15.55%) to the second cycle test of action II (75.83%). The cooperation test showed an increase in the percentage from the initial observation (24.44%) to the second cycle test of action II (75.56%). So it can be concluded that the application of the TGT type of cooperative learning model in soccer learning oriented to the takraw game can improve playing skills and cooperation in sepak takraw.

(1) In specific, the ability to respond towards specific stimulation. This ability does not need the manipulation of symbol, problem solver and rule decision; (2) The intellectual ability is the ability in interpreting concept and sign. The learning evaluation is a process in collecting information. The intellectual ability consists of categorizing ability, the analysis-synthesis ability of conceptual fact and the development of science principle. The intellectual ability is the ability in conducting cognitive activity in specific characteristic; (3) Cognitive strategy is the ability in distributing and directing its cognitive activity. This ability consists of concept and principle in problem solving; (4) Motoric ability in the ability in conducting a series of physical movement in coordination until the automatism of physical movement is created (Van Biesen et al., 2021).

Attitude was the ability in accepting and refusing the object based on its assessment. This ability transforms the assessment into standard behavior (Agus Suprijono, 2015). According to those explanations learning can be described as the process of exploring knowledge in understanding something unfamiliar through the process of studying. This process can be applied into human life to change someone's mindset, acting and behavior. According Dimiyanti dan Mudjiono (2012) knowledge was the result of discovering something new. This is obtained when someone is doing sensing on certain object. Jujun Huda Miftahul (2012) defined knowledge as what is known about certain object including science. Based on Chen et al. (2018) science was human's ability in comprehending an encountered object towards specific matter. This comprehension could be said as the result of human's effort in understanding something. Chen and Xiao (2017) divided knowledge into two types: a) scientific knowledge and b) non-scientific knowledge. Scientific knowledge is the result of someone's comprehension that is obtained using scientific method. Meanwhile, non-scientific knowledge is obtained through certain ways other than scientific method.

Based on the descriptions above knowledge could be gained through curiosity about certain object and it is obtained without using scientific method. Also, knowledge could be acquired through the experience of sensing. In learning sepak takraw technique, scientific knowledge and non-scientific knowledge are needed because it requires good physical conditions such as power, flexibility and the coordination of leg and eyes. IQ and physical condition are very influential on the smash learning skill technique. Physical condition is one of the indispensable requirements in an effort to increase one's achievement, it can even be said to be a basic need. According to Casadio et al. (2017). Physical condition preparation is one that must be considered and considered from several important cases as a necessary element in training to achieve peak performance. And with good knowledge, practice ideas, strategies in the game are easy to understand. High intelligence also has a big influence on achievement. This is in line with research conducted by Ohtani and Hisasaka (2018) shows that people with high intelligence will have better performance than people who have moderate or low intelligence.

For the future research, to improve the smash technique learning skill Researchers are expected not only to discuss IQ and physical conditions but can also be combined with (Emotional Quotient) because EQ is also one of the important aspects that athletes must possess. EQ is the ability to motivate oneself, control feelings and impulses to keep stress from turning off the ability to think, empathize and apply emotional intelligence effectively (Kurniawan and Syakur, 2017).

Conclusions

According to the result of path analysis calculation above, the hypotheses of model-1, model-2 and model-3 indicated the information about the direct influence between knowledge level (IQ) (X_1) and physical conditions (power, flexibility and coordination) (X_2) on smash technique

learning skill in sepak takraw (Y) objectively. In short, the results of the analysis could be seen in following statement:

The direct influence of X_1 towards Y ($X_1 \rightarrow$ Y) or (r_{1y}) = 0.155. Therefore, the influence of knowledge level (IQ) (X_1) affects smash technique learning skill in sepak takraw (Y) as many as $\varepsilon = \sqrt{1 - R^2} = \sqrt{1 - 0.491} = 0.982$ or 9.82%.

The direct influence of X_2 towards Y ($X_2 \rightarrow$ Y) or (r_{2y}) = 0.604. Therefore, the influence of physical conditions (Power, Flexibility and Coordination) (X_2) affects smash technique learning skill in sepak takraw (Y) as many as $\varepsilon = \sqrt{1 - R^2} = \sqrt{1 - 0.155} = 0.845$ atau 8.45%.

The direct influence of X_1 and X_2 towards Y (X_1 and $X_2 \rightarrow$ Y) or (r_{3y}) = 0.484. Therefore, the influence of knowledge level (IQ) (X_1) and physical conditions (Power, Flexibility and Coordination) (X_2) affects smash technique learning skill in sepak takraw (Y) as many as $\varepsilon = \sqrt{1 - R^2} = \sqrt{1 - 0.505} = 0.703$ atau 7.03%.

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

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ВПЛИВ РІВНЯ ЗНАНЬ (IQ) І ФІЗИЧНИХ КОНДИЦІЙ (СИЛА, ГНУЧКІСТЬ І КООРДИНАЦІЯ) НА НАВИЧКИ НАВЧАННЯ ТЕХНІКИ УДАРУ В СЕПАК-ТАКРО

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 7 рис., 9 табл., 28 джерел.

Мета дослідження. Метою цього дослідження було виявити прямий вплив між рівнем знань (IQ) і фізичними кондиціями (сила, гнучкість і координація) на навички навчання техніки удару в сепак-такро.

Матеріали та методи. Метод, використаний в цьому дослідженні, був кількісним. Для аналізу результатів було проведено аналіз шляху ANOVA. Всього було прийнято 50 спортсменів сепак-такро зі столиці Джакарти. Ці спортсмени також були взяті в якості вибірки з генеральної сукупності. До вибірки увійшли спортсмени, які взяли участь в чемпіонатах області і країни.

Результати. На підставі дослідження було отримано: 1) рівень знань (IQ) безпосередньо впливає на навички навчання техніки удару в сепак-такро в розмірі 0,982; 2) фізичні кондиції (сила, гнучкість і координація) безпосередньо впливають на навички навчання техніки удару в сепак такрав на 0,845; і 3) в цілому рівень знань (IQ) і фізичні кондиції (сила, гнучкість і координація) безпосередньо впливають на навички навчання техніки удару в сепак-такро до 0,703.

Висновки. Таким чином, можна зробити висновок, що рівень знань (IQ) і фізичні кондиції (сила, гнучкість і координація) впливають на навички в навчанні техніки удару в сепак-такро у спортсменів столиці Джакарти.

Ключові слова: рівень знань (IQ), фізичний стан, техніка удару, сепак-такро.

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ORIGINAL SCIENTIFIC ARTICLE

THE CURRENT IMPLEMENTATION OF AN EVIDENCE-BASED HAMSTRING INJURY PREVENTION EXERCISE (NORDIC HAMSTRING EXERCISE) AMONG ATHLETES GLOBALLY

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Abstract

Purpose. The Nordic hamstring exercise (NHE) has been shown to be successful in reducing hamstring muscle injury (HMI), which is one of the most common non-contact injuries of the lower limbs. This is especially pertinent in sports that require acceleration, maximal sprints, and sudden changes in the direction of running and sprinting, such as soccer and rugby. This study aimed to evaluate the awareness, implementation, and opinions of athletes worldwide regarding the effectiveness of NHE in preventing hamstring injury.

Materials and methods. A self-administered questionnaire was distributed to 1500 athletes from different sports. The survey consisted of six questions covering country, gender, type of sport, awareness, implementation, and opinions of athletes worldwide regarding the effectiveness of NHE in preventing hamstring injury. The survey was available in ten different languages.

Results. A total of 1142 male and female athletes from different sports participated in the survey. More than half of the athletes 641 (56%) were aware of NHE, and only 519 (45.4%) were implementing NHE in their current training routines. Athletes who implemented NHE reported a positive opinion regarding the program's effectiveness with a score of 8.4 ± 1 out of 10.

Conclusions. Many athletes were aware of NHE and implemented it in their training routine since they found it to be effective in decreasing hamstring injury rates. However, additional work must be done to educate athletes about the importance of implementing this exercise and its effectiveness in preventing hamstring injury.

Keywords: hamstring muscles, muscle injury, athletes, surveys, questionnaires.

Introduction

The most common lower limb injuries in sports are hamstring muscle injuries (HMIs), which occur in sports involving high-speed running, such as rugby, baseball, basketball, soccer, and American football. HMIs are considered the most common noncontact injuries in these sports. However, they can also occur due to direct trauma to the muscle fibers (Reurink et al., 2014). Ueblacker et al. (2015) investigated the incidence of direct and indirect HMIs in 1981 players who were followed prospectively from 2001 to 2013; they scored 2287 HMIs and found that 88% of the injuries were indirect and 12% were direct.

There are two types of HMIs: stretch-type and sprint-type HMIs (Ekstrand et al., 2012). Stretch-type injuries are caused by a slow or sudden uncontrolled stretch that can occur in sports, such as dancing, gymnastics, and water skiing (Ekstrand et al., 2012). These injuries occur in the proximal free tendon of the semimembranosus muscle. In contrast, sprint-type injuries often occur in sports that involve running and cutting, such as Australian football, American football, soccer, and rugby (De Vos et al., 2014). Sprint-type HMIs usually occur in the late swing phase during sprinting when the hamstring submaximally stretches over the knee joint before the foot hits the ground (Chumanov et al., 2011).

Hamstring muscle injuries typically occur along the proximal musculotendinous junction but may also occur anywhere in the muscle belly between the origin and insertion

(Ropiak et al., 2012). The severity of the injury can be estimated according to the number of days the athlete remains absent from training sessions or matches and is classified into four levels: minimal, 0-3 days; mild, 4-7 days; moderate, 8-28 days; and severe, >28 days (Hägglund et al., 2018).

HMIs represent one-third of all muscle strains and 11% of all injuries. Approximately 14% of these HMIs can result in re-injury (Dadebo et al., 2004). In a prospective cohort study, Yeung et al. (2009) investigated the incidence of HMIs in competitive sprinters, and they found that eight of 44 sprinters had sustained hamstring injury over the season at a rate of 0.9 per 1000 h of exposure. An analysis of 23 European professional soccer teams from 2007 to 2011 revealed 516 HMIs, representing 11% of all injuries and one-third of all muscle strains (Ekstrand et al., 2012; Dadebo et al., 2004; Ekstrand et al., 2016).

In a longitudinal analysis of 36 clubs in 12 European countries, 1614 HMIs were recorded from 2001 to 2014, and while the overall prevalence of recorded injuries increased by 2.3% every year, HMIs recorded a 4% increase per year (Ekstrand et al., 2016).

The Nordic hamstring exercise (NHE) has been shown to be effective in increasing eccentric strength. For example, 4–10 weeks of NHE can result in an eccentric strength gain of approximately 11% to 21% with no significant concentric strength gains, and after a 6-week intervention, neural adaptations occurred, resulting in higher hamstring muscle activation during the NHE (Delahunt et al., 2016). In another study, a single NHE training session was followed by an immediate shift (7.7°) in optimum knee flexion torque, which was sustained for ten days post-exercise, and the peak eccentric hamstring torque was unchanged following 4- and 6-week NHE interventions (Seymore et al., 2017). Moreover, a 12-week NHE program decreased the rate of hamstring injury by 65% to 70% (Lovell et al., 2018).

Changes in the architectural characteristics of the biceps femoris long head (BFlh) after eccentric strength training with NHE, followed by a detraining period, were studied after eight weeks of NHE training. The findings showed an increase in the fascicle length (FL) of BFlh by 32.9%, increased muscle thickness (MT), and a decrease in the pennation angle (PA), whereas the 4-week subsequent detraining showed a decrease in FL and MT as well as an increase in PA. Therefore, the authors concluded that the NHE causes alterations in the architecture of the BFlh, and this change facilitates injury prevention and rehabilitation.

The NHE can be easily performed by any athlete (Alonso-Fernandez et al., 2018) with different protocol periods; pre-training protocols for 4 weeks (Brughelli et al., 2010), 6 weeks (Seymore et al., 2017), 8 weeks (Aktuğ et al., 2018), 10 weeks (Rey et al., 2017), or up to 12 weeks (Lovell et al., 2018) all have similar effects, which is an increase in the FL of BFlh that could be due to an increase in the length of sarcomeres after eccentric strength training (Alonso-Fernandez et al., 2018). Even the 4-week NHE protocol was found to be effective in decreasing the risk factors for hamstring muscle injury in young adults, and short-term NHE training (4 weeks, twice a week, three sessions, 9-10 repetitions) with post-training assessments of knee flexor and extensor strength and flexibility showed that the training program reduced many HMI risk factors in young adults (Ribeiro-Alvares et al., 2018).

Al Attar et al. (2017) conducted a meta-analysis to evaluate the effect of injury prevention programs that include NHE on hamstring injury rates in soccer players and concluded that these injury prevention programs are effective in decreasing the risk of HMIs among soccer players, and per 1000 h of exposure, the teams adopting injury prevention programs with NHE showed a 51% reduction in HMIs than teams that did not adopt any injury prevention measures. In a study of 40 amateur soccer teams that compared the injury rates in teams performing NHE and in others that did not, the authors concluded that adopting the NHE for 13 weeks with regular training significantly reduced injury rates (Van der Horst et al., 2015).

Dunlop et al. (2020) published a worldwide survey of 131 soccer teams that reviewed the return-to-play (RTP) criteria they were using to support their decision-making for RTP, specifically if the athlete was ready to continue running at high speed. The results showed that the majority of teams assessed the absence of pain and hamstring strength; the authors also mentioned that hamstring strength and training load were reported more frequently than any other criteria when they returned to full training.

Nevertheless, to our knowledge, there are no published data in the literature regarding the awareness, opinions, and implementation strategies in relation to NHE among athletes in deferent sports. Therefore, the purpose of this survey was to assess the awareness, implementation, and opinion of NHE in relation to the prevention of HMIs among athletes in different sports worldwide.

Materials and methods

Survey development

There are no validated questionnaires addressing athletes' awareness, implementation, and opinion of NHE; therefore, a survey to collect information on NHE awareness and implementation among athletes and to evaluate their opinions of NHE in preventing hamstring injury was developed. The questionnaire was inspired by a review of the recent literature on HMI prevention (Ribeiro-Alvares et al., 2018; Al Attar et al., 2017; Van der Horst et al., 2015; Al Attar et al., 2019; Bahr et al., 2015; Potier et al., 2009). It consisted of three sections: awareness, implementation, and opinion. Each section contained one closed question, except for the awareness section, which had three closed questions. The questions were formulated to obtain information about the efficiency and effectiveness of the NHE program for athletes. Thus, the questionnaire consisted of six questions covering the athletes' demographics (sex, country), type of sports, awareness of NHE (Yes or No), implementation of NHE (Yes or No), and the athlete's personal opinion about the effectiveness of the exercise in preventing hamstring injury, which was rated on a scale of 0 (ineffective) to 10 (very effective).

The study protocols were approved by the Biomedical Ethics Committee, Umm Al Qura University (approval no. HAPO02K012202011496). Informed consent was obtained from all individuals included in this study.

Participants and sample size

An estimated 2 billion people globally play sports, as either amateurs or professionals. Therefore, to achieve a 3%

confidence interval (margin of error) at a 95% confidence level, 1500 male and female amateur and professional athletes from different countries worldwide were invited to complete the online survey on NHE.

Administration and survey software

The survey was conducted using a web-based Google Form (Alphabet Inc, Mountain View, CA) The survey was framed in English, certified translated into 10 languages (Arabic, Chinese, French, German, Italian, Japanese, Portuguese, Russian, Spanish, and Turkish), and distributed across different sports organizations worldwide. Data were collected between June 2019 and June 2021. The structured survey link explained the purpose of the study and sought consent for participation in addition to providing an avenue for communication in case the respondents had any queries. All respondents were limited to one response, and the responses were voluntary and anonymous.

Statistical analysis

Responses were organized in Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA) and analyzed using the Statistical Package for the Social Sciences (SPSS) version 24.0 (SPSS Inc., Chicago, Illinois, USA). Pearson's chi-squared test was used for comparison of the percentage values of the descriptive statistics. A p-value of <0.05 is considered significant.

Results

A total of 1142 male and female amateur and professional athletes from 152 countries completed the questionnaire (response rate, 76%), yielding a confidence interval (margin of error) of 2.9% at a 95% confidence level.

Participant distribution according to the type of sport

The largest number of participants were from four sports, namely CrossFit, bodybuilding, football, and gymnastics, followed by other sports (Figure 1).

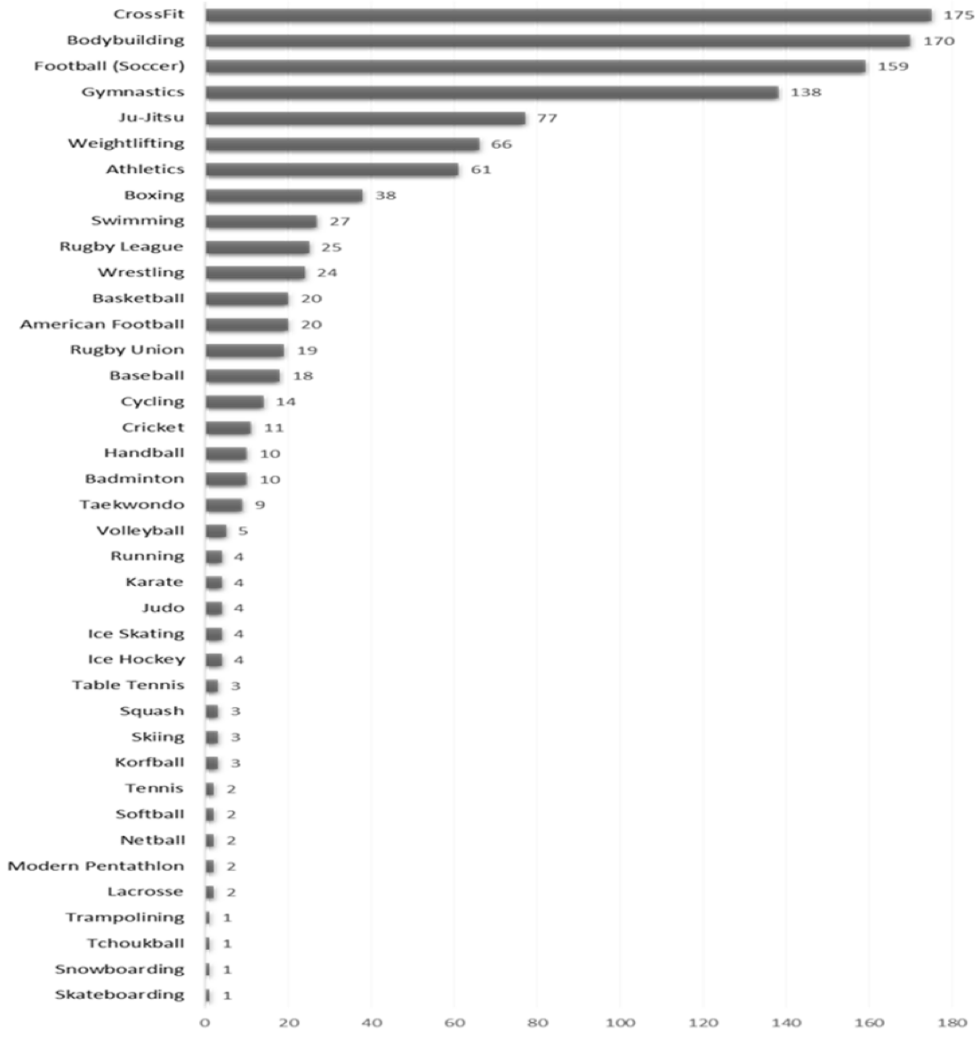

Fig. 1. Number of survey participants from different sports

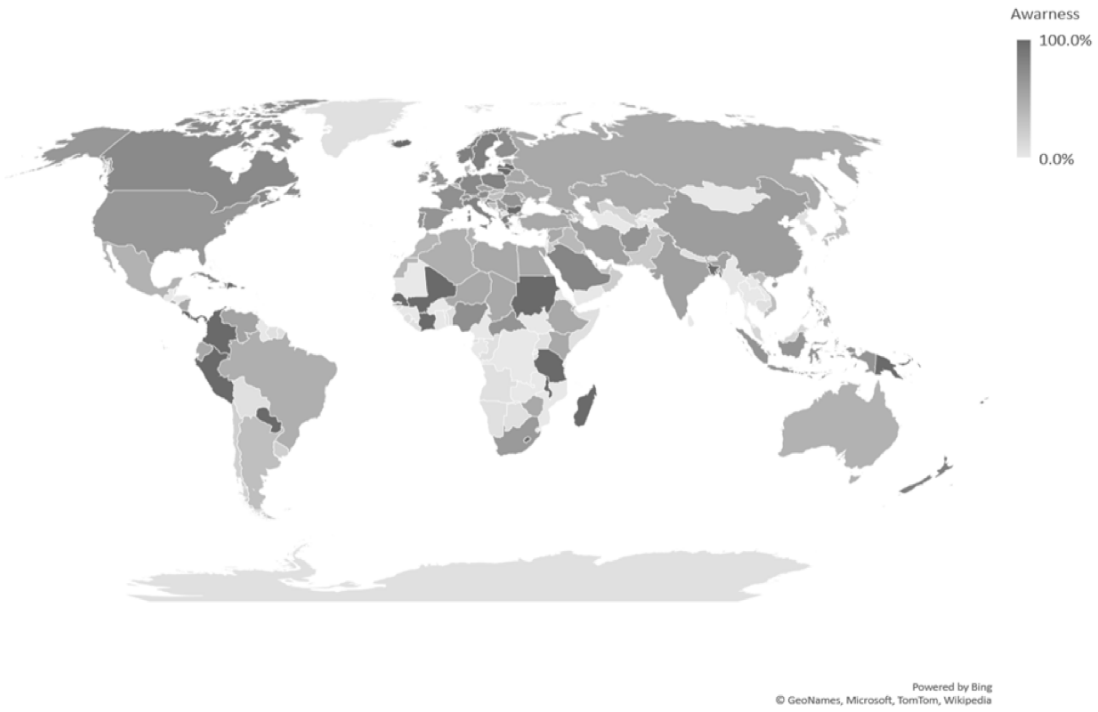

Fig. 2. Awareness of NHE worldwide

Table 1. Distribution of participants according to their continent and gender

	No	%
Continent		
Europe	453	39.7%
Asia	341	29.9%
Africa	125	10.9%
South America	96	8.4%
North America	75	6.6%
Australia	52	4.6%
Gender		
Male	1041	91.2%
Female	101	8.8%

Table 2. Distribution of awareness and practice according to the participant's continent

Continent	Awareness		Imple-ment		Opinion
	No	%	No	%	Range (Mean ± SD)
North America	51	68.0	31	60.8	6–9 (7.9 ± 0.9)
Europe	296	65.3	258	87.2	5–10 (8.6 ± 0.9)
Africa	60	48.0	48	80.0	6–10 (8.4 ± 1.0)
Asia	172	50.4	127	73.8	5–10 (8.3 ± 1.1)
Australia	23	44.2	19	82.6	6–10 (8.7 ± 1.1)
South America	44	45.8	37	84.1	5–10 (8.2 ± 0.9)
Total	646	56.6	520	80.5	5—10 (8.4 ± 1.0)
P-value		.001*		.001*	.001*#

P: Pearson X2 test; #: One Way ANOVA;* P < 0.05 (significant)

Awareness of NHE

Among the participants who responded, 56.6% were aware of NHE, while 43.4% were unaware. The highest number of participants (n = 453) were from Europe, where the awareness percentage was 65.3%, while North America recorded the highest awareness percentage of 68% in 75 participants. The awareness percentages of the participants from the other continents were as follows: Africa, 48.0% of 125 participants; Asia, 50.4% of 341 participants; Australia, 44.2% of 52 participants (Tables 1 and 2). A chart map was used to indicate the awareness percentages by country, and the map indicated minimal or no awareness of NHE among participants in some countries (Figure 2).

Implementation of NHE

Among the participants who were aware of the NHE, 520 athletes were implementing the NHE in their training (Table 2).

Opinions of NHE

Among the participants who implemented the NHE, the total opinion for many participants from different continents regarding the effectiveness of NHE was a mean of 8.4 ± 1.0 out of 10. The opinion section of the survey included a scale of efficacy from 0 (ineffective) to 10 (highly effective), and most implementers of NHE found it to be effective in reducing hamstring injury (Tables 1 and 2).

Discussion

In the literature, HMIs represent the most frequently reported injuries, and the incidence of these injuries has increased in the last decade with high rates of recurrences and poor outcomes for athletes despite the adoption of preventive measures and strategies and the extensive knowledge of the mechanisms underlying these injuries (Van der Horst et

al., 2018). Therefore, this study aimed to address athletes' knowledge of well-established preventive protocols, such as the NHE, which has proven to be effective for decreasing injury rates by at least 50% (Al Attar et al., 2017). A cross-sectional survey study was conducted to assess three new criteria: athletes' awareness of the NHE program, their implementation of this program in their exercise routines, and their opinions about the effectiveness of this program in decreasing hamstring injury rates. Within the limitations of the study, our results showed that most of the respondents were from Europe and Asia (39.7% and 29.9%, respectively), and the overall awareness of the NHE was 56.6% worldwide. Moreover, football (soccer) athletes represented the third-largest population of respondents (13.9%), after CrossFit (15%) and body building (14.9%).

The highest awareness percentages were recorded in North America and Europe (68% and 65.3% of the respondents, respectively). This finding was not surprising because these regions have highly developed sports medicine systems that employ a number of measures to ensure athlete safety, increasing their adoption of injury-prevention protocols. Europe is considered the home of injury prevention programs since Jan Ekstrand published the first-ever injury prevention program in the literature for professional football in 1982 (Ekstrand et al., 1982).

Surprisingly, the results of the current study showed that Australia occupied the last place in participation, representing only 4.6% of the overall sample size, and it showed the lowest awareness percentage (44.2%). The Australian literature is extraordinarily rich in publications about the importance of injury prevention protocols and their effectiveness in decreasing injury rates (Al Attar et al., 2016) and even includes an evidence-based study for the implementation of injury prevention studies in football (Al Attar et al., 2018), confirming the presence of a gap between research and actual practice. However, the low awareness rate may also be attributable to the low response rate from Australia in comparison to those from the other continents.

Despite the conventional logic that greater awareness leads to greater implementation, the study results showed some notable differences between the trends in awareness and implementation. For example, despite showing the highest awareness percentage, athletes from North America showed a low implementation percentage of 60.8%, which was the lowest among the continents assessed in this study. In contrast, Europe, which showed the second-highest awareness rate, showed the highest implementation rate (87.2%). The implementation rates in other regions of the world were similar and ranged between 73.1% and 84.1%.

In the assessments of effectiveness, all rating results were similar with the highest mean value (8.7) obtained for athletes from Australia. The lowest mean value (7.9) was reported for athletes from North America. Despite showing the highest level of awareness of NHE, North American athletes showed the lowest level of NHE implementation, which may be one reason for the low opinion of effectiveness of NHE in athletes from this region. However, these low levels of perceived effectiveness of NHE in North American athletes have not been reported in the literature until now.

Bahr et al. conducted a survey study to determine the efficacy, adoption, and implementation of the NHE program among elite male soccer players in Europe from 2012 to 2014, and although they obtained a response rate of 100% across 150 club seasons, only 10% of the respondents adopted a protocol; the extremely low adoption rate resulted in a compliance rate that was too low to show any effect on hamstring injury rates (Bahr et al., 2015). The evidence from this study could explain the low effectiveness score rated by North American athletes, which may be most probably attributed to their low implementation percentages for the preventive protocol. Thus, consistent with previous literature, that a gap still exists between the awareness of the injury's occurrence and implementation of preventive measures. Furthermore, Al Attar et al. (2021) found limited implementation of the NHE in professional and semi-professional soccer. An online survey was completed by 812 (88.3% male and 11.7% female) players and coaches. Of these, 395 (48.6%) were aware of the NHE, and 355 (43.7%) implement it in their current practice. Those implementing NHE had a positive opinion about its efficacy in reducing hamstring injuries.

This study had multiple limitations. It was not possible to control the percentage of respondents worldwide and the number of athletes responding from each country to obtain the most representative results. Athletes in some countries did not respond to the online survey, which affected the overall percentages of those regions in comparison with other regions of the world. Nevertheless, many of the results reported herein do not have supporting data or explanations in the existing literature; for example, North American athletes showed the highest awareness of the NHE but also showed an extremely low implementation rate. This study thus presents the scope for new research on the topic of NHE implementation in low-implementation regions, such as Asia and North America. In addition to highlighting gaps between awareness and actual implementation, this study also revealed gaps in awareness in some regions, such as Australia and South America. More research is needed on the topics connecting the three factors, and region-specific studies, instead of the global limited study conducted herein, may be more useful to understand these trends. Thus, the present study presents the scope for additional research on these topics for different regions and indicates the need for region-specific studies to understand the gaps in implementation and awareness (or the effectiveness) of the program.

Appropriate implementation of injury prevention programs is an important factor that affects the health of athletes; therefore, more research is needed to increase awareness in regions, such as Asia, where both implementation and awareness percentages were found to be relatively low. Additional studies are also required to evaluate the opinions regarding the effectiveness of the NHE because this study showed that the actual effectiveness of the NHE is low in some regions.

Conclusions

Most athletes around the world are aware of NHE and are implementing it in their exercise training routine because they find it effective in decreasing hamstring injury rates. However, additional work must be done to educate athletes about the importance of implementing this exercise because the adoption percentages differ significantly worldwide.

Athletes who adopt the NHE usually find it to be highly effective in reducing hamstring injury rates.

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Conflict of interest

The authors declared no conflicts of interest.

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ПОТОЧНА РЕАЛІЗАЦІЯ НАУКОВО ОБҐРУНТОВАНОЇ ВПРАВИ ПО ЗАПОБІГАННЮ ТРАВМ ПІДКОЛІННОГО СУХОЖИЛЛЯ (СКАНДИНАВСЬКА ВПРАВА НА ПІДКОЛІННЕ СУХОЖИЛЛЯ) СЕРЕД СПОРТСМЕНІВ У ВСЬОМУ СВІТІ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 2 рис., 2 табл., 29 джерел.

Мета. Скандинавська вправа на підколінні сухожилля (NHE) виявилася успішною у зменшенні травми м'язів підколінного сухожилля (HMI), яка є однією з найпоширеніших безконтактних травм нижніх кінцівок. Це особливо доречно у видах спорту, які вимагають прискорення, максимальних спринтів та різких змін напрямку бігу та спринту, таких як футбол та регбі. Це дослідження мало на меті оцінити обізнаність, реалізацію та думки спортсменів у всьому світі щодо ефективності NHE у запобіганні травм підколінного сухожилля.

Матеріали та методи. Анкету для самостійного розповсюдження було роздано 1500 спортсменам з різних видів спорту. Опитування складалося з шести питань, що охоплюють країну, стать, вид спорту, обізнаність, використання та думки спортсменів у всьому світі щодо ефективності NHE у запобіганні травмам підколінного сухожилля. Опитування було доступне десятьма різними мовами.

Результати. Всього в опитуванні взяли участь 1142 спортсмени з різних видів спорту. Більше половини спортсменів 641 (56%) знали про NHE, і лише 519 (45,4%) впроваджували NHE у своїх поточних тренувальних процедурах. Спортсмени, які впровадили NHE, вказують на ефективність програми з оцінкою 8,4 ± 1 з 10.

Висновки. Більшість спортсменів знали про NHE та впроваджували її у свої тренувальні процедури, оскільки вважали, що вона ефективна у зниженні частоти травм сухожиль. Однак необхідно докласти додаткових зусиль, щоб сформувати знання спортсменів про важливість виконання цієї вправи та її ефективність у запобіганні травм сухожилля.

Ключові слова: м'язи підколінного сухожилля, травми м'язів, спортсмени, опитування, анкетування.

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ORIGINAL SCIENTIFIC ARTICLE

THE RELATIONS OF USING DIGITAL MEDIA AND PHYSICAL ACTIVITY WITH THE PHYSICAL FITNESS OF 4TH AND 5TH GRADE PRIMARY SCHOOL STUDENTS

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Abstract

The study purpose was to determine the relations of using digital media and physical activity with the physical fitness of 4th and 5th grade students of the state of Ngablak Elementary School in the academic year 2019/2020, Turi, Sleman Regency both individually and wholly.

Materials and methods. This research is a correlative study, which aims to find out whether there is a relationship between independent variables and dependent variables. The population of this study was 49 students from 4th and 5th grade of the state of Ngablak Elementary School in the academic year 2019/2020, Turi, Sleman. All of them were used as research subjects. The data collection technique is surveys. The surveys are done by applying collection techniques using surveys, tests and measurements. The instrument used in this study was a questionnaire both for digital media variables and physical activities, as well as the physical fitness test for Indonesian physical fitness variables. Data analysis techniques are regression and correlation analysis, both in simple way and double way through the prerequisite tests for normality and linearity.

Results. The results showed that at the level of 5% error means the correlation between the use of digital media and physical activity and the physical fitness of students in 4th and 5th grade of the state of Ngablak Elementary School in 2019/2020 academic year Turi, Sleman Regency, it was $F_{count} = 11.072 > F_{table} = 3.20$.

Conclusions. Since $F_{count} > t_{table}$, it can be concluded there is a significant relation between the use of digital media and physical activity and physical fitness.

Keywords: digital media, physical activity, physical fitness, elementary school.

Introduction

As the age progresses, technology develops rapidly, therefore everyone is required to be able to keep up with these developments (Limin et al., 2021). There are many positive impacts of this development. The positive impact of the development of science and technology enables everyone to obtain abundant, fast, and easy information from all over the world, penetrating space and time, for example with digital media (Wu, Wang, & Evans, 2019). The rapid development of digital media, it turns out that the psychological situation of children also experiences various reactions (Livingstone et al., 2017). Some use smartphones to add value to school lessons, and some make students lazy to move and often waste time in front of smartphones. In addition, the large number of children using digital media makes them less sociable (Cunningham, 2018).

There are actually a lot of sports games that can make a child healthy, but games in digital media e.g. smartphones dominate more (Kristiyanto et al., 2020). This is what makes the child's movements inhibited because the child is already sleepy on the smartphone (Handa & Ahuja, 2020). Physical activity outside the hours of the lesson as a reference becomes unusual for the children, this is actually on the basis of a rationing philosophy that explains the involvement of the child in the care of games, gymnastics, joint activities, and others

(Pozuelo-Carrascosa et al., 2018). To stimulate the development of efficient children's movements which will later be useful for mastering various skills. These skills can be in the form of basic skills, namely: walking, running, throwing, and jumping as well as special skills such as swimming and gymnastics. In the end, these skills will be used by children in everyday life (Bidzan-Bluma & Lipowska, 2018). Physical education teachers cannot know and directly monitor the physical activities of their students outside of school.

Development of basic movement skills and physical abilities in accordance with the needs of growth and development in a multilateral manner according to the age of students can be the basis for the development of sports movement skills (Sutapa et al., 2020). Physical activity is very important for a person, so everything that supports a good level of physical fitness is strived to be implemented since early childhood (Pramandhika, Rumini, & Kusuma, 2020). Therefore, the government requires the inclusion of physical education subjects in the education level from Elementary School, Junior High School, and Senior High School. Elementary school age is a very decisive period in the possibility of achieving growth and development in the future. The role of physical education as an educational tool is to achieve overall goals. The purpose of physical education is not an activity in itself, but to develop a student's potential through physical activity (Castelli & Mitchell, 2021). So that physical activities carried out during physical education can improve the quality of students' physical fitness, but if they are not active during the learning process.

A person with good physical fitness will be able to carry out daily activities relatively longer when compared to someone who has a low level of physical fitness (Nasrulloh et al., 2020; Nugroho et al., 2021). Physical fitness is very important for someone, so everything that supports a good level of physical fitness, is strived to be applied since early childhood. According to the physical education curriculum, Physical Education is 2 integral parts of education as a whole that is able to develop a child or individual as a whole in the sense that it includes physical, intellectual, emotional and moral spiritual aspects which in the learning process prioritize physical activity and habituation to a healthy lifestyle (Osipov et al., 2021). One of the goals of physical education is to increase physical fitness. With good physical fitness, students can participate in learning optimally and in the end it will improve the quality of human resources (Wilson et al., 2021).

Because a good level of fitness is the initial capital for elementary school age children to achieve further physical fitness. Good physical fitness will affect student learning activities, because students with good fitness status will be more enthusiastic in participating in the learning process (Gråstén et al., 2021). However, in reality, from the results of observations at the Ngablak public elementary school, students in the learning process are not allowed to bring digital media such as cellphones, laptops, tablets, and others. So that at rest time children can use rest time to do physical activities such as running, some are sitting while chatting with friends and some are eating. However, during the break, there are still few students who do physical activities.

Table 1. Instrument Grid

Variable	Factor	Indicator	Question Number	Number of Question
The relationship between the use of digital media and physical activities on the physical fitness of 4th and 5th grade students of the state ngablak elementary school academic year 2019/2020, District of Turi, Regency of Sleman		Use of Digital Media		
	Communication	Use of digital media	1,2	2
		Application use	3,4	2
		The purpose of using media in communication	5,6	2
		Frequency and duration of usage	7,8	2
	Education	Use of digital media	9,10	2
		Application use	11,12	2
		The purpose of using media in communication	13,14	2
		Frequency and duration of usage	15,16	2
	Entertaiment/Recreation	Use of digital media	17,18	2
		Application use	19,20	2
		The purpose of using media in communication	21,22	2
		Frequency and duration of usage	23,24	2
		Physical Activity		
	Physical activity at school	The frequency of P.E. learning	27	1
		The intensity of P.E. Learning	29	1
		Participation in P.E. Learning	31	1
		Use of school breaks	33,34*	2
		Extracurricular activities at school	25	1
	Physical activity outside of the school	The frequency of P.E. learning	28,35	2
		The intensity of P.E. Learning	39,40,41	3
		Participation in P.E. Learning	30,37	2
		Use of school breaks	36*,38*	2
		Extracurricular activities at school	26,32	2
Total			41	41

Information: (*) negative statement item (-)

Materials and methods

Study participants

The population in this study were students of the state of Ngablak Elementary School, Turi District, Sleman Regency, with total of 51 students, namely 4th grade with 25 students and 5th grade with 26 students for academic year 2019/2020. The technique used in research sampling was incidental sampling, namely the technique of determining the sample based on the chance, i.e. anyone who incidentally meets the researcher can be used as a sample, if it is considered that the person who happened to be met is suitable as a data source.

Study organization

This study used an observational research design with survey methods and physical fitness test. Observational research is the research that does not manipulate or intervene in research subjects. The survey method of this research is a correlation study, using the survey method, while the data collection technique uses a questionnaire and the test uses the physical fitness test.

The instrument used in this study was a questionnaire. Compilers use a closed questionnaire so that high respondents choose several alternative answers available. Composers used a questionnaire with a Guttman scale. Research using the Guttman scale is carried out if you want to get a firm (consistent) answer to the problem being asked. Answers from respondents can be made the highest score "one" and the lowest score "zero" for alternative answers in the questionnaire, the compilers assign a category for each positive statement, namely Yes = 1 and No = 0, while the category for each negative statement, namely Yes = 0 and No = 1. The general information regarding the instrument can be shown in table 1 below.

Data collection was carried out by distributing the questionnaire directly by the compilers assisted by other colleagues, and the questionnaire then the researcher provided an explanation of the filling of the questionnaire in accordance with reality and honestly with the Guttman scale model, then the questionnaire was collected to the compilers. Physical fitness test is conducted during P.E. lesson hours.

Statistical analysis

To test the relationship between the independent variable and the dependent variable, the product moment correlation analysis was used. To provide an interpretation of this relationship, the following guidelines can be used:

Table 2. Interval Class Table

Formula	Category
$X \leq M - 1{,}5SD$	Very Less
$M - 1.5\ SD < X \leq M - 0.5\ SD$	Less
$M - 0.5\ SD < X \leq M + 0.5\ SD$	Enough
$M + 0.5\ SD < X \leq M + 1.5\ SD$	Good
$X > M + 1.5\ SD$	Very Good

M = Average Value, S = Standard Deviation

Results

Research Result

Digital media is denoted by X_1, obtained a score with a maximum value of 21.00 and a minimum value of 3.00. The mean obtained is 12.43, the standard deviation is 3.99, the mode is 13.00 and the median is 13.00. Furthermore, the data are arranged in a frequency distribution based on the mean and standard deviation values obtained, which are divided into five categories, namely very good, good, enough, poor, and very poor. The calculation of the category norms for the use of digital media can be seen in the following table.

Table 3. Variable Frequency Distribution of Digital Media Use

No	Interval Class	Category	Frequency	Percentage
1	X = 6.51	Very poor	4	8.16%
2	6.51 < X = 10.45	Poor	10	20.41%
3	10.45 < X = 14.40	Enough	19	38.78%
4	14.40 < X = 18.35	Good	13	26.53%
5	X > 18.35	Very good	3	6.12%
	Total		49	100%

From above table, it can be easily seen with the histogram of digital media below:

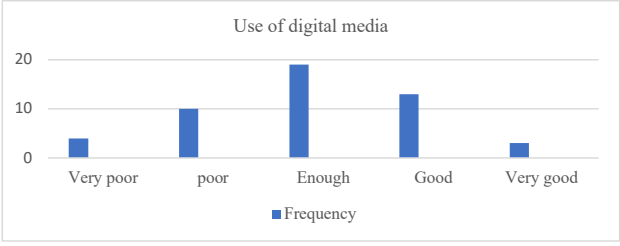

Fig. 1. Variable Histogram of Digital Media Usage

Physical activity is denoted by X_2, obtained a score with a maximum score of 104.00 and a minimum score of 22.00. The mean obtained is 54.53, the standard deviation is 16.66, the mode is 56.00 and the median is 53.00. Furthermore, the data are arranged in a frequency distribution based on the mean and standard deviation values obtained, which are divided into five categories. The following is the calculation of the norms for the physical activity category obtained.

Table 4. Variable Frequency Distribution of Physical Activity

No	Interval Class	Category	Frequency	Percentage
1	$X \leq 29{,}80$	Very poor	2	4.08%
2	$29{,}80 < X \leq 46{,}29$	Poor	14	28.57%
3	$46{,}29 < X \leq 62{,}78$	Enough	20	40.82%
4	$62{,}78 < X \leq 79{,}26$	Good	9	18.37%
5	$X > 79{,}26$	Very Good	4	8.16%
	Total		49	100.00%

From above table, it can be easily seen with the histogram of physical activity below:

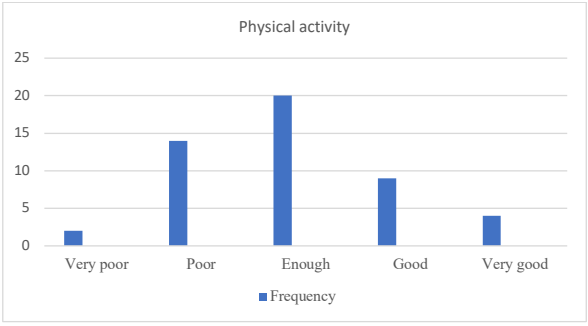

Fig. 2. Physical Activity Variable Histogram

Physical fitness is denoted by Y, the maximum score is 17 and the minimum score is 9. The mean obtained is 13.26, the standard deviation is 2.16, the mode is 12.00 and the median is 13.00. Furthermore, the data are categorized based on the standard norms of physical fitness test. The following is a table of variable frequency distribution of indonesia's physical fitness tests obtained.

Table 5. Distribution of Physical Fitness Frequency

No	Interval Class	Category	Frequency	Percentage
1	5-9	Very poor	2	4.08%
2	10-13	Poor	26	53.06%
3	14-17	Enough	21	42.86%
4	18-21	Good	0	0.00%
5	22-25	Very Good	0	0.00%
	Total		49	100.00%

From above table, it can be easily seen with the histogram of physical fitness below:

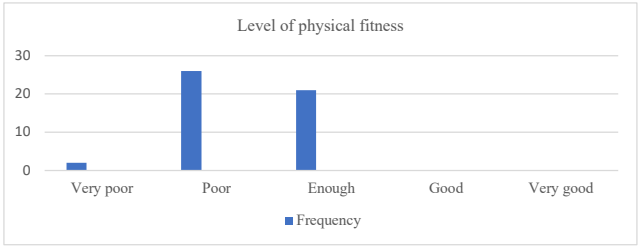

Fig. 3. Variable Histogram of Physical Fitness Test

Normality Test

Normality testing uses the Kolmogorov-Smirnov. This test will test the null hypothesis (Ho) that the sample comes from a normally distributed population. To accept or reject Ho by comparing the Sig price obtained with 0.05. The criterion is to accept Ho if the Sig value is greater than 0.05, in other cases the hypothesis is rejected.

Table 6. Summary of Normality Test Results

No	Variable	KS count	Sig (0,05) (df)	Conclusion
1	Use of digital media	0.090	0.200	Normal
2	Physical activity	0.115	0.124	Normal
3	Indonesian physical fitness test	0.120	0.073	Normal

From the table above the Sig price of the digital media use variable is 0.200, the physical activity variable is 0.124, and the Indonesian physical fitness test variable is 0.070. It turns out that the Sig value of the three variables is all greater than 0.05, thus the hypothesis stating the sample came from a normal distributed population is accepted.

Multiple Correlation

Multiple correlation is the relationship between the independent variables together with the dependent variable. The results of the multiple correlation calculations obtained multiple correlation coefficients in the table below:

Table 7. Multiple Correlation Coefficient

Relations between variables	Regression Line Equations	Correlation coefficient
$X_1X_2.Y$	$\hat{Y} = 7.896 + 0.239X_1 + 0.044X_2$	0.570

From the table above, it can be obtained that the multiple correlation coefficient between the use of digital media and physical activity on the Indonesian Physical fitness test is 0.570.

Test Hypotheses Together

For multiple correlation test used F test from Sudjana, (2002: 385). In this test will test the null hypothesis (Ho) there is no significant relationship jointly between the independent variables and the dependent variable. To accept or reject the null hypothesis (Ho) by comparing the calculated F price (F_{count}) with the F price in the table (F_{table}). The criterion is to reject the hypothesis if the Fcount price is equal to or greater than the Ftable price, in other cases accept the hypothesis. The results of hypothesis testing for the relationship are collectively obtained as shown in the table below:

Table 8. Overall Relationship Test Results

Multiple correlation ($X_1X_2.Y$)	F_o	F_t ($\alpha = 0,05$)(2/46)	Conclusion
0.570	11.072	3.20	Significant

From the table above, it is obtained that the Fvalue of the joint relationship between the use of digital media and physical activity on physical fitness together is 11.072. Meanwhile, the price for F_t ($\alpha = 0,05$)(2/46) was 3,20. Because the price of F_{count} is greater than F_{table}, ($F_{count} > F_{table}$), the hypothesis which states that there is no significant relationship together between the independent variable and the dependent variable is rejected. Thus it can be concluded that "Together there is a significant relationship between the use of digital media and physical activity on physical fitness."

Discussion

Based on the results of the calculation, a significant relationship was obtained between the use of digital media and physical activity on the physical fitness test. Together, there is a significant relationship between the use of digital

media and physical activity on physical fitness. The multiple correlation value between the use of digital media and physical activity on physical fitness together is 0.570. Based on hypothetical testing, it turns out that the correlation of the two independent variables together with the Indonesian physical fitness test is significant. The relationship given by the two independent variables together with the Indonesian physical fitness test is 0.570. The correlation value obtained is positive, so this means that the higher the use of digital media and one's physical activity, the better one's Indonesian physical fitness test will be. From the correlation coefficient also obtained a coefficient of determination of 0.325. This means that the two independent variables have a contribution of only 32.5%. While the remaining 67.5% is influenced by other variables not included in this study.

These results are in accordance with the research of Riso et al. (2019) that Children participating in SC had higher moderate-to-vigorous PA, vigorous PA and cardiorespiratory fitness than children not participating in SC. Overweight children had lower results in cardiorespiratory fitness and all weight-bearing fitness tests, and better results in handgrip strength test in comparison with normal weight children. Significant associations were found between body composition indices and physical fitness tests. PA level was associated with fat-free mass and physical fitness but not with fatness indices. In addition, research by Pope et al. (2019) explained that Intervention adherence was high (~86%), with a retention of 92.1%. Participants implemented health education tips 1-3 times per week. We observed experimental and comparison groups to have 4.2- and 1.6-min/day increases in moderate-to-vigorous PA (MVPA), respectively, at six weeks – partially maintained at 12 weeks. In both groups, similarly decreased body weight (experimental = -0.6 kg; comparison = -0.5 kg) and increased self-efficacy, social support, and intrinsic motivation were observed pre- and post-intervention.

In the current era, learning with digital media is no longer prohibited, even now, during the corona pandemic around the world, learning that was initially face-to-face was replaced with learning using digital media (Cesare et al., 2019). Students of 4th and 5th elementary school grade will be very happy if they hold gadget, now this should not be misused just for playing games or using social media, but actually it will be more useful when children are directed to use gadget to help in the learning they are going through. Due to the joy that exists when holding gadget, learning using digital media will also be fun, so this will be a driving factor for students in completing their tasks to achieve their goals. In physical education learning, digital media is very important, for example when the teacher gives the task "try to do the correct kicking motion". Students can see examples by watching on YouTube, so that children will be more enthusiastic about practicing the information obtained from digital media to do assignments from their teachers.

The effective contribution given by the variable use of digital media and physical activity is 32.5% to the Indonesian physical fitness test. In the variable use of digital media, an effective contribution of 20.3% was obtained. While the physical activity variable gave an effective contribution of 12.2. It turns out that the contributions given from the two independent variables are not the same, namely that the variable use of digital media provides a greater contribution than physical activity.

Referring to the results above, it is suggested that in physical education learning in schools, the school provides concession for students to bring gadget to support the learning process. With digital media-based learning, learning will be more fun, and students will be more enthusiastic about participating in the learning process. In Physical Education learning, students will be more enthusiastic when doing physical activities, so that the level of physical fitness of the students will also be better. But beyond that there are still many other factors that contribute to Indonesia's physical fitness test such as the intensity of physical activity, frequency of exercise and others, which is 67.5%.

Conclusions

Based on the results of data analysis, hypothesis testing and discussion, it can be concluded that there is a significant relationship between the use of digital media on the physical fitness of 4th and 5th grade students of the state of Ngablak Elementary School in academic year 2019/2020, Turi, Sleman Regency. There is a significant relationship between physical activity on the physical fitness of 4th and 5th grade students of the state Ngablak Elementary School in academic year 2019/2020, Turi, Sleman Regency. Together, there is a significant relationship between the use of digital media and physical activity on the physical fitness of 4th and 5th grade students of the state of Ngablak Elementary School in academic year 2019/2020, Turi, Sleman Regency.

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Conflict of interest

All the authors of this research declare if there is no conflict of interest for this research.

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ВЗАЄМОЗВ'ЯЗОК ВИКОРИСТАННЯ ЦИФРОВИХ МЕДІА ТА ФІЗИЧНОЇ АКТИВНОСТІ З ФІЗИЧНОЮ ПІДГОТОВЛЕНІСТЮ УЧНІВ 4-ГО ТА 5-ГО КЛАСІВ ПОЧАТКОВОЇ ШКОЛИ

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Реферат. Стаття: 7 с., 3 рис., 8 табл., 25 джерел.

Метою дослідження було визначити взаємозв'язок використання цифрових медіа та фізичної активності з фізичною підготовленістю учнів 4 та 5 класів початкової школи штату Нгаблак 2019/2020 навчальному році.

Матеріали та методи. Це дослідження є кореляційним дослідженням, метою якого є з'ясувати, чи існує зв'язок між незалежними та залежними змінними. У дослідженні прийняли участь 49 учнів 4-го та 5-го

класів початкової школи штату Нгаблак у 2019/2020 навчальному році. Метод збору даних – опитування. Анкетування використовувалося як для змінних цифрових медіа, так і фізичної активності. Для перевірки фізичної підготовленості використовувалося тестування індонезійських змінних фізичної підготовленості. Методами аналізу даних є регресійний та кореляційний аналіз, як простим, так і подвійним способом за допомогою необхідних тестів на нормальність та лінійність.

Результати. Результати показали, що на рівні 5% похибки існує кореляція між використанням цифрових медіа та фізичною активністю з фізичною підготовленістю учнів 4-го та 5-го класів початкової школи штату Нгаблак у 2019/2020 навчальному році ($F_р$= 11,072 > $F_{табл.}$ = 3,20).

Висновки. Оскільки значення $F_р$> значення $F_{табл.}$, можна зробити висновок, що існує значний зв'язок між використанням цифрових медіа та фізичною активністю з фізичною підготовленістю.

Ключові слова: цифрові медіа, фізична активність, фізична підготовленість, початкова школа.

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