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ORIGINAL ARTICLE

Virtual reality-based tabata training: a professional method for changing levels physical fitness and psychological well-being on student-athletes

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Abstract

Background and Study Aim Physical fitness and psychological well-being of student-athletes had decreased significantly and became the main problem in this study. This study aims to investigate the effect of virtual reality-based Tabata training to increase the level of physical fitness and psychological well-being through a mixed method.

Material and Methods This study used a mixed method. The participants involved in this study were student-athletes (n=40) at Singaperbangsa Karawang University (Indonesia). Quantitative instruments used to measure physical fitness include 20 m shuttle run, 30 m sprint run, horizontal jump and leg dynamometer. While the qualitative instrument used to measure student-athlete perceptions through in-depth interviews for 30 minutes. Quantitative statistical analysis through IBM SPSS was used to find the mean and standard deviation. Independent samples t-test was used to test the difference in values between the experimental and control groups before and after the experiment. Meanwhile, the Paired samples t-test was used to investigate the effect of this training, both in the experimental and control groups. Qualitative statistical analysis was carried out qualitatively thematically, namely the results of in-depth interviews were coded and categorized into three themes.

Results There were several findings in quantitative research. First, there was no difference in physical fitness or psychological well-being between the experimental and control groups before the experiment ($p>0.05$). Second, there were differences in the values of physical fitness and psychological well-being between the experimental and control groups after the experimental program ($p<0.05$). Third, there was a significant effect in the experimental group on the level of physical fitness and psychological well-being ($p<0.05$) and the control group also showed an effect on changes in physical fitness and psychological well-being but smaller than the experimental group ($p<0.05$). In Qualitative research, student-athletes provided positive perceptions about virtual reality-based Tabata training which was easy, efficient and effective, fun and encouraged them to be more active. Negative perceptions were not all student-athletes and universities were equipped with virtual reality facilities. It must carried out in a location or place that was completely safe or far from vehicles.

Conclusions Our mixed study confirms that virtual reality-based Tabata training had positive effect to change the level of physical fitness and psychological well-being among student-athletes.

Keywords: virtual reality, tabata training, physical fitness, psychological well-being, mixed method

Introduction

Entering 2023, all types of professional sports had been competed normally at national and international levels [1, 2], many students-athletes came back active in sports [3, 4, 5] and improved their performance which had decreased during the COVID-19 pandemic crisis. Student-athletes who were involved in swimming was one of the many aspects that affected by COVID-19 [6], so the data recorded that the performance of student-athletes related to physical fitness [7] had decreased significantly. Data showed that the level of physical fitness of people in several countries including Indonesia had decreased and the causative factor was the lack of physical activity and sports during the COVID-19 pandemic crisis [8, 9, 10]. In addition, another factor that were negatively impacted in student-athletes was psychological well-being [11].

Physical fitness included as a crucial and supportive aspect for student-athletes to achieve success in all types of sports [12, 13, 14). According to Gani et al. [6] in swimming a student-athlete was required to have good physical fitness, for

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example with good physical fitness, they can swim in high speed and was not easily felt tired when exercising. A recent study reported that physical fitness was a determining factor in the good or bad performance of student-athletes [15, 16, 17]. In addition, excellent physical fitness has the potential to improve the technique and tactics of student athletes [18]. Whereas if physical fitness was low, student-athletes would experience injuries [19] and difficult to achieve the best performance [20].

Psychological well-being was the second aspect that should be improved after the COVID-19 pandemic crisis [21]. Psychological well-being has a concept as a condition of psychological well-being which was characterized with a feeling of happiness [22], satisfaction and life goals [23] and without the risk of mental disorders [24, 25]. According to Jovanovic, Smrdu, Holnthaner & Kajtna [26], low psychological well-being could trigger anger, depression, anxiety and stress, resulting in poor performance. Meanwhile, a high psychological well-being can trigger positive behaviors such as having good relationships with other people, self-efficacy and goal setting, independence [11]. In addition, previous studies reported that someone who has high psychological well-being was more successful in terms of education, career, socializing and better level of physical health [27]. Considering the importance of physical fitness and psychological well-being for student-athletes to support their success in sports activities, it is needed training system that has the potential to improve these two aspects. Tabata training based on virtual reality was estimated to be a sports method that can change the level of physical fitness and psychological well-being among student athletes.

Tabata is a training method that combines high-intensity and interval training [28, 29]. In Tabata training there are several types of movements, such as jogging, squat jumps, jumping jacks, plank, high knee, climber, where each movement is performed for 20 seconds and rests for 10 seconds [6, 30]. After it was created by Izumi Tabata, the popularity of Tabata training courses has increased and has been widely studied in several countries. For example, Domaradzki, Cichy, Rokita & Popowczak [31], applied Tabata training to male and female aged 16 who came from Poland and it was proven that this training could provide benefits for reducing their weight. In addition, previous studies reported that Tabata training was also effective for increasing the strength of soccer players [32], muscle power in athletes in swimming [6] heart rate and blood lactate [33]. In fact, this training has been noted to increase physical fitness effectively [34]. Unfortunately, research on Tabata training was limited to traditional methods and there was no research on technology-based Tabata training that involved virtual reality. Virtual reality-based Tabata training is a training that uses technological media, so the experience can be similar with the real based [35, 36]. Through Tabata virtual reality training, student-athletes observed pictures or animations that were doing physical activity and student-athletes must follow all the movements (Fig.1). According to Bedir & Erhan [37], the popularity of virtual reality technology has increased in sports, because through virtual reality people can experience events, times and environments that were not real but as if it really happened.

Figure 1. Virtual Reality-Based Tabata Training

The benefits of using virtual reality technology could help student-athletes to have a better understand about the exercises or movements that will be learned in sports [38, 39]. Even though, virtual reality technology provided many benefits in sports and facilitated coaches and student-athletes [40], unfortunately no one has implemented virtual reality in Tabata training. In addition, this study was the first work that tried to implement virtual reality-based Tabata training to change the level of physical fitness and psychological well-being among student athletes. In addition, this study presented novelty in terms of analyzing the effects of virtual reality-based Tabata training through quantitative and qualitative analysis (mixed method), so this research was different from previous studies on Tabata training. It is expected that this research will contribute to the development of the Tabata training method which involve virtual reality technology, so that coaches and student-athletes can use it in the future. Therefore, this study aims to investigate the effect of virtual reality-based Tabata training as an effort to change the level of physical fitness and psychological well-being through a mixed method.

Materials and Methods

Participants

The participants involved in this study were male student-athletes who were active in swimming sports from Singaperbangsa Karawang University, which is one of the universities in Indonesia. Participants were selected through a random technique, by sending invitations via WhatsApp. There was 40 out of 50 student-athletes who were invited, showed a positive response and interested in participating in this study. Before the experimental research was carried out, all participants were required to sign a letter of intent to become participants. After forty participants were selected, the next step was to allocate them to the experimental group who received the virtual reality-based Tabata training program (n=20, mean ± SD= age: 21.05±2.5, weight: 55.68±6.4 kg, height: 1.63±0.5 cm) and to the control group who carried out their daily training activities (n=20, mean ± SD= age: 20.47±0.9, body weight: 51.65±7.8 kg, height: 1.59 ± 0.4 cm). Participation inclusion criteria include; history of participating in Tabata training, participants are physically active, healthy and must be free from injury within the past year. Before the research started, all participants were given information about the rules in conducting this research. Then they are required to make and sign a statement about their willingness to become participants in this research

Research Design

This study used mixed types or a combination of quantitative and qualitative research. Quantitative research was carried out experimentally using a pretest-posttest control group design. While qualitative research through in-depth interviews with participants for 30 minutes.

This research was conducted in November-December 2022 in the University of Singaperbangsa Karawang (Indonesia) with number: 273/SP2H/UN64.10/LL/2022. This research was conducted based on the guidelines of the World Medical Association Code of Ethics (Helsinki Declaration for Humans). In quantitative research, at the first meeting, all participants carried out initial test activities, namely physical fitness tests and filling out the psychological well-being scale (22 November 2022) from 08.00 am until finished. In the second meeting (24 November 2022), the experimental group carried out a virtual reality-based Tabata training program and the control group carried out their daily training such as jumping jacks, side leg raises and running until the twelfth meeting (17 December 2022). At the 13th meeting (20 December 2022) all participants carried out physical fitness tests and filled out the psychological well-being scale. Detail of virtual reality-based Tabata training program is presented in Table 1.

Whereas for qualitative research through in-depth interviews it was carried out on 21-22 December 2022. In-depth interviews were carried out using Bahasa inside the room for 30 minutes per person. In this study, the interview was conducted for experimental group who received the virtual reality-based Tabata training program which was in accordance with the objectives of this study. After the interview was completed, the data from interview was analyzed by 3 people who were experts in sports training methodology and Dr. degree holders. The mixed research design is presented in Figure 2.

Research Instruments

Quantitative Instruments

Physical Fitness. Quantitative instrument was used to measure the level of physical fitness of athletes which had been adopted from previous studies [41], with the following test items:

20 m Shuttle Run (ml/kg/min). This instrument has a function to measure the level of VO2max endurance. This test was carried out by running continuously with a distance of 20 meters following the "bleep" audio. The participant was standing in cone A after the audio bleep sounded, the participant run towards cone B. Repeat this running motion until the participant was no longer able or unable to adjust with the speed set in the audio recording. Assessment was conducted by calculating

Table 1. Virtual Reality-Based Tabata Training Program

Training Unit Components	Activities	Duration
Warm-up	Warm-up	2 min
Virtual Reality-Based Tabata Training	Squat jump. Kick sideways. Kick back. Jumping Jack. Side Lunges. Single movement was performed with a duration of 20 seconds and 10 seconds rest.	5 min
Cool-down	Cardiorespiratory cool down and the poststretch.	2 min

the number of levels and feedback obtained then converted into Vo2max. This instrument had been tested previously, with a validity value of 0.89 and a reliability of 0.84.

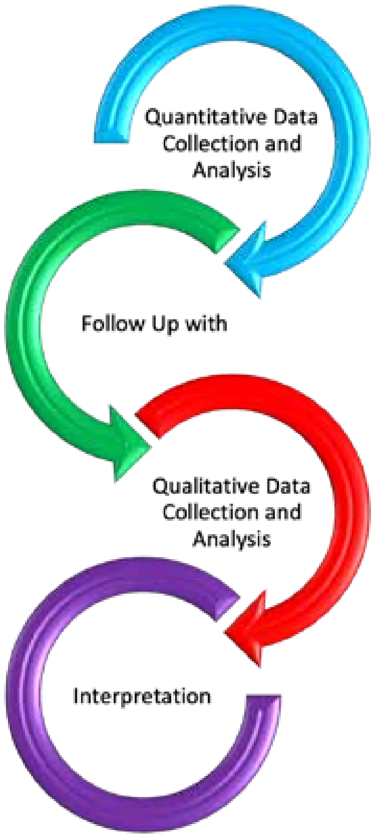

Figure 2. Mixed Method Research Design

30 m Sprint Run (s). This instrument used to measure the level of speed. This test was carried out by standing at the start line and after the whistle sounded, the participant run as fast as possible for 30 meters to the finish line. The assessment was carried out by calculated the score which was based on the fastest time. This instrument was tested beforehand in this study with a validity value of 0.80 and a reliability of 0.83.

Horizontal Jump (cm). This instrument was used to measure the level of power. This test was carried out by conducting horizontal jumps for twice times and the best value was used for statistical analysis. This instrument was tested beforehand in this study with a validity value of 0.87 and a reliability of 0.80.

Leg dynamometer (kg). This instrument aims to measure muscle strength of lower leg [42]. This test was conducted by standing on the leg dynamometer, hands holding the handle, body upright and legs bent. Then the participant pulled the handle as hard as possible and straightened the knee until it stands straight. The leg muscle strength score can be seen on the leg dynamometer measurement tool. This instrument has a validity level of 0.87 and a reliability of 0.75 in this study.

Psychological Well-Being Scale (points). The instrument for measuring the level of psychological well-being was psychological well-being scale, adopted from Simons & Bird's [11]. The instrument had 14 question items which were divided into three subscales. The first subscale related to subjective well-being has 3 item questions (for example "during the last week, how often did you feel happy when participating in sports"). The second subscale related to social well-being has 5 item questions (for example "during the last week, how often did you feel you had something to contribute to a sports team/community). The third subscale related to psychological well-being has 6 item questions (for example "during the last week, how often have you felt purposeful in sports). This questionnaire was answered by using a Likert scale from a value of 0 (never) to a value of 5 (every day). This instrument based on previous studies has high internal consistency reliability for all subscales (subjective well-being, α = 0.85; social well-being, α = 0.83; psychological well-being, α = 0.87) and Cronbach's α coefficients of 0.88, 0.88 and 0.90 [11].

Qualitative Instruments

A qualitative instrument was used to measure the effect of implementing virtual reality-based Tabata training towards changes in physical fitness and psychological well-being levels through in-depth interviews of 30 minutes per person. This test aims to investigate participants' perceptions about the convenience and difficulty when participating in virtual reality-based Tabata training. In addition, this test aims to reveal the impact of this training towards changes in the level of physical fitness and psychological well-being. The results of interviews with participants were recorded both in audio and text and then analyzed by researchers and 3 experts [6].

Statistical Analysis.

Quantitative analysis

Data on test results and measurements of physical fitness and psychological well-being were analyzed through IBM SPSS version 25.0 (Armonk, NY: IBM Corp). The measurement test was conducted in several stages. First, conducting the normality test of data through Shapiro-Wilk analysis ($p>0.05$). Second, statistical descriptive testing, by calculating the mean ($\overline{X}$)±standard deviation (S). Third, Independent samples t-test to analyze the difference in values between the experimental and control groups before and after the experiment ($p<0.05$). Fourth, the Paired samples t-test which aims to test whether there was an effect from the experimental and control groups ($p<0.05$).

Qualitative analysis

Data from in-depth interviews were analyzed qualitatively thematically, the results were coded and categorized into three themes [6], namely theme 1: the advantages of virtual reality-based Tabata training, theme 2: difficulties from using virtual reality-based Tabata training and theme 3: impact of using virtual reality-based Tabata training on physical fitness and psychological well-being.

Results

Quantitative results

Table 2 shows that data in the experimental and control groups was normally distributed. Table 3 shows the mean and standard deviation values of the experimental and control groups have increased from pretest to posttest. Table 4 shows that there was no difference in the value of physical fitness and psychological well-being between the experimental and control groups before the experiment ($p > 0.05$). Tables 5, 6 shows that there were differences in the values of physical fitness and psychological well-being between the experimental and control groups after the experimental program ($p<0.05$).

Meanwhile, the Paired samples t-test showed that there was a significant effect from the experimental group on changes in the level of physical fitness and psychological well-being ($p<0.05$) and the control

Table 2. Normality test calculation

Dependent Variable	Experimental Group	n	p	Control Group	n	p	Description
Physical Fitness							
20 m Shuttle Run (ml/kg/min)	Pretest	20	0.070	Pretest	20	0.240	Normal
	Posttest	20	0.167	Posttest	20	0.149	Normal
30 m Sprint Run (s)	Pretest	20	0.234	Pretest	20	0.207	Normal
	Posttest	20	0.087	Posttest	20	0.366	Normal
Horizontal Jump (cm)	Pretest	20	0.275	Pretest	20	0.204	Normal
	Posttest	20	0.188	Posttest	20	0.156	Normal
Leg Dynamometer (kg)	Pretest	20	0.261	Pretest	20	0.200	Normal
	Posttest	20	0.356	Posttest	20	0.344	Normal
Psychological Well-Being							
Subjective Well-Being (points)	Pretest	20	0.200	Pretest	20	0.383	Normal
	Posttest	20	0.090	Posttest	20	0.068	Normal
Social Well-Being (points)	Pretest	20	0.182	Pretest	20	0.179	Normal
	Posttest	20	0.322	Posttest	20	0.308	Normal
Psychological Well-Being (points)	Pretest	20	0.395	Pretest	20	0.299	Normal
	Posttest	20	0.337	Posttest	20	0.095	Normal

Table 3. Descriptive Statistics

Dependent Variable	Experimental Group (n=20)		Control Group (n=20)	
	Pretest	Posttest	Pretest	Posttest
	$\bar{X} \pm S$	$\bar{X} \pm S$	$\bar{X} \pm S$	$\bar{X} \pm S$
Physical Fitness				
20 m Shuttle Run (ml/kg/min)	27.85±1.49	41.60±5.61	27.15±1.18	37.75±3.21
30 m Sprint Run (s)	5.10±0.64	3.40±0.50	5.40±0.59	3.80±0.52
Horizontal Jump (cm)	1.45±0.51	2.70±2.70	1.35±0.48	2.25±0.55
Leg Dynamometer (kg)	18.40±3.20	40.85±3.45	19.60±3.16	38.30±2.83
Psychological Well-Being				
Subjective Well-Being (points)	5.75±1.25	11.55±2.13	5.35±0.98	10.00±1.52
Social Well-Being (points)	10.95±10.95	20.85±3.42	10.10±2.12	18.00±2.86
Psychological Well-Being (points)	12.65±2.94	22.65±2.99	11.35±1.69	19.65±2.41

Table 4. The results of differences physical fitness and psychological well-being on the experimental (n=20) and control (n=20) groups before the experiment

Dependent Variable	Group	Statistical Indicators		
		X±S	t	p
Physical Fitness				
20 m Shuttle Run (ml/kg/min)	Experimental	27.85±1.49	1.642	0.109
	Control	27.15±1.18		
30 m Sprint Run (s)	Experimental	5.10±0.64	-1.531	0.134
	Control	5.40±0.59		
Horizontal Jump (cm)	Experimental	1.45±0.51	0.632	0.531
	Control	1.35±0.48		
Leg Dynamometer (kg)	Experimental	18.40±3.20	-1.191	0.241
	Control	19.60±3.16		
Psychological Well-Being				
Subjective Well-Being (points)	Experimental	5.75±1.25	1.122	0.269
	Control	5.35±0.98		
Social Well-Being (points)	Experimental	10.95±2.41	1.181	0.245
	Control	10.10±2.12		
Psychological Well-Being (points)÷	Experimental	12.65±2.94	1.712	0.095
	Control	11.35±1.69		

Table 5. The results of differences physical fitness and psychological well-being on the experimental (n=20) and control (n=20) groups after the experiment

Dependent Variable	Group	Statistical Indicators		
		X±S	t	p
Physical Fitness				
20 m Shuttle Run (ml/kg/min)	Experimental	41.60 ±5.61	2.663	0.011
	Control	37.75±3.21		
30 m Sprint Run (s)	Experimental	3.40±0.50	2.466	0.018
	Control	3.80±0.52		
Horizontal Jump (cm)	Experimental	2.70±0.47	2.781	0.008
	Control	2.25±0.55		
Leg Dynamometer (kg)	Experimental	40.85±3.45	2.554	0.015
	Control	38.30±2.83		
Psychological Well-Being				
Subjective Well-Being (points)	Experimental	11.55±2.13	2.640	0.012
	Control	10.00±1.52		
Social Well-Being (points)	Experimental	20.85±3.42	2.855	0.007
	Control	18.00±2.86		
Psychological Well-Being (points)	Experimental	22.65±2.99	3.488	0.001
	Control	19.65±2.41		

Table 6. The results of the Paired Samples t-test

Dependent Variable	Experimental Group (n=20)			Control Group (n=20)		
	Pre-Post X±S	t	p	Pre-Post X±S	t	p
Physical Fitness						
20 m Shuttle Run (ml/kg/min)	13.75±5.81	10.581	0.000	10.60±3.53	13.428	0.004
30 m Sprint Run (s)	1.70±0.86	8.794	0.004	1.60±0.68	10.514	0.006
Horizontal Jump (cm)	1.25±0.63	8.753	0.002	0.90±0.78	5.107	0.007
Leg Dynamometer (kg)	22.45±3.98	25.227	0.000	18.70±4.54	18.407	0.000
Psychological Well-Being						
Subjective Well-Being (points)	5.80±2.09	12.395	0.001	4.65±1.66	12.504	0.000
Social Well-Being (points)	9.90±4.03	10.964	0.000	7.90±3.86	9.141	0.003
Psychological Well-Being (points)	10.01±3.21	13.924	0.000	8.30±3.10	11.213	0.000

group also showed that there was an effect on changes in physical fitness and psychological well-being ($p< 0.05$) but not as big as the experimental group.

Qualitative Results

In-depth interviews with participants obtained the following results:

Theme 1: Advantages of virtual reality-based Tabata training

This first theme relates to the perceptions of the participants (student-athletes) about the advantages of the virtual reality-based Tabata training program. In this case the participants argued that:

> "In our opinion, this program has several advantages, such as we felt happy and enthusiastic in carrying out the training, because we were guided by an animation that was in virtual reality" (Results of interviewed with Participants 1, 2, 3, 4, 6, 7).

> "The Tabata training program based on virtual reality is amazing!!..We can actively move in this training program even without a trainer or lecturer who guided us, because in virtual reality there was an animation that replaced the role of trainer or lecturer" (Results of interviewed with Participants 8, 9, 11, 12, 13, 14).

> "The advantages of this training program are it is more efficient, effective and fun, because there was an animation who guided us exercises in virtual reality" (Results of interviewed with Participants 16, 18, 19, 20).

Another advantage of the virtual reality-based Tabata training program is it can be carried out anywhere and at any time, without the presence of a trainer or lecturer (Results of interviews with Participants 5, 10, 15, 17).

Theme 2: Difficulties in implementing virtual reality-based Tabata training

The second theme related to difficulties in carrying out virtual reality-based Tabata training which must be explained clearly, so that later it can be minimized. In this case the participants argued that:

> "According to us, there are several difficulties in carrying out the virtual reality-based Tabata training program, namely: (i) we could not conduct this exercise without cellphones and virtual reality glasses (ii) For student-athletes who have eye disorders, it will be harm for their eye health if they use it in long term" (Results of interviews with Participants 2, 5, 7, 9, 11, 13, 15, 17).

> "Not all student-athletes and universities own virtual reality facilities, so we think this will be a difficulty in implementing this program. Thus, this program is limited only to student-athletes and universities with proper facilities" (Results of interviews with Participants 1, 3, 4, 6, 8, 10, 12, 14).

Virtual reality-based Tabata training must be carried out in a location or place that is truly safe, because if it is carried out in a place with vehicles going back and forth it will have the potential to cause an accident (Results of interviews with Participants 16, 18, 19, 20).

Theme 3: Impact of implementing virtual reality-based Tabata training

The last theme related to the impact of implementing virtual reality-based Tabata training on changing levels of physical fitness and psychological well-being. In this case the participants argued that:

> "Obviously the implementation of virtual reality-based Tabata training program has really helped us to change our level of physical fitness and psychological well-being for the better

results, for example, previously we were easily got tired, and after joining this program, we were able to do physical activity for a long time without fatigue. Apart from that, this program allowed us to release our stress" (Results of interviewed with Participants 3, 6, 8, 9, 12, 14, 16, 19).

The Tabata training program based on virtual reality with high intensity and intervals triggered us to be more active, so that was the main factor that causes our physical fitness increase gradually (Results of interviewed with Participants 1, 4, 5, 7, 10, 11, 13). In addition, virtual reality-based Tabata training accompanied by energetic music which helped us felt comfortable, calm, happy and it was the main factor to reduce all problems that exist in our mind (depression, anxiety and stress), thus encouraged us willing to involve and set our goals to exercise (Results of interviewed with Participants 2, 15, 17, 18, 20).

Discussion

This study aims to investigate the effect of virtual reality-based Tabata training to change the level of physical fitness and psychological well-being through a mixed method.

This study obtained several results related to the effect of virtual reality-based Tabata training First, there was no difference in the value of physical fitness or psychological well-being between the experimental and control groups before the experiment. Second, there were differences in the values of physical fitness and psychological well-being between the experimental and control groups after the experimental program. Third, there was a significant effect of the changes in physical fitness and psychological well-being level in experimental groups. Likewise, the control group also showed a significant effect on changes in physical fitness and psychological well-being. However, the experimental group showed a greater increase than the control group.

The increase in physical fitness components (e.g., VO2max endurance, speed, power, strength) in the experimental group was happened because researchers tried to present an innovation and novelty in Tabata training that was different from previous studies, namely virtual reality-based Tabata training. This training presented exercises which rich in movement for student-athletes, to guided them became more active in the training process. In addition, high intensity Tabata training with intervals involving virtual reality technology was much more effective and attractive for student athletes, which can accelerate the results of achieving physical fitness. It was inline with Sohail, Firdos, Ikram & Talha [38], agreed that virtual reality technology had the potential to encourgate student athletes more easily carry out and achieve sports goals. The results of these findings were in line with previous studies which show that Tabata training has proven effective in improving components of physical fitness such as power and speed [43] and strength ([6]. Similarly, Ambrozy et al [44], reported that there was an increase in the level of physical fitness in men between the ages of 35 and 40 due to the effect of applying Tabata training. Other studies reported that high-intensity Tabata can increase the aerobic capacity of men [31]. According to Tabata [28], high-intensity interval training was a key factor for increasing maximum aerobic power. Reinforced by the study of Murawska-Cialowicz et al. [45], Tabata protocol training is characterized by high intensity and punctuated by short rest, this can promote the development of oxygen capacity and increase in VO2max. Similar results were reported by Scoubeau, Bonnechère, Cnop, Faoro & Klass [46], that the importance of using Tabata training turns a low level of physical fitness into a high one. Thus, the uniqueness and novelty of this study was virtual reality-based Tabata training had an effect on changes in the quality of physical fitness based on quantitative and qualitative (mixed) research.

On the other hand, psychological well-being among student-athletes was also change, because virtual reality-based Tabata training was a fun training, student-athletes can do exercises by following the animations presented in virtual reality. Borrega-Mouquinho, Sánchez-Gómez, Fuentes-García, Collado-Mateo and Villafaina [47], described that Tabata/high-intensity interval training had been shown to be effective in reducing levels of anxiety, stress and depression simultaneously. The strength of virtual reality-based Tabata training can trigger student-athletes felt happy, thereby significantly reducing psychological disorders [48]. Other research confirms that Tabata training can reduce risk symptoms for psychological disorders such as anxiety and depression [49]. Similar results were reported by Terada et al. [50] conducted Tabata/high-intensity interval training for twelve weeks had a positive, sustained effect on reducing depressive symptoms. Alves et al. [51] reported that Tabata/high-intensity interval training has a strong effect on improving psychological well-being. Thus, the uniqueness and novelty of this study was the virtual reality-based Tabata training had an effect on changing the quality of psychological well-being based on quantitative and qualitative (mixed) research.

While the qualitative findings in this study showed that participants (student-athletes) gave positive perceptions that the virtual reality-based Tabata training program was easy, efficient and effective, fun and could help them more active. In addition, participants also gave negative perceptions such as not all student-athletes and universities were equipped with virtual reality facilities and it must be carried out in a location or place that was completely safe or far from vehicles. Then they also agreed that overall the virtual reality-based Tabata training program was effective in changing the level of physical fitness and psychological well-being to be better than previous.

Conclusions

This mixed research confirms that virtual reality-based Tabata training has positive effect to change the level of physical fitness and psychological well-being of student-athletes to a better direction. In addition, this research contributes to the development of technology-based training methods which can increase student-athletes achievement. Similar with other studies, this research also has limitations in terms of the limited number of participants who came from one university in Indonesia. Future studies are needed to cover a large quantity of participants from several universities in Indonesia.

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Conflict of interest

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

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ORIGINAL ARTICLE

Suspension training versus free weight training: effects on explosive power, dynamic balance, and discus throwers performance

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

Abstract

Background and Study Aim	This paper aims to compare the effects of two types of resistance training programs (suspension training and free weight training) on the explosive power, dynamic balance, and discus throwers performance.
Material and Methods	Twenty-four male discus throwers (with an average age: 19.17 ± 0.99 years; body mass: 99.87 ± 3.63 kg; height: 177.23 ± 3.16 cm) were assigned into three groups (eight subjects in each group); suspension training (STG), free weight training (FWTG) and control (CG). For eight weeks, subjects underwent training consisting of three sessions a week. Prior to and after the training period, explosive power, dynamic balance, and discus throwing distance variables were measured. The explosive power was measured using the medicine ball throw (SLJT) and standing long jump (MBTT) tests. The dynamic balance was measured using the Y excursion balance test (YBT). The discus throwing distance was measured according to the IAAF rules (DTT).
Results	The results showed that both experimental groups had a significant effect on MBTT, SLJT, and DTT compared to the control group. There was a significant difference in YBT favoring STG when compared to the FWTG and CG, and also, favoring FWTG when compared to CG in the three directions (anterior, posterolateral, and posteromedial). All three groups improved the tests from pre- to post-test.
Conclusions	We can conclude that suspension training and free weight training have created almost the same improvements in explosive power. Also, suspension training was more effective than free weight training for improving dynamic balance.

Keywords: TRX training, resistance training, functional training, discus throwing distance, athletics.

Introduction

One of the explosive athletics events is the discus throw. It belongs to the four throwing competitions (discus throw, shot put, javelin throw, and hammer throw), which demand the production of high muscular power[1]. The discus throwing technique is divided into four consecutive phases; preparation, momentum building, delivery, and recovery [2]. The discus throw is a tremendously technically and physically demanding sport because of these phases that must be completed quickly inside a circle with a diameter of 2.5m [3, 4]. Performing the discus throw skill requires increasing the release velocity and throwing power, which was crucial for the measurement of a tool's maximum distance after landing. The distance of the throw indicates the thrower's proficiency [2, 5, 6]. Hence, the dominant element in discus throw is explosive power. Explosive power is the result of combining strength with the concreted speed in the form of muscular ability when making the throw. This is started by holding the discus, swinging it, twisting the body 1.5 circles, and then reversing the body to throw it explosively [2, 7]. The strength increases the speed of the object from the beginning of the movement until the throwing. Also, the speed appears during the short kinematic path in which the movement is accomplished. Thus, the thrower does not perform well without developing the speed and strength together, where the speed is transferred to the object during throwing as a co-factor [8]. Stated that excellence in throwing events requires strong muscles, and fast white muscle fibers [9]. According to the literature, throwing velocity is a crucial factor in an overhand throwing power athlete's performance [10].

The discus throw movement depends not only on explosive power but also on balance. The capacity to retain one's center of gravity within the base of support required to move in a coordinated and controlled manner with minimal sway is known as balance [11]. Balance involves the synchronization of many muscles of the body and the incorporation of sensory information [12]. The body situation dynamism is justified by this difficult motor skill, which also keeps the body from falling [13]. Balance is thus quite important in the discus throw and optimizing performance [12]. Dynamic balance refers to a person's ability to retain poise or

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equilibrium when moving or transitioning from one situation to other [14]. The sensory data gathered by the somatic sensory, vestibular, and visual systems as well as the motor reactions that impact coordination, joint range of motion, and strength are variables that contribute to maintaining balance [15]. Dynamic Balance is profound in sports players as they are frequently exposed to situations where balance is dynamically challenged [16]. Many sports need dynamic balance as a basic skill as football, basketball, and throwing events. Each sport has different balance requirements and demands on the players according to their physical tasks and environmental conditions [17]. In actuality, sportsmen encounter circumstances where their equilibrium shifts with each motion, they make during throwing performance. So, dynamic balancing is very important to improve discus throwers' performance, reduce the risk of injury, and maintain rules. As a result, resistance training should be included in conditioning programs to promote Explosive power and dynamic balance.

Suspension training is a contemporary kind of resistance training performed by using two handles and straps that may be readily fastened in several environments [18, 19]. Many exercises in it make use of the body's weight as resistance by selecting a point of contact with the ground [20], which allows for the performance of exercises of various intensities based on stability and load [19]. The level of training intensity is changed by altering the "working angle" while using TRX belts, which produce a steady force that, together with body weight, gains resistance [19, 21]. The principle of stability is the fundamental idea of this sort of exercise, it asserts that the size and placement of the support base about the center of mass, determines the stability of the exercise [20]. Suspension training is used to train all components of physical fitness, either as a standalone training regimen or as a part of workout regimens [22, 23]. In recent years, TRX's beneficial effects on strength, power, speed, agility, and balance have drawn increased attention from academics and sportsmen [24].

Free weight training is a popular kind of resistance training that aims to develop strength, explosive power, and balance. It focuses on certain muscle groups and movement patterns using specialized equipment. To counteract the power produced by the muscle, it employs the force of gravity in the form of weighted bars, barbells, dumbbells, sandbags, medicine balls, and kettlebells [25, 26, 27, 28]. The objectives of the individual completing the exercise determine the precise combinations of repetitions, sets, exercises, and weights [26, 28].

Numerous studies have compared suspension training with traditional training and plats training and others. It has been shown that suspension training is just as effective as other forms of exercise, producing comparable gains in muscle strength, core muscular endurance, and balance [29], and improvements in power, muscular strength and functional performance have been observed regardless of age and gender [30, 31, 32, 33, 34]. For example, when non-athlete underweight women trained for eight weeks using two various techniques, traditional training, and suspension training, both training methods almost equally improved physical fitness factors, leading researchers to conclude that suspension training can be considered an equally effective choice alongside traditional training or as its substitute [35]. Another research found that ballet swimmers, who underwent 12 weeks of combined or hybrid resistance exercises and suspension training, improved in terms of fitness and body composition despite the disparities between the two forms of exercise [36]. Similar to conventional resistance training, suspension training has been shown to increase muscular fitness in both kids and adults [37]. One study found that, compared to unsuspension resistance training, TRX training after eight weeks seems to be more beneficial in children›s physical fitness components and may be developed as a fitness training approach for young athletes [19]. Another research found that suspension training, when compared to other training techniques, significantly improves several physiological parameters for such cardiovascular systems[38]. Also, suspension exercise has been shown to increase muscular activation compared to other traditional training [39]. Physical fitness, strength, physiologic impacts, injury rehabilitation, biomechanical analysis, and EMG activity are all areas of suspension training research that have drawn a lot of researchers' attention [22, 30, 40, 41, 42, 43, 44]. However, there is little data on how suspension training for discus throwers compares to free weight training in terms of its impact on dynamic balance and explosive power.

Purpose of the Study. The study purpose was to compare the effects of two types of resistance training programs (suspension training and free weight training) on the explosive power, dynamic balance, and performance of discus throwers.

Materials and Methods

Participants

The subjects consisted of Twenty-four male discus throwers selected from Al Ghrbia Athletics region Clubs. They were divided into two experimental groups (suspension training group (STG) and free weight training group (FWTG)) and one control group (CG). With eight participants in each group. The following inclusion criteria were met: all participants (willingness to participate and continued in the training; (ii) had skill with more than four years of training; (iii) personal best record must not be less than 27m; and (iv) none had any medical conditions or musculoskeletal injuries that could affect training or test outcomes.

The subjects' descriptions were presented in Table 1 that showd the participants' homogeneity concerning the previous aspects. All participants were fully apprised, both verbally and in writing, of the study's purpose and any possible risks and benefits before the study's start. Each participant completed a written permission form before the pre-test. The study was approved by Mansoura University (code: 202209011).

Research Design

A nonrandomized trial research was carried out on three groups: suspension training group (STG), free weight training group (FWTG), and control group (CG) using a plan with the pre- and post-test. This paper was broken up into four phases: (i) phase 1 represented a preparation study that lasted one week that was carried out to familiarize the participants with the exercises and tests. Also, this phase was used to check for the reliability of the tests and tools used in this search; (ii) phase 2 consisted of three days for pre-testing; (iii) phase 3 the participants completed eight weeks of concurrent training; and (iv) phase 4 consisted of three-days for post-testing. All participants were tested before and after eight weeks of training (pre-test and post-test). Pre-testing occurred on three different days separated by at least 48 hours. On the first day, presented measurements of the medicine ball throw test were conducted to measure the explosive power of the upper limb followed by a standing long jump test to measure the legs' explosive power. While the second day included the Y excursion balance test to measure the dynamic balance. The third day included the discus throw test to measure the throwing distance. A prescribed 10-minute warm-up period with low-intensity exercises, including running and stretching, was done before the testing began. One week before the collection of data, each participant had two trials to become used to the testing procedures. Post-tests followed the same protocol as the pre-tests. A familiarization session and a succinct explanation of the ideal technique were conducted before each exam. The tests had been done as follows.

Medicine ball throw test (MBTT): The participants sit on the floor with their legs fully extended, with the back against a wall. The sitting participants grasp the medicine ball with both hands and push the ball explosively from the chest as far straight forward as possible at forty-five degrees. The back should stay in touch with the wall the whole time the throw is being made. The distance from the front of the seating line to the spot where the ball landed was used to calculate the score. The measurement is recorded to the nearest centimeter. Three measurements of these tests are taken using a 3-kg medicine ball and were recommended based on the previous studies [45, 46]. Of the three measurements, the best result is the one that will be taken into account. Magnesium carbonate chalk powder is sparingly sprinkled over the medicine ball to help with a firm grip on the ball and absorb perspiration. The talc also leaves a mark on the ground where the ball fell, making it possible to calculate the throwing distance precisely [46].

The standing long jump test (SLJT): The athletes stand behind a starting line without touching the line, with their feet slightly apart, and explosively leap as far forward as possible. Three trials should be measured, with a 5 min break between trials. From the takeoff line until the closest point of touch on the landing, the measuring distance in cm is obtained (line of the heels), as used in previous studies [19, 23]. The standing long jump is regarded as a solid and trustworthy field-based indicator of muscle fitness and is included in the Eurofit test battery [23, 47, 48, 49].

The Y balance test (YBT): A common clinical dynamic balance assessment technique is this test. The ability to maintain balance while completing a maximum reach in three designated directions is a real and precise measure of balance success, these directions are: anterior (YBTanterior), posteromedial (YBT posteromedial,) and posterolateral (YBTposterolateral) [50, 51, 52, 53]. The participants stand in the middle and place both hands on the waist. Participants are instructed to maintain the non-dominant foot in the middle, while their dominant foot reached as far as possible to each of the three excursions. They are also instructed to reach with their opposing leg as far as they can along the excursion of their choice. They used the most distal portion of their

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

Variables / Groups	STG (n=8)		FWTG (n=8)		CG (n= 8)		P	Sig
	Mean ± SD	CV	Mean ± SD	CV	Mean ± SD	CV		
Age (year)	19.2 ± 1.03	5.38	19.3 ± 0.95	4.92	19 ± 1.05	5.55	0.573	NS
Height (cm)	177.9 ± 3.18	1.79	176.7 ± 3.65	2.07	177.1 ± 2.81	1.58	0.703	NS
Body mass (kg)	100.7 ± 3.77	3.75	100.2 ± 3.29	3.29	99.87 ± 3.63	3.84	0.829	NS

n = sample size; CV = coefficient of variation; P= P-value; Results are given no significant between groups reach foot to make the furthest and lightest contact possible along a predetermined excursion. After then, the subjects were told to revert to a bilateral position while keeping their balance. When the other leg is moving, the support leg must not be raised or moved. The subject's dynamic balancing scores were determined after practicing six times in each excursion, taking a two-minutes break, and measuring the average of three trials for each excursion [53, 54].

Discus throw test (DTT): Participants were asked to perform six trials within a legal throwing circle and throw the discus at maximum power. The greatest correct throwing distance is calculated according to the IAAF rules [55].

The training program

The training program was started on 18/09/2022. Experimental groups performed training for eight weeks, 3 sessions per week. Each training session lasted about 90 min and was carried out on the same days of the week (on Sunday, Tuesday, and Thursday) at the same time of the day. The Participants started each session with a warm-up consisting of 10 to 15 min of easy running, dynamic flexibility, and muscular stretching drills. Then, suspension exercises or free weight exercises were carried out in four 10 to 15 - repetition sets in circuit design lasting from 25 to 30 min. Each exercise was carried out in 10 -repetitions during weeks 1 to 4 and 15 -repetitions during weeks 5 to 8. The rest interval was two to three min between sets. After that, participants trained in discus throwing skills and technique for 30 to 35 minutes, and the last 5 to 10 min of the session was devoted to cool-down. During the same period, the control group continued their normal training routine.

Suspension training protocol

The TRX equipment was used to carry out the suspension training program. TRX device is connected with a rod of 2.44 meters above the ground. This made it possible for the participants to perform exercises just below the connecting point. In general, progress in training levels for the suspension group was as distance placed closer to the connection point, alter of two feet to one foot, and an increase in body angle to maintain intensity within the specified range. The 10-rating Borg scale, as utilized in earlier research, was employed to consider a one-unit increment to exert overload every two weeks [35]. According to the Borg scale and depending on increasing load, exercise intensities were in the range of 4-5 for the first and second weeks, 5-6 for the third and fourth weeks, 6-7 for the fifth and sixth weeks, and 7-8 for the seventh and eighth weeks. Suspension exercises included: TRX Chest Press (a), TRX biceps curl (b), TRX triceps extension (c), TRX row (d), TRX T deltoid fly (e), TRX squat (f), TRX lunge (g) (right and left), TRX hamstring curl (h), TRX single leg RDL (j) (right and left) and TRX single leg squat (k) (right and left) (See Fig. 1- a to k).

Free weight training protocol

The Free weight training program was performed using dumbbells, barbells, and kettlebells. According to the Borg scale based on increasing load, the intensity of the free weight training program was as follows: 60-65% of 1RM for the first and second weeks, 65-70% of 1RM for the third and fourth weeks roughly 70-75% of 1RM for the fifth and sixth weeks, and 75-80% of 1RM for seventh and eighth weeks, as used in previous studies [35]. The movement of the free weight exercises, number of sets, times, and intensity were similar to suspension training. Free weight exercises included: Dumbbell flat bench press (l), standing dumbbell biceps curl (m), two dumbbell triceps extensions(n), bent-over two dumbbell row (o), dumbbell rear deltoid fly (p), squat with a barbell (q), lunge with a barbell (r) (right and left), dumbbell leg curl (hamstring) (s), dumbbell single leg RDL (t) (right and left) and kettlebell single leg squat (u) (right and left) (See Fig. 1- l to u).

Statistical Analysis

IBM SPSS Statistics version 26.0 software as a computer-aided software system was utilized, which had a significant role in interpreting the results and their derivatives to handle and analyze the outputs accurately and with high efficiency in this paper. To verify the assumptions of normality and equal variance, the Shapiro-Wilk and Levene tests were run on each variable, respectively. The pre-post change was examined using one-way analysis of variance (ANOVA) with Tukey post hoc testing to spot any group differences. By using paired sample t-tests, it was possible to determine significant differences in each group between pre- and post-tests. Effect sizes were estimated as partial eta-squared values ($\eta 2$) and classified as "small" if they were < 0.2, "medium" if they were between 0.2 and 0.5, and "large" if they were > 0.8 (56). Change ratio (Δ%) was used to verify differences between groups. For all findings provided, the significance level $p \leqslant 0.05$ was utilized.

Results

Baseline data

One-way ANOVA revealed no significant baseline differences in any of the variables between the groups at pre-test [F= .335 to 1.343, p= .278 to .718 (P>0.05)]. All participants completed an eight-week training period with a mean training attendance of 100%.

The effects of training intervention

The effect on explosive power

A significant difference in change between the groups was observed for MBTT (F= 20.559, P= .000, η2= .604) and SLJT (F= 16.089, P= .000, η2= .544). Post hoc comparisons demonstrated that there were significant differences in favor of both suspension training and free weight training groups compared to the control group in both tests. While there were no significant differences between the suspension training and the free weight training groups for MBTT and SLJT. Both training groups significantly increased MBTT from Pre (STG 5.87±.27 m; FWTG 5.83±.3 m) to Post (STG 6.87±.389 m, 16.95%; FWTG 6.65±.325 m, 14.06%; P=.000 <.05 for both (see Fig.2). Also, the training groups significantly increased SLJT from Pre (STG 2.18±.058 m; FWTG 2.17±.052 m) to Post (STG 2.45±.085 m, 12.08%; FWTG 2.42±.081 m, 11.12%; P=.000 <.05 for both (see Fig. 3). No significant differences were found in MBTT and SLJT from Pre (5.73±.174 m and 2.16±.051 m, respectively) to Post in CG (5.91±.326 m, 3.15%, and 2.25±.09 m, 3.87%, respectively) ; P>.05 for both (See Fig. 2 and 3).

The effect on dynamic balance

There were a significant difference between the groups was observed for YBTanterior (F= 54.379, P=

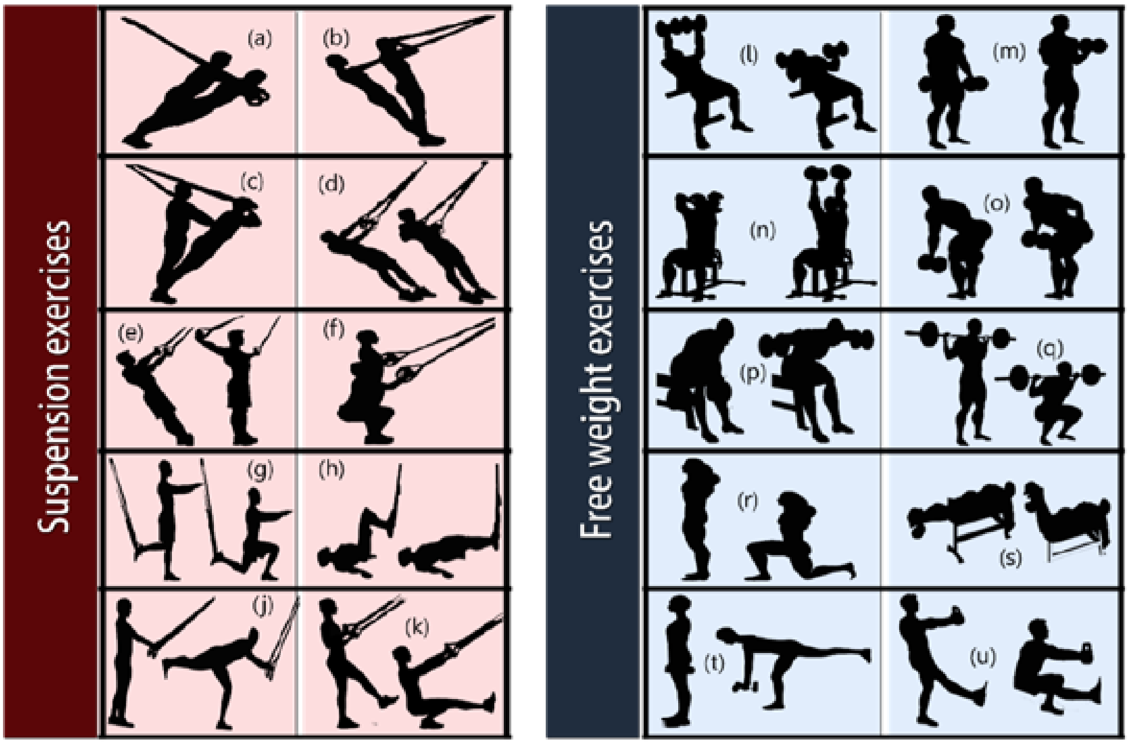

Figure 1. Exercises in different training programs (suspension training VS free weight training)

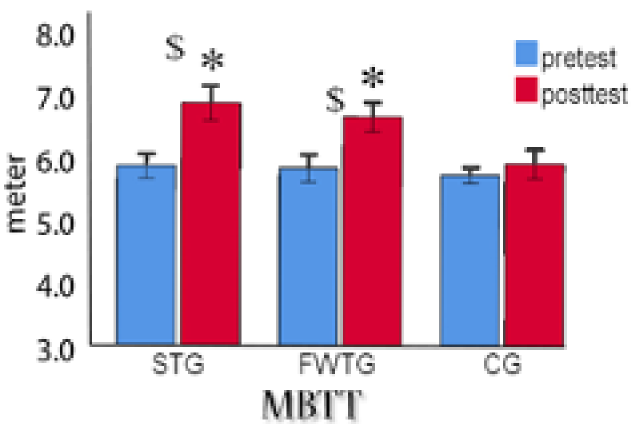

Figure 2. The effects of training intervention on MBTT. *significant difference from pre-test, $ significant difference from the CG.

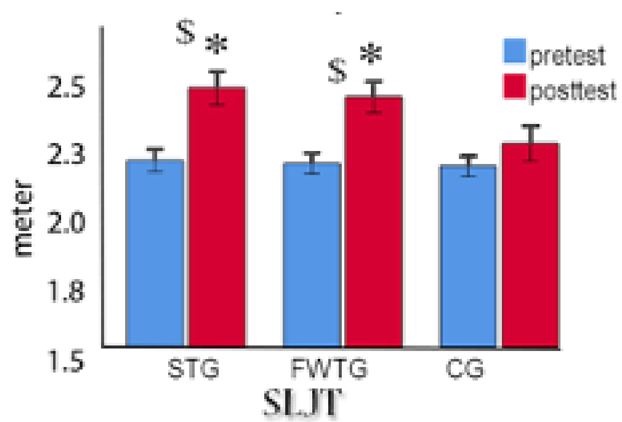

Figure 3. The effects of training intervention on SLJT. *significant difference from pre-test, $ significant difference from the CG.

.000, η2= .801), (F= 87.741, P= .000, η2=.867) and YBTposteromedial (F= 57.585, P= .000, η2= .81). The post hoc analysis showed that there were significant differences in favor of both suspension training and free weight training groups compared to the control group. Also, we found significant differences between the suspension training and the free weight training groups in the three directions in favor of the suspension training. The training groups significant increased YBT in the three directions (anterior, posterolateral and posteromedial) from Pre (STG 98.69±1.91, 109.94±2.38 and 92.09±2.64 cm; FWTG 98.08±2.97, 109.7±2.7 and 91.51±2.03 cm, respectively) to Post (STG 112.99±3.41, 126.5±2.1 and 106.66±2.97 cm with 14.49%, 15.09% and 15.86%; FWTG 108.68±2.28, 120.77±1.62 and 102±2 cm with 10.85%, 10.13% and 11.47%, respectively); P=.000 <.05. No significant differences in the three directions (anterior, posterolateral and posteromedial) from Pre (97.79 ±2.54, 108.61±2.66 and 90.7 ±2.49 cm, respectively) to Post in CG (100.1 ±2.63, 111.76 ±3.44 and 93.43 ±3.26 cm with 2.41%, 2.97% and 3.07%, respectively) ; P>.05 (See Fig. 4- A,B,C).

The effect on discus throw performance

There was a significant difference between the groups was observed for DTT (F= 19.443, P= .000, η2= .59). The post hoc test revealed significant differences in favor of both suspension training and free weight training groups compared to the control group. While there were no significant differences between the suspension training and the free weight training groups. The training groups significant increased DTT from Pre (STG 31.3±1.67 m; FWTG 30.74±2.02 m) to Post (STG 36.74±1.43 m, 17.54%; FWTG 35.42±1.95 m, 15.36%; P=.000 <.05 for both. No significant differences from Pre (30.01±1.55 m) to Post in CG (31.37 ±2.5 m, 4.51%); P>.05 (See Fig.5).

Discussion

Our main findings suggest that after eight weeks, both experimental groups showed better performance than the control group on explosive power, dynamic balance, and discus throw performance. Also, suspension training improves explosive power similarly to free weight training, while suspension training improves dynamic balance better than free weight training. Regarding explosive power, similar increases were found between suspension training and free weight training in MBTT and SLJT. Throughout the literature review

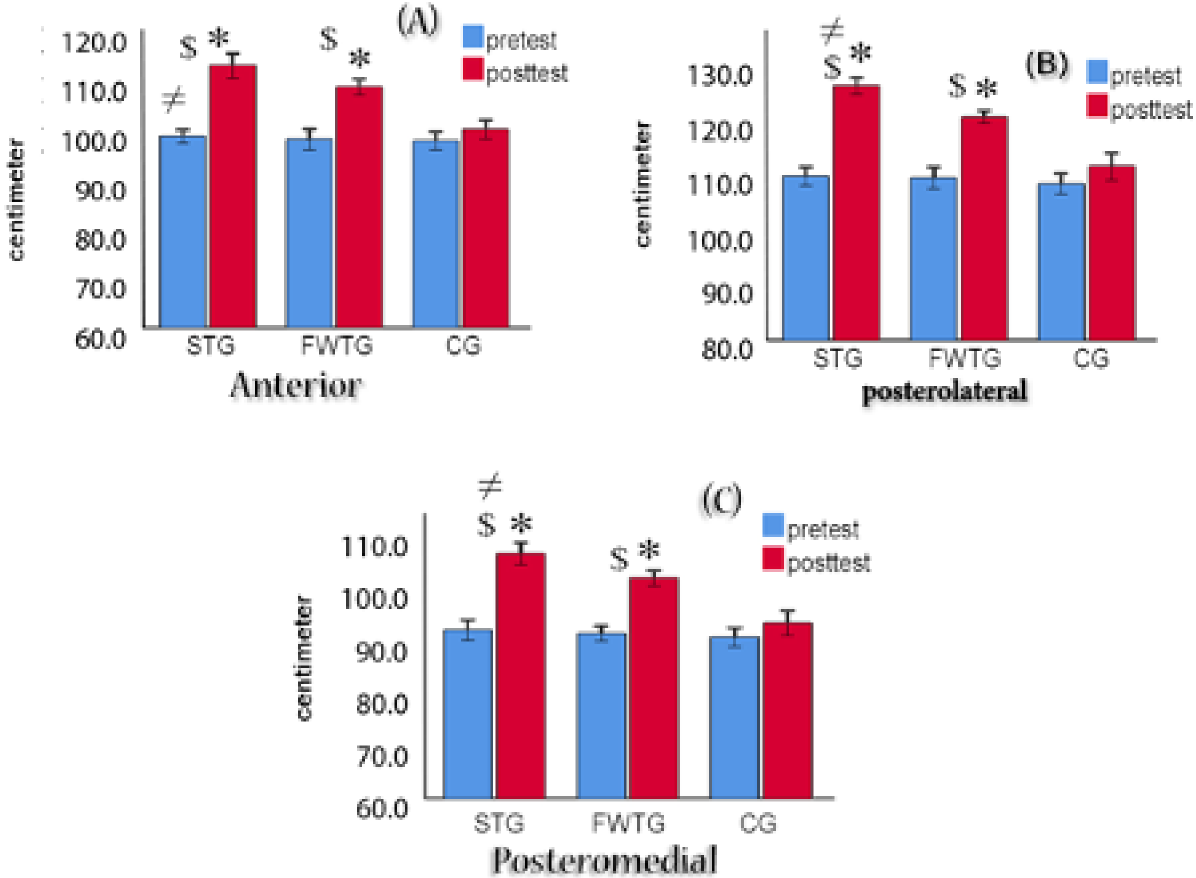

Figure 4. The effects of training intervention on YBT in the three directions; anterior (A), posteromedial (B), and posterolateral (C). *significant difference from pre-test, $ significant difference from the CG. ≠ significant difference from the FWTG. P value set at 0.05.

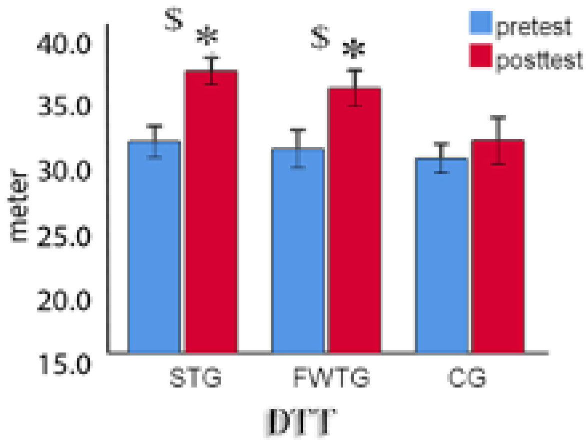

Figure 5. The effects of training intervention on DTT. *significant difference from pre-test, $ significant difference from the CG.

concerning the effects of resistance exercises. We encountered a study that was conducted by Maté-Muñoz et al., which reported increased power in upper and lower limbs after 7 weeks (three times weekly) in both resistance training groups, with no significant differences detected in the posttest variables recorded for the two experimental groups [34]. Yu et al. observed increased Physical fitness after 12 weeks of combined resistance training and suspension training. However, there were no differences based on training type. Therefore, both resistance training and combined resistance training with TRX improved physical fitness in athletic fin swimmers [36]. These results are parallel with the data we obtained after 8 weeks which could justify elevated explosive power in both experimental groups. Similar explosive power responses brought on by both types of training demonstrate that suspension training's body posture had an analogous impact on the production of external load during free weight exercise. The neurological adaptations support the advancement discovered in this paper [56]. Our findings are consistent with the theory of neural adaptation, which states that high muscular strength develops quickly during the first six to eight weeks of training. We could interpret the results of our study as suggesting that suspension training produces similar adaptations in explosive power to those of free weight training. Thus, exercises executed using suspension exercises could improve power in discus throwers in the same measure as free weight exercises.

Dynamic balance has significant improvement in both experimental groups, due to the impacts of eight weeks of suspension training and free weight training, demonstrating the benefits of both training regimens on the development of dynamic balance. In this context, Janot et al, reported increased Balance and Lower Body Strength following training for both the TRX and traditional groups after seven weeks of training [37]. However, suspension training caused higher improvement in dynamic balance in this paper. When the studies concerning dynamic balance in literature were reviewed, we encountered only the ones designed for suspension training and their effect on dynamic balance. Where Onur Demirarar et al., observed significant improvement in the dynamic balance of basketball players after 8 weeks of using suspension training [57]. The increase in dynamic balance in this paper is most likely a result of neural adaptations formed during the eight weeks of training. Since the nervous system is heavily involved in suspension training regarding the suspension condition. In this study, we found a statistical difference was observed when compared to FWTG. Suspension training, in our opinion, makes more motor units operate and maintain stability, while also more effectively activating the synergist muscle groups, so there is a good impact on balance parameters [57]. The issue with suspension training's effect that is raised in this study is one of many intricate issues that may be thought of as a reflection of an alternate free-weight training approach.

As to the discus throwing distance, we found similar increases were found between suspension training and free weight training in DTT with a very small relative increase for the suspension training. Where Δ% DTT (STG17.54%; FWTG15.36%; CG 4.51%). We believe this improvement was a result of improved explosive power and dynamic balance.

Conclusions

The purpose of this paper was to compare the effects of suspension training and free-weight training programs on the explosive power, dynamic balance, and performance of discus throwers. Our study indicated that suspension training and free weight training have created almost the same enhancement in explosive power. Also, suspension training was more efficient than free weight training for optimizing the dynamic balance. Suspension training include simple exercises, can be done in a small area, and are more cost-effective to employ at the practitioner's residence. Furthermore, a wide range of exercises may be completed with suspension training since it can be modified to the needs of the practitioners. It is concluded that suspension training seems to be associated with larger improvements in many aspects compared to free weight training. So, we recommended using suspension training alongside free weight training or as an alternative in the training for explosive power or dynamic balance or increasing the discus throwing distance. It is preferred to focus more on suspension training when developing dynamic balance.

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Conflict of interest

There was no declared conflict of interest by the authors.

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ORIGINAL ARTICLE

The effects of recreational cardio fitness programs on the body composition of young women

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Abstract

Background and Study Aim Group fitness programs are a form of programmed physical exercises with the aim of improving health, aesthetic appearance, satisfying the motivation to preserve health and reduce body weight. The aim of this study was to determine the effects of an experimental cardio fitness program on the morphological status of female subjects aged 21.5 ± 3.5 years.

Material and Methods The experimental program was implemented over a period of three months (12 weeks), with a weekly frequency (3 x 20-60 min). Initial and final measurements were performed and Body weight, Body fat percentage, Body fat mass, Free fat mass, Body muscle mass, Body mass index and Basal metabolism rate were analyzed. All test subjects have their doctor's confirmation that they are healthy and can undergo training loads in a planned and clearly defined cardio program.

Results The exercise program on cardio equipment caused changes in all body composition parameters between the initial and final measurements t-test (except for muscle mass). The total average Body weight at the initial-final measurement (66.45 vs. 64.70kg; $t= 5.225$, $p<0.000$), which represents a difference of -1.75kg after the program.

Conclusions The assumption is that a controlled and monitored program with a special focus on nutrition would lead to even more precise results on the effects on body composition. Continuous application of the content of this program throughout the entire one-year macrocycle with a higher weekly frequency would certainly give even more significant results.

Keywords: fitness cardio program, body composition, evaluation.

Introduction

Lack of physical activity (hypokinesia) is a major problem in the modern world, and as a reason to impose: psychic overload, static lifestyle and overeating. The population of the modern world in developed countries due to technological development is characterized by a lower degree of physical activity than ever before - even 2/3 of the population is not sufficiently physically active [1]. According to Prskalo [2] creating habits for proper use of leisure time devoted to exercise and movement becomes, from the point of view of Kinesiology, a primary educational task. Particularly noteworthy is the positive attitude towards physical exercise, without which a healthy lifestyle today and even more tomorrow's human is unthinkable. Public health of people and individuals is the most important resource in the modern world. The sugar epidemic and cardiovascular diseases are linked to the obesity epidemic. As obesity appears at younger and younger ages, it is to be expected that the proportion of people who have been obese for the number of years will increase and that those practicing a "sedentary lifestyle" will move less and less [3]. Modern and fast lifestyle, sedentary style, industrial development, the rapidly advancing technological advancements in the world have greatly facilitated this way of living in people, but, on the other hand, in man it caused a great an increase in a number of chronic diseases including diabetes mellitus (DM) and cardiovascular disease (CD) [4]. In the era of modern living, physical activity comes as a benefit to the organism. Physical activity also helps reduce obesity, positively affects people with mental difficulties, reduces the osteoporosis index and most importantly, we can conclude that it has a positive effect on insulin regulation in humans with diabetes. The benefits of physical activity for the prevention of DM and CD are multiple. Regular physical activity has been shown to help in the prevention treat non-communicable diseases, such as heart disease, stroke, diabetes disease, and breast and colon cancer [5-7]. It also helps prevent hypertension, overweight and obesity and can improve mental capacity, quality of life and well-being [8, 9]. American College of Sport Medicine-ACSM [10] recommends all healthy adults between

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the ages of 16 and 65 years engage in moderate aerobic physical activity at least 5 times a week for a time of 30 minutes or intense aerobic physical activity at least 3 times a week. ACSM recommends in its physical activity guidelines:

- Moderate aerobic physical activity at least 150 minutes per week, 75 minutes of intense aerobic activity per week or a combination of both activities;
- Additional aerobic physical activity of 300 minutes per week, or 150 minutes of vigorous exercise per week, provides additional health benefits;
- Adults are recommended to be physically active with strengthening activities muscles of moderate or high intensity and include all major muscle groups twice a week, as these activities provide additional health benefits.

Health should be viewed in the broadest sense, not only as the absence of disease, but as the ability to adequately respond to the numerous challenges of everyday life through the social, psychological and physical dimensions. The awakening of awareness that health is the most important part of a quality life has made more and more people of different ages and both sexes engage in some kind of sports and recreational exercise. A person can use his/her free time to satisfy his/her needs for movement, through the application of various forms of physical exercise, and thus he can improve the functional abilities of his organism [11].

The WHO [12] emphasized in its annual report from 2012 that mortality, morbidity and disability associated with chronic non-communicable diseases are responsible for more than 60% of mortality in the world, and that unhealthy diet and lack of physical activities are the main risk factors for those diseases. In 2019, there were an estimated 351.7 million able-bodied people (20-64 years) with diagnosed or undiagnosed diabetes [13]. That number is expected to rise to 417.3 million by 2030 and to 486.1 million by 2045. According to the estimates of the American diabetes association, the 2017 annual cost of diagnosed diabetes is 327 billion dollars (American Diabetes Association, 2020). According to the International Diabetes Federation IDF (2019) it was estimated that in 2019 the incidence of diabetes in adults is the lowest in the 20-24 age group (1.4% in 2019). Where adults aged 75-79, the incidence of diabetes is 19.9% in the 2019 year, and it is predicted to increase to 20.4% by 2030 and 20.5% by 2045. It is slightly lower in women aged 20 to 79 than in men (9.0% compared to 9.6). Females differ from males in a large number of physiological parameters, including physical activity. This especially applies to endurance sports such as running, cycling, rowing or swimming. The NSCA (National Strength and Conditioning Association) has provided a summary of research related to women's strength training, which is reflected in the following.

- Women can improve fitness, athletic performance and reduce the chance of injury through strength training.
- Physiological responses to weight training are similar in men and women.
- Women should use the same exercises and performance technique as men in weight training.
- There is no significant difference between the sexes in the ability to generate force per unit cross-sectional area of the muscle. Men show greater absolute strength than women due to higher body mass, greater amount of muscle compared to fat tissue and increased testosterone in the body.

Physical exercise allows women in their mature years to control their body weight, and thus prevent the possibility of various diseases of the heart and blood vessels, as well as injuries to the locomotor apparatus [11]. Before starting any physical activity, it is of crucial importance to determine the initial state of the person who wants to engage in physical exercise. In addition to determining the initial condition, there are three important components of each training, namely progressivity (gradual increase in load during the time spent in exercise), continuity (regular physical activity) and a professional (creator and leader of the entire training process). According to Mandarić [14] group fitness programs are a form of programmed physical exercise for women with the aim of improving health and improving aesthetic appearance. The goal of these programs for women is to satisfy the motives for maintaining health, improving physical appearance and reducing body weight. When it comes to the female population, more and more of them exercise because they feel better, the tension is less, they are functionally and emotionally more capable, and thus more operational, more resilient in numerous jobs, family activities and many other obligations. Group fitness programs by structure, belong to the polystructural cyclic activities and have a positive effect on the anthropological characteristics and abilities of both women and men [15]. Some of the group fitness programs can be realized and can be selected in relation to the content of the activity. Group fitness programs differ from other exercise programs in that they act on human feelings, motivation, cheer up, and also help to perform physical movements with extreme dexterity and precision [16].

Aerobics, as a form of physical exercise, aims to master muscle functions, to acquire the ability of gradual and increasingly stronger innervation, and to improve the functional abilities of the cardiovascular and respiratory systems. Energy consumption in aerobics depends on the form and intensity with which it is carried out. Aerobic of lower intensity or aerobic weakness of the participation of large muscle groups of the legs and a slower rhythm, conditions lower energy consumption (4-5kcal/min), in contrast to aerobics, which requires a large expenditure of energy, high intensity, which conditions energy consumption (about 11 kcal/min.). McCord [17] determined the impact of a program of low-intensity aerobics on the reduction of subcutaneous fat tissue and the improvement of functional abilities. At the end of 12 weeks in the work mode (3 x 45 min. per week) at 75-85% of VO2max, significant changes in the improvement of the cardiorespiratory apparatus and body composition were determined. Changes in morphological and motor measures, that is, the potential differential effects of the STEP program and High-Low aerobics, is the subject of research by [18]. The program consisted of 25 training sessions (3x60 min. per week). In the area of morphological characteristics (skin folds), statistically significant differences were found between the initial and final measurements.

Some research [19] analyzes the impact of aerobics programs on the transformation of anthropometric characteristics, motor and functional abilities of girls up to 18 years of age. The obtained results confirm the multifunctional impact of aerobics on defined spaces. The obtained results confirmed the multifunctional impact of aerobics on defined spaces. Sulemana et al. [20] examined correlations between physical activity and BMI among girls aged 14-17 years. The results showed that there is a significant inverse correlation between the level of total daily physical activity and BMI and a statistically significant relationship between extracurricular activities and BMI. In McTiernan et al. work [21] it was proven the possibility to influence the reduction of body weight and certain segments of body circumference through physical exercise. Confirmation that aerobic physical activity can affect the reduction of body weight, i.e. nutrition in women aged 19 to 25 years has been proven in research [22] and other researchers have come to similar results.

Sarsan, Ardiç, Ozgen, et al. [23] found in their study that weight loss occurs after an aerobic exercise program. The recreational aerobic exercise, which is realized three to five times a week for 20 to 60 minutes, can contribute to quantitative and qualitative changes in certain variables of morphological characteristics [4, 24, 25]. These changes are primarily related to their reduction, so it can be stated that the realized model of regular recreational aerobic exercise led to positive changes in the subjects of the experimental group. Viskić-Štalec et al. [26] investigated the impact of the aerobics program on the morphological characteristics and motor skills of the subjects of the experimental group (conducted the aerobics program) and the control group (conducted the physical and health culture program). The results show that the experimental group, compared to the control group, achieved better results in motor tests (agility, strength, flexibility) and functional abilities with a reduction in body weight and skinfold measurements. The authors concluded that the existing programs of physical and health culture should be valued and supplemented with programs that cause better transformational effects. The relationship between the environment and variables of the recreational environment with physical activity and BMI in a sample of 98 adolescents is the subject of Kligerman et al. study [27]. In a linear regression, the pedestrian-friendliness index within 0.5 miles of home was associated with minutes of physical activity (moderate to vigorous), explaining about 4% of the variation. Different approaches to measuring physical activity and obesity in young people have led to different studies with completely conflicting results [28], from no to a very strong relationship between physical activity and obesity. Significant differences were obtained in the level of activity determined among girls whose weight category was determined by BMI (but not among boys) and between groups divided according to body fat deposits for boys and girls.

Madić et al. [29] were compared with the results of different methods for assessing body composition on a sample of 100 young women (BIA, BMI and assessment of subcutaneous fat tissue). The results of the research showed that all three applied variables for the assessment of body fat have high values, but, nevertheless, it is concluded that the variables for the assessment of body fat Body mass Index (BMI) and the total amount of body fat estimated by bioimpedance (BIA) have higher projections, whereby the first one was slightly superior, while the third variable - the coefficient of total body fat (FAT) - had a slightly lower projection on the common object of measurement. On a sample of 80 female subjects from the University of Novi Sad, Čokorilo et al. [30] measured fat tissue, body mass, and skin folds with the aim of determining differences. After the successfully implemented program in which the progressive load model was used, there was a decrease in the measured variables of the experimental group compared to the control group. Body mass decreased by 1.8kg on average, the average value of the upper arm crease decreased by 3.6mm, the abdominal crease decreased by 3mm on average and the upper leg crease value decreased by 8.1mm.

Šarić [31] performed the valorization of an experimental aerobics program lasting three months and defining its adaptive potential in adult inactive test subjects who, for a period of three months, performed an aerobics program with 36 training units (3x 60 min. per week). The subjects were measured in the initial, transitive and final state with 6 anthropometric measures: height, mass, fat tissue, body mass index, waist circumference, and hip circumference, as well as with 1 variable of functional abilities VO2 max. The results of the t-test for dependent samples showed that there were significant changes under the influence of the appropriate aerobic program in all measurement variables, except for the variable - hip circumference. Ljubojević et al. [32] examine the effects of an eight-week Zumba fitness program on changes in the body composition of women on a sample of 12 recreational women with 24 training sessions. Before and at the beginning of the Zumba fitness program, body mass, percentage of fat tissue, amount of fat tissue (kg), lean mass and total amount of water in the body were measured. The results showed that there were statistically significant changes in the reduction of body mass, the percentage of fat tissue, the amount of fat tissue (kg). Although the values of lean mass and the total amount of water in the body increased after the program, they were not statistically significant. The Zumba fitness program has proven to be a very effective means of exercise aimed at reducing fat tissue in women. Hadžić et al. [33] determined the value of the experimental program (high - low aerobics) and its impact on the viability of the motor skills with a high school student. The results clearly indicate that the statistically significant positive changes in the transformation of the evaluated motor skills at the final measurement are in favor of the experimental group compared to the control, which supports the effectiveness of applied programs highlow aerobics.

Previous studies confirm the health impact of different models of physical exercise on modifications of the body composition, morphological and motor abilities. It is a fact that physical activity significantly impacts the consumption of energy, leads to energy deficit which contributes to reduction in body weight [34]. A significant segment is dosing the load, for it is in close correlation with the exercise outcome, i.e., lost weight and changes in body composition [35, 36]. Body composition represents relative values of muscles, fat, bones and other anatomic components that contribute to the total body weight of a man. Percentage of body fat increases with age and it is more pronounced among the female than male population [37].

Application of certain group fitness programs brings significant changes in body composition, because the application of certain movement structures is a significant anabolic stimulant for the body [38]. Due to the extent, intensity and character of the applied group fitness programs and constant muscle contractions, the biggest changes are reflected in the change of muscle mass and body fat percentage. According to Elmahgoub et al. [39] and Stasiulis et al. [40] group fitness programs are an efficient tool for the control and reduction of body weight and positive changes in body composition. The current study is based on a selected model of the cardio program and its transformational capacities on the body composition of female recreational athletes. The aim of the work is to determine and the valorize quantitative effects of the modelled experimental cardio program on the body composition of women.

The current study is based on a selected model of the cardio program and its transformational capacities on the body composition of female recreational athletes. The aim of the work is to determine and the valorize quantitative effects of the modelled experimental cardio program on the body composition (BC) of young women.

Material and Methods

Participants

The sample of respondents included in the current research consisted of 12 female persons, aged 21.5±3.5 years, who recreationally engage in some form of physical activity. All test subjects have their doctor's confirmation that they are healthy and can undergo training loads in a planned and clearly defined cardio program.

Research Design

To assess the physical status of the test subjects, seven parameters were measured to define the body composition:

1. Body weight - BW (kg),
2. Body fat percentage - BFP (%),
3. Body fat mass - BFM (kg),
4. Free fat mass - FFM (kg),
5. Body muscle mass- BMM (kg),
6. Body mass index - BMI (kg/m^2)
7. Basal metabolism rate - BMR (KCal)

Experimental design study

Convenience sampling was performed. Body weight and Body composition (BC) were assessed with the Bioelectrical Impedance Analysis (BIA) using a body composition analyser (TANITA TBF-300A, JAPAN), in accordance with the measurement protocol. The participants were informed in detail about the nature of the study and investigational procedures, and all the participants have voluntarily given their consent to be the part of this study. Prior to the survey, each respondent signed a consent form to participate. During the testing, the air temperature was between 18°- 22°C The measurements were according to the procedures in the Helsinki declaration.

Statistical analysis

The statistical program SPSS 19.0 was used to process the data obtained from the initial and final measurement of Body composition (BC). The basic statistical parameters were calculated and the differences between the arithmetic means of the initial and final measurements were determined by the T-test for small dependent causes.

Table 1. Experimental cardio program (three-month duration)

I MONTH			
I week	**II week**	**III week**	**IV week**
1. training: 15 minutes of cycling (heart rate 80% max F(H)).	**4. training**: 3 x 10 min. cycling, break 3 min., (heart rate 70% max F (H)).	**7. training**: 30 min. vožnje bicikla (puls 70% max F(H)).	**10. training**: 4 x 15 min. cycling, (heart rate up to 80% of max F(H)), break 3 min.
2. training: 10 minutes of cycling, break 3 minutes, 10 minutes (heart rate 70% max F (H)).	**5. training**: 2 x 15 min. cycling, break 3 min., (heart rate 75% max F (H)).	**8. training**: 2 x 20 min. cycling, break 3 min., (heart rate 75% max F(H)).	**11. training**: 1 x 35 min. cycling (heart rate 75 % max F(H)).
3. training: 20 min. cycling (heart rate 70% max F(H)).	**6. training**: 1 x 30 min. cycling continuously (heart rate 65% of max F(H)).	**9. training**: 30 min. cycling discontinuously, break 5 min., (heart rate 60% max F(H)), next 15 min. pulse 80% max F(H), last 10 min. pulse up to 70% of max F(H).	**12. training**: 1 x 25 min. cycling (heart rate up to 65% max F(H)).
II MONTH			
I week	**II week**	**III week**	**IV week**
13. training: 2 x 25 min. cycling (heart rate up to 80% max F(H)), break 2 min.	**16. training:** 1 x 30 min. discontinuous cycling (first 5 min. pulse up to 60% max F(H), next 15 min. increase pulse up to 85% max F(H), 10 min. continuous (pulse up to 70 % max F(H)).	**19. training**: 1 x 30 min + 1 x 20 minutes of cycling (1 min. fast, 1 min. easy) heart rate up to 85% max F(H), 5 min. light rides pulse up to 65 % max F(H).	**22. training**: 1 x 30 min. cycling, heart rate up to 70 % max F(H).
14. training: 1 x 40 min. riding a bicycle continuously (pulse up to 75 % max F(H)).	**17. training**: 3 x 20 min. bike rides (heart rate: 1. 75% 2. 85% 3. 80% max F(H)).	**20. training:** 2 x 30 min. cycling, break 3 min, heart rate up to 70 % max F(H).	**23. training**: 1 x 40 min., 10 min. pulse up to 65% max F(H) + 10 min. pulse 80% max F(H), then 10 min. pulse 75% max F(H), 10 min. pulse up to 65% max F(H).
15. training: 3 x 20 min., cycling (heart rate up to 75% max F(H)), break 3 min.	**18.training**: 1 x 45 min. continuous cycling (heart rate 75% max F(H)).	**21. training:** 1 x 50 min. continuous cycling, heart rate up to 75% max F(H).	**24. training:** 1 x 50 minutes of continuous cycling, heart rate up to 70 % max F(H).
13. training: 2 x 25 min. cycling (heart rate up to 80% max F(H)), break 2 min .	**16. training**: 1 x 30 min. discontinuous cycling (first 5 min. pulse up to 60% max F(H), next 15 min. increase pulse up to 85% max F(H), 10 min. continuous (pulse up to 70 % max F(H)).	**19. training**: 1 x 30 min + 1 x 20 minutes of cycling (1 min. fast, 1 min. slow) heart rate up to 85% max F(H), 5 min. light rides pulse up to 65 % max F(H).	**22. training**: 1 x 30 min. bike ride, heart rate up to 70 % max F(H).
III MONTH			
I week	**II week**	**III week**	**IV week**
25. training: 2 x 30 min. cycling, break 2 min. pulse up to 80 % max F(H).	**28. training**: 2 x 30 min. cycling, break 3 min., heart rate up to 70% max F(H).	**31. training**: 60 minutes of continuous cycling, heart rate up to 70% max F(H).	**34. training**: 1 x 50 minutes of discontinuous cycling, heart rate at 75% of max F(H).
26. training: 1 x 30 minutes of cycling, heart rate up to 70% max F(H).	**29. training:** 1 x 45 min. cycling, heart rate up to 70% max F(H).	**32. training**: 20 min. of discontinuous cycling (10 minutes easy, heart rate up to 65% max F(H), 10 minutes heart rate up to 70% of max F(H).	**35.training**: 1 x 30 min. of continuous cycling, heart rate 70% max F(H).
27. training: 1 x 50 min. discontinuous cycling (10 min. pulse up to 65% max F(H), 10 min. pulse 70% max F(H), 30 min. pulse 75 % max F(H).	**30. training**: 1 x 30 min. discontinuous cycling (5 min. heart rate up to 60% max F(H), 15 minutes: 1 min. fast, 1 min. slow, heart rate up to 80% max F(H), 10 minutes of continuous riding, heart rate 70 % max F (H).	**33. training**: 1 x 50 min. continuous cycling, heart rate 65% max F(H).	**36. training**: 1 x 45 min. continuous cycling, heart rate up to 65 % max F(H).

Results

The results contained in Table 2 and Figures 1, 2 present the effects of a three-month experimental cardio treatment on the body composition of twelve young women, where it is evident that there have been significant changes. The results of the t-test confirm statistically significant differences (changes) in 6 out of 7 parameters (85.71%) for the p=0.001 level, which are a consequence of the programmed experimental program.

Body weight (BW), as the largest carrier of the total variance of all parameters of body composition, recorded a lower value at the end of the experimental program of 1.75kg (66.45 vs. 64.70kg), where the recorded value was t =5.225; p=0.002 (Figure 1). This is a relatively good result and a consequence of the transformation of all other body parameters that are the result of the implemented cardio program and matches the aim of the study. The percentage of body fat (BF%) in the final measurement was reduced by 1.23% (27.88 vs. 26.65%) or BMF=1.02kg (19.42 vs. 18.74kg), where the evident difference t = 4.484 and statistically significant p=0.000. The lean body mass of the subjects increased (differs) by 0.21 kg (47.05 vs. 47.26kg) in the final measurement (t = -2.755; p=0.001). Linearly with lean mass, muscle mass (BMM) recorded a slight increase in the final measurement (44.65 vs. 45.22kg). However, there was no statistically significant difference (t = -1.771; p=0.104). The cumulative effect of all body parameters is the BMI value, which is part of the research area. It was reduced in the final measurement by 0.7 kg/m² (BMI 22.75 vs. 23.45)

Table 2. Differences between the initial and final measurements BC after the three-month cardio program

Body composition parameters		Mean±SD (min.-max.)	Mean I Mean F	T - value	Sig. (2-tailed)
BW (kg)	IN	66.45±11.82 (50.00-86.90)	1.75	5.225	0.000
	FI	64.70±11.18 (49.80-84.10)			
BF (%)	IN	27.88±8.50 (15.40-39.10)	1.23	4.484	0.001
	FI	26.65±8.11 (15.30-37.40)			
BFM (kg)	IN	19.42±8.97 87.70-33.50)	1.02	4.285	0.001
	FI	18.74±8.76 (7.60-33.10)			
FFM (kg)	**IN**	47.05±3.15 (42.30-53.40)	0.21	-2.755	0.019
	FI	47.26±3.12 (42.80-53.70)			
BMM (kg)	**IN**	44.65±3.01 (40.10-50.70)	0.57	-1.771	0.104
	FI	45.22±2.32 (40.50-51.00)			
BMI (kg/m²)	IN	23.45±4.02 (18.40-31.20)	0.7	6.009	0.000
	FI	22.75±3.84 (18.30-30.10)			
BMR (Kcal)	IN	1460.33±119.72 (1302.0-1690.0)	-28.75	-4.052	0.002
	FI	1489.08±134.83 (1298.0-1763.0)			

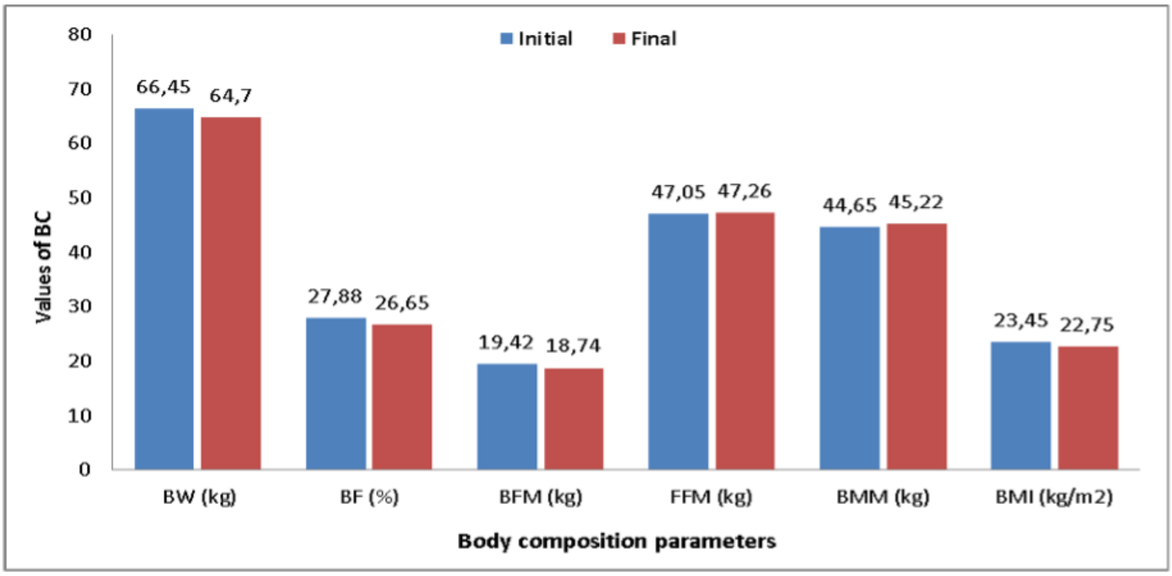

Figure 1. Differences between mean values in Body composition

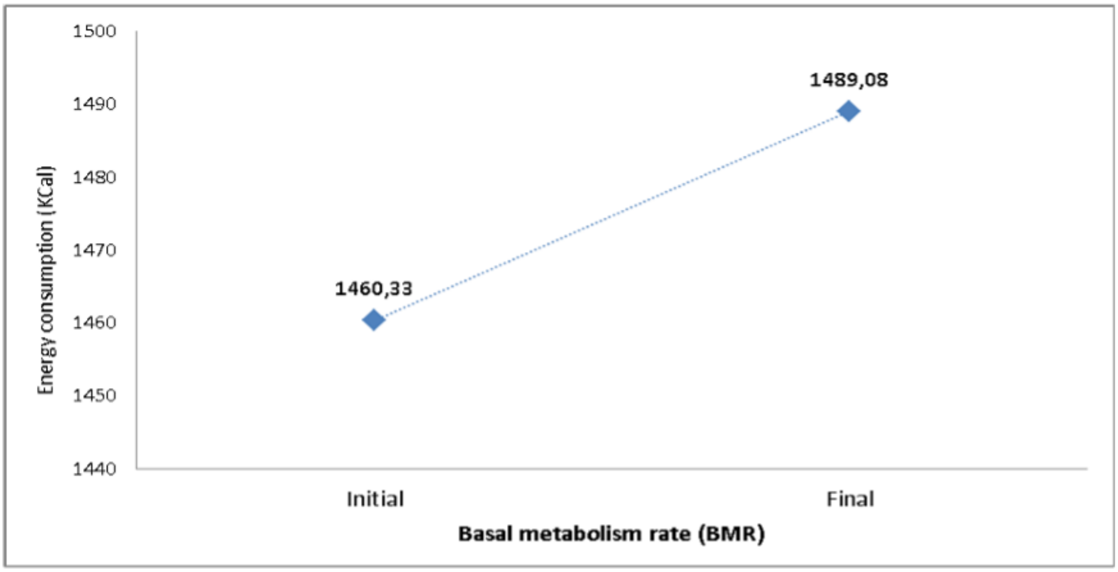

Figure 2. Effects of the cardio program on energy consumption (KCal)

where t= -6.009; p=0.000. Caloric consumption (BMR) after the final measurement showed a higher average consumption by 28.75 kcal for t = -4.052; p=0.002 (BMR=1460.33 vs. 1489.08) (Figure 2).

Discussion

Hypokinesia, obesity and psychological stress are the biggest causes of illness and death in modern man. Insufficient and inadequate physical activity reduces the functional abilities of many organic systems, primarily cardiovascular and respiratory, and nervous tension leads to various mental illnesses. Such a condition leads to a decrease in people's working capacity and to the impairment of their physical and mental health [11]. Exercise is very important for adolescent girls, because training improves their morphological characteristics (physical status), which positively affects their psychological state. They have a better perception of their own body, reduce the possibility of entering into various crises, depression or eating disorders due to the application of various "instant" diets. The goal of physical activities and exercise in view of the above should be the development of the cardiovascular and respiratory systems on the one hand, and the muscular and skeletal systems on the other hand, thus increasing the level of health and quality of life, extending working and life expectancy, and delaying and slowing down the aging process. The most suitable activities for the development of the first system are cyclical activities, that is, activities where there is one closed movement structure that is continuously repeated. Group fitness programs of different duration, intensity and frequency are most often discussed. An important motive for the majority of recreational women to participate in such programs is shaping the body into a harmonious whole while reducing subcutaneous fat and body mass. AAHPERD [41] states the so-called components of physical fitness, including body composition.

The goal of the current study was to determine and evaluate the quantitative effects of a modelled three-month experimental cardio program (Table 1) on the physical status of young women, aged 18-25 years. The obtained extracted results confirm significant differences in most body composition parameters between the two measurements (85.71%). It is mainly about the reduction of fat tissue and body weight, in contrast to muscle mass, which showed a slight increase (Table 2, Figure 1). Based on the descriptive parameters for the assessment of body composition, as one of the fitness components, it can be concluded that our female subjects have different values between the initial and final measurement BF% (27.88 vs.26.65%) and BW (66.45 vs.64.7kg), which is the product of the implemented cardio program. Total BF (%) is lower at the final compared to the initial measurement, which corresponds to a normal distribution for the given population [42, 43]. High-intensity load programs lead to a faster reduction in body composition, slight increase to energy consumption (Figure 2), which results in reduction in total body weight. The intensity of the load during the program has a beneficial effect on fat loss in all parts of the body [44, 45].

A possible decrease in muscle mass in our sample would not be a good indicator of the program's effects, since the goal was to decrease the percentage of body fat and body weight. The basic intention of the programs in which the body composition is corrected is related to the reduction of fat, and at the same time the maintenance or increase of muscle tissue. Every person, no matter how low the BMI index is, must have a certain percentage of fat in the body, because fat is necessary for life. Without fats, certain vitamins and minerals cannot be absorbed in the body, hormones cannot be produced, but fats also have important reproductive functions. Energy is stored in fats, fats regulate body temperature, and in addition to the above, they are responsible for many other mechanisms in the human body. Fats in the body are stored in the subcutaneous fat tissue, and in addition, fat deposits also have a protective function around the internal organs [46]. Our sample has the so-called "healthy level" of fat in both measurements which is consistent with the unified table results.

Health should be seen not only as the absence of disease, but as the ability to adequately respond to the numerous challenges of everyday life through the social, psychological and physical dimensions. According to Anderson et al. [47] women who are moderately physically active compared to women who sit all the time, have a lower rate of carcinomas and better functioning of the immune system (more leukocytes and increased concentration of immunoglobulins), less depression and better mental abilities, speed, higher IQ, more persuasiveness, spontaneity and enthusiasm, better attitude towards oneself and better acceptance of oneself, stronger bones, increased bone density, increased bone mass and increased ability of bones to withstand mechanical stress and fractures. The experimental three-month cardio program led to significant changes in the body composition parameters (Table 2; Figure 1,2) of our sample, which is in accordance with the results of previous studies [17, 18, 19, 24]. In our study, the body mass of the subjects, as the main representative of body composition, was reduced by 1.75 kg in the final measurement, it is identical to the results of the study by [30], which is an indicator of a well-implemented cardio program and its positive effects that are valued through the obtained results. The results are another important confirmation that directed aerobic, cardio activity can affect the reduction of body weight, which supports earlier research [26, 31, 32] on the same sample or of a similar age who found that weight loss occurs after a program of aerobic exercises, which are performed three to five times a week for 20 to 60 minutes, which can contribute to quantitative and qualitative changes in individual body composition variables.

Conclusions

This experimental research was conducted on a sample of 12 (twelve) women of recreational age of 21.5±3.5years. The program lasted 3 months with a frequency of work (3x20-60min. per week). Based on the results of the T-test for dependent samples, there were statistically significant changes caused by the three-month experimental program on the sample of female recreational athletes. Changes were found in all variables except muscle mass, which was expected considering that the goal of the program was to reduce body fat parameters and reduce the body weight of the test subjects. The assumption is that a controlled and monitored program with a special focus on nutrition would lead to even more precise results on the effects on body composition. Continuous application of the content of this program throughout the entire one-year macrocycle with a higher weekly frequency would certainly give even more significant results.

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ORIGINAL ARTICLE

Teaching wrestling at school: proposal of a new pedagogical approach based on games for learning of technical moves

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

Abstract

Background and Study Aim The purpose of this study was to find the effect of the game based on educational method and technical approach on the performance of legs attacks in free-style wrestling.

Material and Methods The type of research was semi-experimental. Participants included 20 boys' students who were divided into two groups based on the game-based approach (10) and technical training (10). The teaching unit was a format of 12 lessons over 4 weeks (2 days per week). Each lesson lasted 60 minutes. At the end of each training session, the participants played benchmark bouts, one on one, for 2 x 6 minutes. The data were analyzed using SPSS 16 software at a significance level of 0.05.

Results The results showed that both the game-based and technical approach groups had a significant improvement in successful leg attacks in free-style wrestling. With regard to the preparation of leg attacks, there was no improvement for the technical approach group. However, the game-based group had a significant improvement in the total number of attacks compared to the technical group.

Conclusions The results suggest that the use of a game-based educational method can significantly increase the important factors of wrestling performance related to leg attacks in young wrestlers. Teachers can connect actions from other technical movements from the same family of leg attacks.

Keywords: game, educational method, traditional practice, performance.

Introduction

Physical Education and Sport teachers have an important part to play in introducing students to sport, as qualified professionals to provide experiences and motivation for a physically active life for every young student. Sport can offer a wide range of educational opportunities for students, but it should be noted that a new specific pedagogy should replace the current traditional pedagogy, which is based on technique as the only learning approach to sport [1-4]. Generally, traditional approach emphasizes skills and techniques regarded as fundamental to the successful practice of specific popular sports such as wrestling. These techniques were practiced repeatedly until the students could practice them sufficiently [5]. Moreover, practical knowledge for sports initiation are limited and sports teachers should not rule out the possibilities of offering multiple physical practices. This must provide a learning environment that promotes positive young people's development [6-9]. It seems essential in this sense that pedagogical models should be thought by objectives in order to provide learning contexts that promote opportunities and experiences for children to become competent and enthusiastic players in the game and motivated to engage in physical activities [2]. Melki et al. [10] indicate that wrestling is universal and offers opportunities for students of all sizes and physical abilities. Wrestling can be safe and playful, and give children the opportunity to develop physical skills such as speed, agility and muscular endurance [11-13]. Participation in wrestling, due to its physical and tactical character pushing emotional levels, offers unique experiences of moral development such as maturity of self-concept, decision-making, self-control and sports man ship [14-16]. For Gibbons et al. [17] under the concept of fair play, students can learn to respect the rules and develop personal and social responsibility for their behavior. Wrestling also differs from other combat sports in that it does not allow opponents to hit each other, which makes it safer for students. Wrestling is a physical as well as a mental challenge and the objective is not to hurt another person but to outwit and control the opponent [18]. Zi-Hong [19], defined wrestling as a dynamic and combative sport of high intensity that requires complex skills and technical excellence to succeed. According to the research results of Fujiyama et al. [20] the technical-tactical analysis of freestyle wrestling bouts showed that leg attack moves were the most used technique for scoring points. Cipriano [21] showed that winners of international wrestling tournaments

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performed almost two times more successful leg attack manoeuvres than their opponents. While the leg attack might be more effective by reducing the distance between the attacker and the opponent, this would also inevitably increase the risk of an attack by the opponent. Therefore, maintaining a committed minimum distance between the wrestlers is essential to execute effective attack and defense manoeuvres. Wrestling can play an important role in attracting kids to do combat sports and develop their physical abilities. However, the problem is that they do not like technical learning exercises that have little physical mobility and joy and this is the result of traditional educational models in physical education classes. In this sense, Williams [22] confirmed that the traditional method of training and performance improvement emphasises the use of a teacher-centered approach. As a result, skills are practiced in the form of exercises and in a form that is separate from the real context. Ohya et al. [23] stated that one of the important limitations of traditional training models is the inability to transfer the skills learned on the wrestling mat, which results in a significant performance gap in the fight performance. Gabbett et al. [24] concluded that wrestling is an intermittent sport that requires wrestlers to compete in short, frequent periods of high-intensity exercise followed by periods of low-intensity activity. Because of its physical and physiological demands, Perriello et al. [25] mentioned that wrestling has a limited presence in secondary schools and teachers generally select sports according to their field and their knowledge of the disciplines. In addition, viewpoints, perceptions of danger and violence among combat sports teachers do not allow them to be seen as capable of developing the values and positive attitudes associated with the practice of sport.

Finally, we want to make clear that in the literature these teaching proposals based in an educational-training model are very scarce [26]. This lack of scientific production in the area creates a great interest to know the opinions and beliefs of future graduates about wrestling. An approach called learning based games has been developed in recent years in order to combine the elements of competence and conditioning in a coherent approach [27]. According to Magill [28], moving from practice to the gaming environment depends on how closely the practice or training resembles the game. In order to expose players to the intensity, decision-making, speed and skill execution required in competition, practice sessions must replicate actual events and phases of play. The use of game-based methods as learning exercises allows for the simulation of movement patterns in attack and defense in wrestling, while maintaining a competitive environment in which students must work under pressure and fatigue [29]. However, research regarding the effectiveness of game-based training is limited, and many of the suggested advantages and disadvantages of game-based training are present. Therefore, further research is needed to confirm this theory. In proposing an organisation of wrestling content. We seek to find ways to promote the most positive experiences for students by developing opportunities to teach and learn this broad content in physical education and sport sessions. At this point, we start to think about the different fighting actions that can be taught. This proposal is an initiative for teachers who do not have experience and training in combat sports. However, teachers who have this specific knowledge as wrestling teachers and coaches can also benefit from this proposal when seeking to develop a positive environment for the initiation of wrestling. The purpose of this study was to compare the effect of two educational methods, and to propose the game-based method as a new pedagogical approach for learning technical moves in freestyle wrestling.

Materials and Methods

Participants

The participants in this study were 20 boys in the first year (average age 18.6 years) of the physical education course at the Higher Institute of Sport and Physical Education in Ksar-Said, Tunisia. They voluntarily agreed to participate in this research. The students had no previous experience of learning to wrestle and had not participated in any sports education seasons prior to this study. The participants were randomly divided into two equal groups (10 subjects); the experimental group "GE" based on game-based training, the other group, the control group "CG" trained in the traditional way.

Study Design

A quasi-experimental study with a non-equivalent control group pre-test-post- test design, based on intact groups, was conducted to compare the effectiveness of two teaching approaches (wrestling games approach and technique-oriented approaches) in improving participants' skills bout; a) number of attempted legs attack, b) number of successful legs attack and c) number of unsuccessful legs attack. Before each training session, information about the content of the lesson was given to the participants.

Both groups of participants learned freestyle wrestling. The teaching unit was a format of 12 lessons over 4 weeks (2 days per week). Each lesson lasted 60 minutes. The control group is trained in a traditional program and the experimental group is trained on the game's methods. At the end of each training session, the participants played benchmark bouts, one on one, for 2 x 6 minutes.

Experimental Group: Pedagogical approach based *on wrestling Games*

In a wrestling school, the teacher addresses young people who must be made to play. Thus, at the beginning, wrestling “games” are proposed to prepare the students to the spirit of wrestling and to the technique, in order to gradually approach the “real” wrestling thanks to the advice given through the games. Progressive measures are put in place to introduce students to wrestling. The teaching-learning process of wrestling has been described in three stages:

Step 1: Cooperative games

This stage is divided into two levels, the first being the touch games, which are considered an introduction. The second level is devoted to scarfing games. The objective is to introduce the students to contact, through games where they have to touch and act on their partner by holding on, respecting the notions of stability through the different forms of guarding in wrestling.

Step 2: Body to body games (opposition games)

The purpose is to bring the student to learn progressively the fundamental notion of bout and to lead him towards a closer and frequent contact, because it is a question of acting to win. These games require participants to place themselves within a fighting area and it do not present a risk of impact with the opponent. This level represents the opposition games which is also divided into two stages, the first one being the defending an object game. The second stage is devoted to traditional wrestling games, mainly Sumo and eagle fighting.

Step 3: Wrestling learning situations; Leg Attacks

At this time the controls will be discussed, which will not be the same for all apprentice wrestlers. We present the possibilities of actions that can be chosen as objectives. This could provide diverse experiences that could lead students to pursue wrestling in other contexts, through their affinity in fighting games. In school contexts, it may be interesting to provide support and security to teachers with no previous experience, without the need to depend on a specialization.

Control Group: Technique Approach

The Technique group began the lessons with a demonstration of the leg attack technique, followed by a series of progressive and complex learning situations. The leg techniques taught in the 12 lessons were common to those of the Games approach, namely the attacking body positions, arm control and head position. The complexity of the exercises increased progressively throughout the sessions. At the end of each training session, the participant played wrestling matches for 6 minutes freely.

Procedure

Body composition measurements

Body weight was measured using an electronic scale and rounded to the nearest 0.1 kg. The height was measured using a stadiometer (Seca 220 (CM), Seca gmbh, Hamburg, Germany) and rounded to the nearest 0.5 cm.

Physical fitness measurements

For physical performance measures a Wingate test (WAnt) was applied to identify anaerobic power and capacity of the students' wrestlers for leg. We implemented that 7.5% of body weight for leg and 5.5% of it for arm as load in wingate test. We applied 4-5-minute-warm-up protocol including two or three sprints with the pedal speed of 60- 70 revolutions per minute longing 4-8 seconds. Each athlete performed at least three and no more than three trials, with intervals of 3 to 5 minutes between him. The interval between exercises was at least 30 minutes (Table 2).

Statistical Analysis

All the findings were examined by applying the basic descriptive statistics in which the following elements were calculated; t-test, mean, standard deviation, standard error. To compare the effect of two methods of training with traditional approach and game-based learning on the performance of selected wrestling bout skills, first, the effect of each two methods in three skills was calculated by t-test and then for comparison of these methods effects in each three skills single-variable covariance analysis (ANCOVA) was used. Shapiro-Wilk test was used to examine the distribution of research data. The confidence interval were analyzed with 0.95 ($P = 0.05$). All statistical analysis was carried out by the software package SPSS 16.0, whereas the value $p<0.05$ was used for the level of statistical significance.

Results

At the beginning of the experiment, anthropometric characteristics was assessed by morphological measurements that assessed Age, (year), Weight (kg), Height (cm) and Body Fat (%).These tests aim to determine the initial physical fitness level of participants at the start of the experiment and, therefore, the formation of homogeneous groups with an approximately similar level of fitness to ensure the validity of the experiment.

Morphological Characteristics of Participants

The anthropometric characteristics showed in Table 1 from participants in both analytical groups (Control Group ‘’CG’’ and Experimental Group ‘’EG’’) show no difference ($p > 0.05$).

For the Wingate test (Table 2), the power and anaerobic capacity of leg student's wrestlers were identified. We did not identify a statistically significant difference in the values of the average leg capacity (W/kg) of the student's wrestlers selected from National Control Group "CG" and those who selected Group "EG" with (p>0.05).

Effect of two Teaching Methods on Legs Attack Performance in Wrestling Bout

In order to investigate the effect of traditional (technical) training and training based on wrestling games on the three combat skills, the values of the two groups in the present study were compared in the pre-test and post-test, the results of which are presented in table 3. The results showed that the data of all three wrestling bout skills in the two stages of the test were normal distribution (P> 0.05), therefore, for statistical analysis, parametric statistical method was used. According to the test results (Table 3), both pedagogical methods enabled participants to make significant progress in the area of attack skills in a freestyle wrestling bout, such that the performance from pre-test to post-test were significantly improved (P = 0.001).

In the case of successful legs attack skills, the difference between the two stages of the test (pre-test and post-test) was statistically significant (P <0.05). However, with regard to the mean of the two groups at the two stages of the test, it was observed that the two groups influenced by the wrestling games approach performed better at the test stage than at the pre-test stage. Nevertheless, the results on the unsuccessful legs attack variable are different, so that there is significant improvement in the technical education group among the subjects, and the wrestling games teaching method has significant effect on the improvement of the unsuccessful legs attack performance (P = 0.055), but in the game-based education group, the results indicate that the progress of the subjects from the pre-test stage to the performance test is statistically significant (P = 0.001). In other words, game-based education has a significant effect on the subjects' passing technique in the present study.

Comparison of the Effects of two Teaching Methods on Leg Attack Skills in Wrestling Bout

First, the equality of variances was confirmed by the Levin test for the three skills (P> 0.05).

To compare the effects of two pedagogical methods on leg attack skills in a wrestling bout, we used a covariance analysis with one variable (table 4).

For the competence of number of legs attacks ,the results of the pre-test show that F-value of the concordance variable is significant (P = 0.001, P = 1.072), therefore, the correlation is verified and the choice of post-test is a perfect concordance. However, the value of the F variable at group level relative to methods of teaching is statistically insignificant (P= 0,223 F = 0.87). There is no significant difference between the averages of the two research groups in the post-test. Therefore, we find that there is no significant difference between the two proposed

Table 1. Anthropometric characteristics (n=20)

Characteristics	CG (mean ±)	EG (mean ±)
Age, (year)	18.5±4.0	18.6±3.0
Weight (kg)	66.3 ±7.0	64.4 ±4.0
Height (cm)	166.5±2.0	167.5±5.0
Body Fat (%)	9.2±6.0	8.75±5.0

Table 2. Characteristics of anaerobic power and capacity of students' wrestlers participated for the experimental group ''EG'' and control group ''CG'' (n = 20)

Characteristics	CG (mean ±)	EG (mean ±)
Leg peak power (W)	1009±357	0944±382
Leg peak power (W/kg)	13,3±2,3	12±2,7

Table 3. The effect of two teaching methods on legs attack performance in a wrestling bout (n = 20)

Group	Skills bout	M (SD)		Sig	t
		Pre-test	Post-test		
Experimental Group (wrestling games approach)	a) Nb of attempted legs attack	4.26	6.87	0.001	-3.36
	b) Nb of successful legs attack	4.05	4.0	0.004	2.5
	c) Nb of unsuccessful legs attack.	2.33	3.02	0.055	-3.1
Control Group (Technique Approach)	a) Nb of attempted legs attack	6.33	5.88	0.001	-2.02
	b) Nb of successful legs attack	3.0	3.50	0.001	1.5
	c) Nb of unsuccessful legs attack.	4.55	4.11	0.001	2.02

Table 4. Analysis of the covariance between the results of two pedagogical methods concerning legs attacks capacity.

Characteristics	df			M (SD)			F			sig		
	a	*b*	*c*	*a*	*b*	*c*	a	b	c	a	b	c
Post-test		1		12.04	12.04	8.28	4.455	8.23	2.74	0.005	0.001	0.001
Group		1		1.31	0.31	2.69	1.072	0.38	1.58	0.001	0.123	0.001
Errors		12		2.55	0.48	1.95						
Total		14					5.52			0.006		

Note: a) Nb of attempted legs attack; b) Nb of successful legs attack; c) Nb of unsuccessful legs attack.

teaching methods; technical and game-based on the performance of legs attacks.

The results of the covariance test for the skills of successful leg attacks indicate that the pre-test F-value is significant (P=0.001, F=80.23). However, for the group variable, F in relation to the technical method is not statistically significant (P = 0.38, F = 0.123). In addition, it has been found that there is no significant difference between the two proposed pedagogical approaches on the performance of successful leg attacks during a wrestling bout. Regarding the performance of unsuccessful leg attacks in a wrestling bout, the pre-test results show that the F-value of the co-variance is significant (P=0.001, F=2.74). The F-value of the group variable in relation to the technical method is statistically significant (P=0.001, F=1.58). We distinguish a significant difference between the two teaching methods (technical and game-based) on the success of the tests in the present study. Thus, we find that the game-based teaching method has a more significant effect on reducing the total number of unsuccessful leg attacks than the technical method. The findings of this study showed that the game-based training method, compared to the technical method, had a higher effect on the performance of the research subjects' successful leg attacks and total attacks. Nevertheless, there was no significant difference between the two training methods on unsuccessful attacks during a wrestling bout.

Discussion

The aim of the present study was to find out the effect of two teaching approaches and to propose the game-based method as a new pedagogical approach for learning technical moves in freestyle wrestling. The results were evaluated in the form of a pre-test and a post-test. The main results of this study indicate that the anthropometric characteristics of both groups of students are identical, but it is interesting to note that both groups have a low skinfold thickness and a high percentage of body fat. This proves that these wrestlers were very thin. This is consistent with previous studies in which no differences in anthropometric and physical characteristics were found between the two research groups [30]. Indeed, the body fat content of both groups in this study is similar to the research of Ito et al. [31] who have the same age and skill level.

The results show that the technical and game-based trainers significantly improved the number of leg attacks, while the game-based trainers significantly improved the success of leg attacks. In contrast, those who participated in traditional training did not improve. These results are consistent with the findings of Gerodimos et al. [32] and inconsistent with the findings of Whitley at al. [33]. A possible reason for these conflicting results may be the type of game selected. The experimental group performed better than the technical group in the post-test of successful leg attacks. These results are in contradiction with the results of another research [34]. These results are consistent with the content of the training programme for the technical group in this study.

In the area of leg attack performance and the programme to improve it at the end of the learning cycle. For the experimental group it is likely to improve attacking performance. This may have led to a significant improvement in the 'low approach' group on the game from pre-test to post-test. A previous study reported that some college wrestling participants with shorter movement times using the leg attack had a higher percentage of wins and losses during bouts [35], which is not consistent with the lack of group differences in movement time in the present study. This could be due to the different skill levels of the participants in the two studies. In the present study, the movement quality of a leg attack was correlated with the forward movement of the upper body in all participants. Although a reduced distance between opponents may be beneficial in terms of reaching the opponent's legs faster. Despite the superiority of the game-based approach group in the leg attack performance tests, these groups had no impact on the combat environment and the success of these attacks. Villamon et al. [36] concluded in their review research that there is a relationship between the total number of attacks and successful attacks through the game-based approach.

Conclusions

The researcher's work is not driven by a desire to prescribe to coaches or teachers a good way of thinking, as they do not need to. However, to inform them of what is happening during a physical activity session that might be useful in conveying content, promoting learning and subsequently improving performance [37]. The latter is a concern of all teachers in the field of physical education, coaches and physical trainers in the field of sport. All these considerations lead them to seek new teaching and training approaches to achieve a successful learning situation with the student and with the athlete in his or her desired form on the day of the competition. In recent years, wrestling has gained popularity and offers physical educators the opportunity to teach character development because of the unique moral development experiences inherent in the sport. Wrestling bout for kids as a new approach to learning wrestling provides essential information to improve the situation of teaching wrestling in physical education classes. First through the teaching of Olympic wrestling by physical education teachers, and then as wrestling taught by specialists who can be those same physical education teachers, provided they continue to take courses that include wrestling. In order to help teachers who do not have a specialized knowledge of combat sports such as wrestling, we also wanted to propose an organization of the content. Although our objective in this study is directed towards the teaching of combat sports in schools, it is also possible to use this proposal in other contexts, such as in wrestling promotion centers and in any other place with the objective of teaching Olympic wrestling. To do this, games would be used to get wrestlers to think in different ways to regain balance. Teachers can connect actions from other technical movements from the same family of leg attacks. In conclusion, the game-based training method seems to have beneficial effects similar to those of the classical training method in improving attack techniques in freestyle wrestling. Wrestling coaches could use this information in the teaching-learning process and planning of wrestling programmes. In this way, the training will be more specific and the transfer of the effects of this training to the efficiency of the game will be faster. Finally, and most importantly, school level wrestlers are still children and should have fun wrestling.

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Conflict of interests

The authors state that there is no conflict of interest.

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ORIGINAL ARTICLE

Relationship of anthropometric measurement and handgrip strength in Malaysian recreational tenpin bowlers

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

Abstract

Background and Study Aim Established studies show that athletes with longer fingers and broader hand surfaces have more muscular grips. Therefore, some research studies have examined various contributing factors and anthropometric characteristics. Thus, the aim of this study was to investigate the effect of hand dimensions and selected anthropometric characteristics on handgrip strength in recreational tenpin bowlers.

Material and Methods This cross-sectional study recruited 32 (12 females, 20 males) healthy Malaysian recreational tenpin bowlers from Kuala Lumpur. Their anthropometric characteristics including height, weight, body mass index (BMI), the dimensions of the right hand, and age were measured accordingly. Handgrip strength was assessed using a Takei 5401 Grip D (Digital Grip Dynamometer) with 3 trials for both hands. A Pearson correlation coefficient and multiple regression analysis were used to study the relationship between the parameters.

Results The body height and the minimum breadth of the right hand had a significant impact on handgrip strength among recreational tenpin bowlers. There was a significant difference between males and females in left and right handgrip strength ($p<0.05$). Males showed a greater handgrip strength compared to females in both hands' strength. Body height ($p = 0.00$) and the minimum breadth of the hand ($p = 0.03$) were found to be significantly correlated with the handgrip strength thus indicating the two variables as strong predictors of handgrip strength.

Conclusions This study confirms that there is a relationship between anthropometric characteristics and handgrip strength in Malaysian recreational tenpin bowlers. Hence, it will be a great note for new bowlers to advance their bowling performance.

Keywords: handgrip strength, tenpin bowling, anthropometry, hand dimensions, dynamometer

Introduction

Tenpin bowling is a widely known sport and is played at a professional level and as a recreational activity by the general public. In 2018 it was s reported that 4.45% of Malaysian played tenpin bowling [1]. The aim of this sport is needed a bowler to roll down the bowling ball onto the lane and knock down the pins at the edge of the bowling lane as many as the bowler can during an event. Accumulated pinfalls would determine the winner.

3 major essential roles that contribute to the performance are a bowler, a bowling ball, and a bowling lane. A fingertip grip is one of a skill that a bowler could bowl with a hook style [2]. The middle, ring, and thumb finger are inserted into designated holes with specific lengths and depths. Meanwhile, the remaining fingers and another dimension of playing hands will support carrying a bowling ball during the approach and delivery phases. This requires a configuration of the bowler's hand dimensions and grip measurement that will be mapped and hence, drilled on a bowling ball [3]. The palm and forearm include the muscles that move the finger joints [4]. The forearm muscles are crucial for the upper limb's fine motor activities, enabling intricate motions of the arm, wrist, and fingers [5]. The wrist joint, also known as the radiocarpal joint, is a distal upper limb condyloid synovial joint that links and acts as a transition between the forearm and hand. A condyloid joint is a type of modified ball and socket joint that enables flexion, extension, abduction, and adduction motions [6]. Therefore, stronger forearms lead to a stronger grip [7].

Handgrip strength (HGS) can be a popular indicator of muscle strength in tenpin bowlers as it became a tool to investigate and determine the muscular force in humans. Many methods have been found to measure handgrip strength, such as using an analogy or digital dynamometer [8]. A study has found that elite bowlers were heavier, had longer lower leg and hand lengths, and had wider arm spans as compared to non-bowlers [9]. The study also explained that elite bowlers had stronger forearm or wrist rotation and arm flexion [10]. The importance of anthropometrics measurement was suggested that coaches would benefit by selecting larger-built bowlers with long limbs for their tenpin bowling

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teams [9]. Although the differences in body types between men and women, sedentary and athletes caused the variations in their muscular strength [11], the relationship between hand dimensions, anthropometry characteristics, and HGS are still vague among recreation bowlers.

Thus, this present study was conducted to determine whether age, weight, height, body mass index (BMI) and hand dimensions were predictive of handgrip strength, specifically in recreational tenpin bowlers.

Materials and Methods

Participants

Thirty-two (12 female, 20 male) healthy recreational tenpin bowlers from the Endah Parade Bowling Centre, Kuala Lumpur (Malaysia) participated in this cross-sectional descriptive study. All 32 subjects had a mean ± SD age of 33.81 ± 7.82 years. They were all right-hand dominant.

Research Design

A descriptive cross-sectional study was used in this study. Data collection was conducted at the Endah Parade Bowling Centre as well. The inclusion criteria were as follows: (i) Free from any illness and injuries at the time of the study, (ii) have a minimum 5 years of experience in tenpin bowling, (iii) have a hook playing pattern. Meanwhile, the exclusion criteria were as follows: (i) have a straight playing pattern, (ii) aged below 18 years old. This study received ethical approval from the University of Malaya Research Ethics Committee (reference number UM.TNC2/UMREC – 962). All subjects gave their written informed consent after being provided with the description of the study.

Anthropometric. Age was recorded for each subject. The body weight and body height were measured using a standard digital weighing scale and a standard height scale and the BMI was calculated. The hand dimensions were measured using a flexible tailor tape between the midpoints of the distal transverse of the wrist to the anterior projection of the middle finger. The handbreadth was then measured from the lateral points of the head of the index finger to the medial point of the little finger. Meanwhile, the maximum handbreadth was measured from the lateral point of the thumb to the medial point of the little finger. The palm length was measured from the middle of the inter stylion to the proximal of the middle finger. The thumb length as well being measured from the distance from the tip of the thumb to the crease with the palm. For the index finger length, the measurement was collected from the tip of the index finger to the border crease with the palm. The middle finger length was measured from the distance of the tip of the middle finger to the border crease with the palm. Meanwhile, the ring finger length was measured from the tip of the ring finger to the border crease with the palm unliked the little finger length measured from the tip of the little finger to the border crease with the palm.

The hand measurements were collected on the right hand of the participants. In this study, all the participants are right-hand dominant. The right hand was measured with the hand on a flat horizontal surface with the thumb in an abducted position and the other fingers in an extended position (see Fig. 1.) Anthropometric measurements were repeated three times.

Handgrip Measurement. Subjects were given

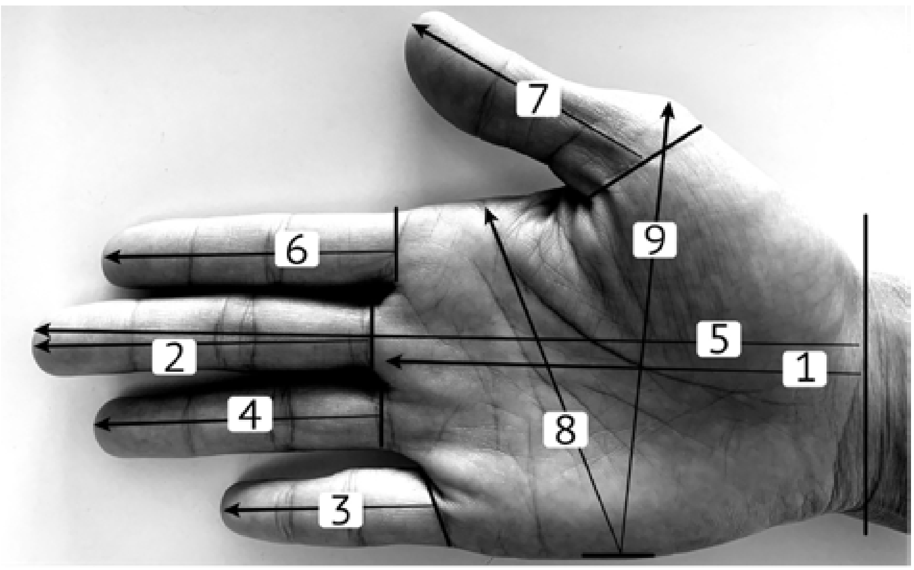

Figure 1. Hand dimensions (Hand anthropometric (1-palm length, 2-middle finger length, 3- little finger length, 4- ring finger length, 5-hand length, 6- index finger length, 7- thumb finger length, 8- minimum handbreadth, 9- maximum handbreadth)

a demonstration and underwent five minutes of familiarization with the Takei 5401 Grip D (Digital Grip Dynamometer) made in Japan. Prior to data collection, subjects were instructed to stand comfortably with their left hand resting whilst their right hand was holding the dynamometer over their head. Subjects were advised to maximally squeeze alongside shoulder adduction with elbow extension at 90° for three seconds. The step was repeated with the left hand and thus considered as one set of measurements. Measurements were taken for three sets with one minute of rest in between sets (see Fig. 2.).

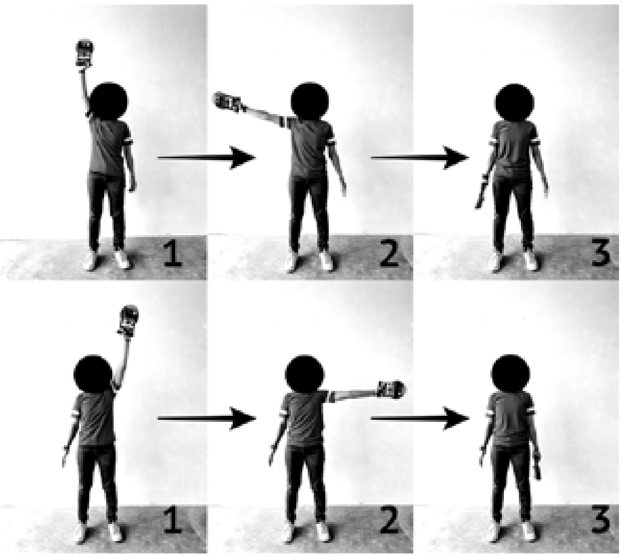

Figure 2. Steps for measuring handgrip strength

Statistical Analysis

All data were analyzed using one-way analysis of variance (ANOVA). The data were expressed as mean ± standard deviation. Differences between the groups were evaluated by LSD post hoc test and considered significant at $p<0.05$. Correlation and multiple regression analysis were conducted to see a relationship between hand dimensions, anthropometrical, and handgrip strength.

Results

The anthropometric measurements are presented in Table 1. Table 2 showed that there was a significant difference between males and females in left and right handgrip strength ($p<0.05$). Males showed a greater handgrip strength compared to females in both hands' strength. A Pearson correlation coefficient matrix was carried out to determine the relationship between the body weight, body height, BMI, age, right-hand dimensions (palm span, hand length, thumb finger, index finger, middle finger, ring finger, minimum and maximum breadth) and the right handgrip strength (RHGS) are presented in Table 3. There was a strong, positive correlation between body height and RHGS ($r = 0.71$, $n = 32$, $p = 0.00$), palm span and RHGS ($r = 0.52$, $n = 32$, $p = 0.00$), hand length and RHGS ($r = 0.565$, $n = 32$, $p = 0.00$), middle finger and RHGS ($r = 0.43$, $n = 32$, $p = 0.01$), ring finger and RHGS ($r = 0.45$, $n = 32$, $p = 0.01$), minimum breadth and RHGS ($r = 0.59$, $n = 32$, $p = .00$) and maximum breadth and RHGS ($r = .44$, $n = 32$, $p = 0.01$). The multiple stepwise regression model with thirteen predictors was conducted and it showed that the body height ($p = 0.00$) and the minimum breadth of the hand ($p = 0.03$) were found to be significantly correlated with the handgrip strength thus indicating the two variables as strong predictors of handgrip strength (Table 4). The model with two predictors produced $R = .758$, $F (2, 29) = 19.59$, $p < 0.05$, and accounted for 58% of the variation in handgrip strength.

Table 1. Anthropometric characteristics for healthy recreational tenpin bowlers to determine the relationship between anthropometric measurements and dimension of the right hand (n = 32)

Variables[a]	**Mean ± SD**
Age	33.81 ± 7.82
Height	1.66 ± 0.08
Weight	67.81 ± 14.25
BMI	24.49 ± 4.94
Palm Span	18.58 ± 1.42
Half Span	10.76 ± 0.83
Thumb	6.62 ± 0.52
Index	7.33 ± 0.48
Middle	7.88 ± 1.00
Ring	7.30 ± 0.57
Little	6.00 ± 0.48
Min Breadth	8.38 ± 0.79
Max Breadth	10.46 ± 1.14
Handgrip Strength (kg)	29.60 ± 7.65

[a] Data are presented as mean ± SD.

Discussion

This study aimed to determine whether age, BMI, body weight, body height, and hand dimensions were predictive of handgrip strength in recreational tenpin bowlers. Tenpin bowling sport consists of five steps of approaches in delivering a bowling ball onto the lane to knock down the ten pins while engaging the upper and lower limbs of a tenpin bowler including shoulder flexion, trunk rotation, hip, and knee flexions [9, 12, 13].

The results of this study showed that strong handgrip strength is determined by the stature of

Table 2. Handgrip strength performance in recreational tenpin bowlers

Parameters	Females	Males	P value
	Mean ± SD (kg)	Mean ± SD (kg)	
Left handgrip strength	21.51 ± 3.52	33.19 ± 5.35	0.00*
Right handgrip strength	23.05 ± 3.44	34.79 ± 5.69	0.00*

* Significant at the 0.05 level (2-tailed).

Table 3. Pearson correlation coefficient matrix for anthropometric characteristics and handgrip strength in recreational tenpin bowlers

	BW	BH	BMI	PS	HL	TH	IN	MI	RI	LI	MB	MX	AG	HS
BW		0.03*	0.00*	0.07	0.12	0.24	0.7	0.00*	0.35	0.31	0.84	0.04	0.68	0.13
BH	0.03*		0.71	0.00*	0.00*	0.04	0.01*	0.01*	0.01*	0.28	0.00*	0.01*	0.43	0.00*
BMI	0.00*	0.71		0.62	0.85	0.83	0.37	0.09	0.75	0.07	0.25	0.39	0.38	0.82
PS	0.07	0.00*	0.62		0.00*	0.00*	0.00*	0.00*	0.00*	0.04*	0.00*	0.00*	0.32	0.00*
HL	0.12	0.00*	0.85	0.00*		0.00*	0.00*	0.00*	0.00*	0.02*	0.00*	0.00*	0.44	0.00*
TH	0.24	0.04*	0.83	0.00*	0.00*		0.00*	0.02*	0.00*	0.01*	0.01*	0.01*	0.02*	0.1
IN	0.7	0.01*	0.37	0.00*	0.00*	0.00*		0.1	0.00*	0.00*	0.00*	0.02*	0.28	0.14
MI	0.00*	0.01*	0.09	0.00*	0.00*	0.02*	0.1		0.00*	0.29	0.13	0.13	0.65	0.01*
RI	0.35	0.01	0.75	0.00*	0.00*	0.00*	0.00*	0.00*		0.03	0.00*	0.00*	0.65	0.01*
LI	0.31	0.28	0.07	0.04*	0.02*	0.01*	0.00*	0.29	0.03*		0.00*	0.07	0.09	0.48
MB	0.84	0.00*	0.25	0.00*	0.00*	0.01*	0.00*	0.13	0.00*	0.00*		0.00*	0.36	0.00*
MX	0.04*	0.01*	0.39	0.00*	0.00*	0.01*	0.02*	0.13	0.00*	0.07	0.00*		0.76	0.01*
AG	0.68	0.43	0.38	0.32	0.44	0.02*	0.28	0.65	0.65	0.09	0.36	0.76		0.79
HS	0.13	0.00*	0.82	0.00*	0.00*	0.1	0.14	0.01*	0.01*	0.48	0.00*	0.01*	0.79	

* Correlation is significant at the 0.05 level (2-tailed). BW - body weight; BH - body height; BMI - body mass index PS - palm span; HL - hand length; TH - thumb; IN - index; MI - middle; RI - ring; LI - little; MB - minimum breadth; MX - maximum breadth; AG - age; HS - handgrip strength

height and hand dimension (minimum breadth) in recreational tenpin bowlers. To the best of our knowledge, this study is the only one to report the predictive relationships between standing handgrip strength and the anthropometric measures in recreational tenpin bowlers. This study also provides evidence that hand dimensions can influence handgrip strength, which might have an impact on force-velocity relationships.

Along the movement and approaches, a bowler would carry a heavy bowling ball to knock down the pins as much as possible by generating a lot of momentum using these heavy bowling balls and releasing them accurately [14]. When the joint torques of the torso and the arm moved together, it indicated that the bowling ball was in a push-like motion [15]. The study also agreed that bowlers used the steps to increase the linear velocity, simple pendulum, and torques in the torso and the arm to enhance the power at the release of the bowl.

As the amount of maximum force transmits from every approach; lower and upper limbs, it explains that a bowler needs great strength to play this sport [16]. Thus, muscle strength is defined by a larger muscle girth with a larger cross-sectional area, hence generating a greater force [17]. The forceful flexion of the thumbs, finger joints and wrist with the maximum voluntary force leads to handgrip strength [18].

Therefore, handgrip strength is a predictor of physical fitness, hand functions, and nutritional status to measure strength in recreational tenpin bowlers. According to that, there are many factors that may contribute including gender, age, body mass index, and even hand dimensions [19]. Interestingly, anthropometry can be a major contributor to successful performance in sports. A significant relationship was found between height, leg length, shoulder width, and hip width in long jumpers in long jump performance sports [20].

A bowler supports the bowling ball with hands during the addressing phase, holding, gripping and swinging from the second phase until the final approach. Each swing is executed at a speed that generates a high ball momentum [10]. The study also stated that arm flexors contribute to the

Table 4. Multiple regression analysis for anthropometric characteristics and handgrip strength in recreational tenpin bowlers (n=32).

Coefficients[a]	Standardized Coefficients Beta	t	Sig.	R	R Square	Adjusted R Square	df	F
(Constant)				0.76	0.58	0.55	regression=2, residual=29	19.59
AG	0.19	-1.55	0.13					
BW	0.06	0.41	0.69					
BH	0.55	3.92	0.00*					
BMI	0.07	0.52	0.61					
PS	0.05	0.28	0.78					
HL	0.15	0.89	0.38					
TH	-0.07	-0.52	0.61					
IN	-0.21	-1.43	0.16					
MI	0.11	0.8	0.43					
RI	-0.06	-0.35	0.73					
LI	-0.19	-1.37	0.18					
MB	0.32	2.26	0.03*					
MXB	-0.05	-0.28	0.78					

[a] Dependent Variable: RHGS. BW - body weight; BH - body height; BMI - body mass index PS - palm span; HL - hand length; TH - thumb; IN - index; MI - middle; RI - ring; LI - little; MB - minimum breadth; MX - maximum breadth; AG - age; HS - handgrip strength. * Significant at the 0.05 level (2-tailed).

forward motion of the forearm in the final phase of the swing. As follows, strength is required to assist the deliveries.

Release parameters is determining the measured distance of the throw [21]. Wrist torque and kinematics were also found to be most associated with speed [22, 23]. This explains why wrist torque is important as the wrist rotates to deliver a bowling ball in the final phase of the approach [24]. Hence, release velocity is a crucial factor in determining the distance of a throw whereas the bowling ball will be thrown and glide onto the bowling lane [25]. The differences in delivery and release on wrist rotation over the different weights of bowling balls onto bowling lanes can be investigated in future studies as the trajectory was generated from the wrist motion [26].

In this study, the handgrip strength was higher in males compared with female recreational tenpin bowlers. Male has greater strength as male has a greater mass that may generate larger forces. This is in agreement with several past studies that stated the gender factor can be the most significant predictor of handgrip strength [19, 27, 28].

A Pearson correlation coefficient matrix for body height, palm span, hand length, middle finger, ring finger, minimum breadth, maximum breadth, and handgrip strength showed strong correlations with each other. Meanwhile the body height and the minimum breadth of the hand) were found to be significantly correlated in the multiple regression model analysis. In accordance with the present results, previous studies have demonstrated that height [29, 30, 31], BMI [32, 33, 34] and the length and dimensions of the forearm, arm, and hands were significantly correlated with handgrip strength [35, 36, 37].

A greater height will lead to a long arm as the shoulder be the axis of the long arm and it will generate a greater force [19]. As the shoulder acted as an axis and rotated during the approaches, the length of the shoulder is crucial as it depends on the distribution of the mass relative to the axis of the rotation [38]. This element may explain the relatively good correlation between anthropometry and pattern of entries (pocket entry board position, pocket entry speed, and pocket entry angle) in pinfalls.

It was reported earlier that physical performance had a strong association with the body strength, shape, size, form, and structure of an individual [39]. As a larger hand size may have higher strength due to a larger muscle area, smaller hands may contribute to weaker handgrip strength due to the muscle area involved [32, 40]. A dominant hand may influence the handgrip's strength as much as hand circumference does [41]. A study also supported that elite and semi-elite tenpin bowlers' results showed significantly longer upper limbs than non-tenpin bowlers. It is proven that anthropometry may influence muscular strength in recreational tenpin bowlers as well [10].

Body height can be a general factor that affects all body dimensions. When a player has a greater segment, the player has the advantage of throwing the ball at a higher speed, which increases the rotation radius, thus causing a proportional increase of the torque and consequently an increase in the linear velocity [42]. Therefore, considering this information, recreational tenpin bowlers should be conscious of the importance of handgrip strength and body dimensions to avoid injuries and increase performance [43].

Handgrip strength is important to enhance the performance of several gross motor movement patterns in sports and athletic disciplines involving the hand. Thus, to improve one's strength the study suggested increasing upper and lower body strength is increasing muscle mass through resistance training interventions. This can be done by looking at some factors that can be implemented in sport-specific movement such as technical ability; (coordination, sequencing, timing, physical ability; strength, flexibility, neuromuscular function, body composition anthropometry), and tactical ability [43].

Conclusions

The aim of this study was to confirm the relationship between anthropometric characteristics and handgrip strength in recreational tenpin bowlers. The present results demonstrated that basic anthropometric characteristics (body height and hand dimension – minimum breadth) have a strong relationship with handgrip strength among recreational tenpin bowlers.

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Conflict of interest

The authors declare no conflict of interest, financial or otherwise.

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ORIGINAL ARTICLE

Analysis of gross motoric analysis of elementary school students: A comparative study of students in hill and coastal areas

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

Abstract

Background and Study Aim Motor skills are a very important ability for every student to have because they can affect their full development. However, the growth and development of elementary school-age children is likely to be influenced by environmental factors such as family, social environment, school environment. This study aims to determine differences in gross motor skills in elementary school students in lower grades in hilly and coastal areas.

Material and Methods This research includes quantitative research with a cross sectional study approach. In this study were given tests and measurements to measure gross motor skills in elementary school students using the Gross Motor Development-2 Test (TGMD-2): running tests, gallops, hops, horizontal jumps, leaps, slides, striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll. The subjects in this study were male students in the lower grades of SD Negeri 38 Nanga Tayap in the hilly area and SD Negeri 27 Sungai Kakap in the coastal area. The purposive sampling technique resulted in a sample of 45 samples consisting of 21 students from hilly areas and 24 students from coastal areas. Data analysis in this study was assisted by the SPSS Version 26 application.

Results Based on these results, it can be concluded that there are significant differences in gross motor skills between students in hilly areas and coastal areas. The results also show that the gross motor skills of students in hilly areas are classified as low. These results tend to be in the Poor category. Compared to the gross motor skills of students in coastal areas which show a Very Superior dominance.

Conclusions The results of the study proved that the gross motor skills of students in hilly and coastal areas had significant differences. These findings have provided additional references regarding gross motor skills of students. This can be used as material for evaluation by teachers and sports practitioners in designing suitable programs to stimulate gross motor skills in elementary school students.

Keywords: motor skills, elementary school, students in hill areas, students in coastal areas

Introduction

Motor skills are currently a very common topic that is being explored globally from different perspectives [1, 2, 3, 4]. Where poor motor skills have become an increasing problem in adolescents [5]. In addition, motor skills are fundamental to child development [6]. This statement is reinforced by Gustian that every student must have good motor skills in order to assist full development [7]. The need to improve basic motor skills in pre-schoolers will help optimize the learning process [8]. That way, in elementary school physical education is one of the important subjects to be taught [9], and is mandatory for students [10].

Growth and development in elementary school-age children is strongly influenced by the surrounding environment, such as family, social environment, school environment [11], and also stimulates physical fitness and motor development children [12]. Besides that in the school environment the teacher is an important agent in providing services to improve motor skills, in order to meet the development and growth and behavioral needs of each student in the future, knowing the student development phase is an important part so that all phases of motor skills can be carried out and that phase mastered according to the age level of the student [13]. Children's gross motor movements need to be well developed so that in the future they will have good hard good [14, 15].

Other research proves that by doing movement

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activities, children can explore their environment so that they can stimulate them development cognitive and student academic achievement [16]. Next, the development of fitness through learning movement activities in elementary schools is very effective in maximizing the gross motor development of school-age students [17]. Movement activities carried out by students make the body healthy and fit [18, 19], because it can improve fitness [20, 22, 23] and the cardiorespiratory system, as well as improving the performance of the metabolic and neuromuscular systems, also having a positive effect on children's achievement and cognitive outcomes.

Movement activities also provide positive changes in the physiological and anthropometric indices of the health of students who have normal weight and are obese. In addition, physical activity through sports is very easy to do for both adults and children [24]. Next, a study says that sports science has an important role in developing gross motor skills [25]. Thus, it is very important to integrate physical activity into a child's life and become a cornerstone in facilitating and maintaining a healthy and active lifestyle throughout adulthood. The problem that occurs is that most schools and parents lack understanding of the importance of stimulating motor skills and are more focused on improving students' cognitive abilities so that this impacts students' motor skills [26]. The inability of children to regulate their body balance, accuracy in throwing and catching things, and agility when moving are also problems in gross motor development [27]. The facts also show that the physical activity of students at school has a short duration of time [28]. Several studies say that gross motor skills are very important to learn as a whole for students [7, 29], so that they can encourage improvement in psychological and mental health [30].

Based on the results of a preliminary study through physical education teacher interviews students' gross motor skills problems are also still not monitored. Meanwhile, motor skills are basic [6], and important aspects related to the healthy development of children [9], children with down syndrome, and typically developing children [31]. Furthermore, Marlia et al. [32] compared children who took part in rhythmic and non-rhythmic gymnastics. However, no research has been found that compares the gross motor skills of elementary school children in hilly and coastal areas, which have different environments, climates and locations. So this is one of the gaps that can be developed as well as the reason why this study is important. This study aims to show the level of gross motor skills in elementary school students in hilly and coastal areas and do a comparison between the two. Of course, this research plays an important role in knowing gross motor skills, so that this can be a basic exercise.

Materials and Methods

Participants

The subjects in this study were male students in the lower grades of SD Negeri 38 Nanga Tayap and SD Negeri 27 Sungai Kakap. As for this study, the determination of the sample using a purposive sampling technique so that is obtained the sample consisted of 45 students (21 elementary school students in hilly areas and 24 elementary schools in coastal areas) who were sampled.

Research Design

This research includes quantitative research with a cross sectional study approach namely a type of observational design that analyzes data from a population at a predetermined time [33]. As for this research, it is to see the gross motoric development of students SD Negeri 38 Nanga Tayap and SD Negeri 27 Sungai Kakap. The instruments in this study used tests and measurements by O'Brien et al., [34], namely, Test Gross Motor development-2 (TGMD-2) running tests, gallops, hops, horizontal jumps, leaps, slides, striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll.

Statistical Analysis

Data analysis in this study uses descriptive analysis. This aims to determine gross motor skills in elementary school students in hilly and coastal areas as well as facilitating the presentation of research data. Furthermore, to find out the difference using the normality test, if the data is normal, the independent t test will be used, and if the data is not normal, it is non-parametric. In this study, data analysis was assisted by using the SPSS Version 26 application.

Results

Based on the results of the research, the description of the recording data for *Test Gross Motor development - 2* TGMD- 2 for gross motor skills of the sample in detail can be seen in the following table. The results can be seen in table 1.

The results in table 1 show that the average value of gross motor skills in male students from the lower grades of the hills is 11.8, while in the coastal areas it shows an average of 31.6. Based on these results, the average value of motor skills in students in coastal areas is greater than the average value of gross motor skills in students in hilly areas.

Before the differential test was carried out, a prerequisite normality test was first carried out using the *Shapiro-Wilk test formula.* The results show that the significance value for students in hilly areas is 0.248 > 0.05 and in coastal areas 0.204 > 0.05 based on these values, it can be concluded that the data is normally distributed. The results can be seen in Table 2.

The homogeneity test in Table 3 shows a significance value of 0.706 > 0.05. The results indicate that the data is homogeneous. Next, a different test will be carried out, in this study using the *Independent Samples Test formula*.

After the prerequisite test was carried out, it was continued with the t test, the results of the study showed a significance value of 0.000 <0.05. Based on these results, it can be concluded that there are significant differences in gross motor skills between male students in elementary schools in hilly areas and coastal areas. The results can be seen in table 4.

The data in table 5 describes the assessment of gross motor skills in male elementary school students in hilly and coastal areas. The results show that the skills of male students in hilly areas are low, where these results tend to be in the Poor category. Furthermore, the skills of male students in coastal areas show the results of Very Superior dominant percentages. The results are explained in figure 1.

Discussion

This study aims to determine the differences and gross motor skills in elementary school students in hilly and coastal areas, so that they can be used as an evaluation picture in learning physical education

Table 1. Descriptive Data on Students' Gross Motor Skills

Group	N	Means	std. Deviation	Minimum	Maximum
Hill Region Students	21	11.8	4.5	5.00	20.00
Coastal Students	24	31.6	4.7	20.50	42.50
Total	45	22.4	11.02044	5.00	42.50

Table 2. Shapiro-Wilk Normality Test

Results	Group	Shapiro-Wilk		
		Statistics	df	Sig.
Students' gross motor skills	Hill Region Students	0.943	21	0.248
	Coastal Students	0.944	24	0.204

Table 3. Test of Homogeneity of Variances

Results		Levene Statistics	df1	df2	Sig.
Students' gross motor skills	Based on Means	0.144	1	43	0.706

Table 4. Independent Samples Test

Results		F	Sig.	t	df	Sig. (2-tailed)
Students' gross motor skills	Equal variances assumed	0.144	0.706	-14,308	43	0.000
	Equal variances not assumed			-14,364	42,729	0.000

Table 5. Motoric Assessment of Lower Class Students in Hilly and Coastal Areas

Gross Motor Quoutient	Hills (Men)	Relative (%)	Coastal (Men)	Relative (%)	Descriptive Ratings
>130	0	0%	13	54.1%	Very Superior
121 - 130	0	0%	9	37.5%	Superior
111 - 120	0	0%	1	4.2%	Above Average
90 - 110	2	9.5%	1	4.2%	Average
80 - 89	6	28.6%	0	0%	Bellows Average
70 - 79	6	28.6%	0	0%	Poor
<70	7	33.2%	0	0%	Very Poor

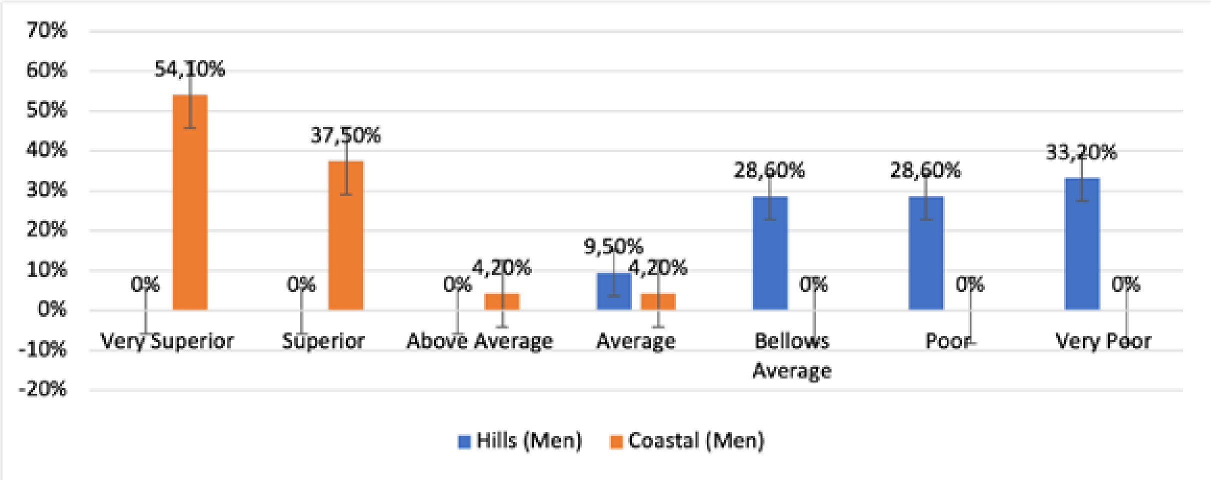

Figure 1. Description of Gross Motor Assessment

at school. The results of this study showed that there was a difference in the mean value of the gross motor skills of students in hilly areas of 11.8 and the gross motor skills of students of coastal areas or there was a difference of 31.6. In addition, the significance value indicates a significant difference, the results also show that the t count is greater than the t table. Based on these results, this study proves that there are differences in the gross motor skills of students from hilly areas and students from coastal areas, where the gross motor skills of hill students are better. The results of previous research conducted by Aydin & Gulac on students aged 8-10 years who took part in sports activities, where the results of the study showed that soccer students had better gross motor skills than sports by basketball and taekwondo [35].

A study that is relevant to the research that we have done, the results of the study show a real difference between those found in children with down syndrome, typically developing children, and children with borderline intellectual functioning [31], where children with down syndrome are likely most of the identified developmentally advanced age-appropriate or delayed [36]. Furthermore, it was found that motor skills in boys showed better than girls [35], and athletes in volleyball and gymnastics had lower gross motor skills when compared to other sports. Another study was conducted by Suryadi there was a significant difference in physical fitness between basketball and futsal extracurriculars, in which basketball has a better level of fitness [19].

Furthermore, to master the ability to move, of course, requires a relatively long time [37]. Based on this statement, research conducted by Gustian by providing treatment in the form of traditional games can actually stimulate gross motor skills in elementary school children [7]. Apart from that, improvements also cover locomotor movements, fundamental movements, and object control [38, 39, 40]. In line with research by Domville playing methods are consistently carried out with fun designs [41], this will increase students' enjoyment in doing motor learning [7]. Thus, learning activities by playing are considered capable of being a medium for forming behavior on condition that it goes according to the rules [42]. Recent findings prove that by combining integrative physical activity learning with various forms of games it turns out to have an effective effect on stimulating cognitive in elementary school students [43].

Based on these various reviews, it has been illustrated that a well-designed game model will have a positive influence on gross motor results in students. Next Pham by implementing the BRAINballs program can have a positive influence on motor outcomes in children and can help to understand the development of motor skills [44]. In addition, where at the elementary school level, students' motor skills are in the basic movement phase of the adult stage and the special movement phase of the transition and application stages [45]. Research Johari providing training in handling parents is beneficial for improving the motor function of children with cerebral palsy [46]. Based on the research results obtained, this can be an illustration for designing exercise programs by teachers and sports practitioners as a treatment that will give to help gross motor development and improve athlete performance [47].

Conclusions

The results of this study have a strong foundation regarding differences in gross motor skills in male elementary school students in hilly areas and coastal areas, based on the references listed in the discussion results. Research shows that there is a mean difference in gross motor skills of students in hilly areas and coastal areas. The results of the study proved that the gross motor skills of elementary school students in hilly and coastal areas had significant differences. These results have provided a new reference regarding the gross motor skills of elementary school students, so that this can be used as material for evaluation by teachers and sports practitioners in preparing lesson plans and exercises to provide improvements to gross motor skills. Recommendations for further research can conduct research on developing appropriate and fun training programs to stimulate gross motor skills in elementary school students.

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Conflict of interest

There is no conflict of interest.

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ORIGINAL ARTICLE

Comparison of physiological characteristics and physical performance measures among athletes from random intermittent dynamic type sports

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

Abstract

Background and Study Aim The physiological characteristics [Maximum oxygen uptake (VO2max), Peak Inspiratory Flow (PIF), Peak Expiratory Flow (PEF), Force Vital Capacity (FVC)] and physical performance measures [power, dynamic balance, flexibility, agility, and speed] are the key determinants in random intermittent dynamic type sports which enable the players to address decisive situations. Therefore, the purpose of this study was to determine the physiological and physical measures among athletes from random intermittent dynamic type sports.

Material and Methods A comparative cross-sectional study with 56 male athletes, 14 in each sport (Rugby, Soccer, Volleyball, Futsal) was conducted. The mean age was 23.59±4.27 years, body mass 71.96±10.10 kg, body height 174.71±6.82 cm, and BMI 23.51±2.38 kg/m^2. Physiological characteristics and physical performance measures were measured by using dry spirometer and functional tests respectively. A one-way analysis of variance test was performed to determine differences between athletes for physiological characteristics and physical performance measures.

Results There were significant differences for physiological characteristics (VO2max, PIF, PEF, and FVC) and physical performance measures (power, dynamic balance, flexibility, agility and speed) in athletes from random intermittent dynamic type sports.

Conclusions These findings showed significant differences for physiological characteristics and physical performance measures among athletes from random intermittent dynamic type sports. These measures are responsible for improving physiological and physical performance to achieve top athletic achievements. While constructing the training program, morphological and functional factors should be considered based on the game's nature.

Keywords: VO2max, power, dynamic balance, flexibility, agility.

Introduction

Sports like rugby, soccer, volleyball, and futsal belong to the random intermittent dynamic type sports. In these sports, skillful movement activity patterns are selected randomly at various intensities during the game [1]. Many movements and skills are involved in playing these games, and a high level of physical demands is required [2]. Physical performance abilities (strength, speed, agility, flexibility, dynamic balance) and other physiological abilities are essential components in such sports [3].

Physiological characteristics changed as an effect of regular participation in sporting activities. People who engage in at least 30 minutes of moderate-intensity exercise most days have a 20%-30% lower risk of all causes of mortality than those who do not [4]. Random intermittent dynamic sports performance depends mostly upon the aerobic component that maintains a high intensity throughout the game, delays fatigue and achieves a faster/better recovery between the matches [5]. The aerobic capacity is usually expressed in maximal oxygen uptake (VO2max). Aerobic capacity is the most reliable and valid physiological measures in exercise physiology and is also commonly used as an indicator of cardiovascular fitness during athletic performance [6]. In theory, the higher the maximum oxygen uptake better the performance — physical performance component directly related to the changes in physiological characteristics in athletes.

Physical performance is described as the capacity to engage in physical activities, ranging from activities of daily living to more complicated activities that require a combination of sports-specific skills [7]. Many physical performance tests usually measure physical performance objectively [8]. The physical performance components that affect overall performance in random intermittent dynamic-type sports include strength, endurance, power, speed, agility, and flexibility [9]. Sports participation results have been significantly

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positively correlated with physical performance components [10].

Regular monitoring and measuring athlete performances is a challenging phase in any sports training and selection process of athletes because the training load, the training schedule, and the physical "load" during training are all highly dependent on the athletes' level of fitness [11]. Regular monitoring and measuring physiological characteristics and physical performance during training and athletes' selection may provide valuable information to physical educationists, sports scientists, and coaches. This study aims to compare the physiological and physical measures among athletes from random intermittent dynamic type sports. The hypothesize stated as that there would be significant differences across athletes from random intermittent dynamic type sports for physiological and physical performance measures.

Materials and Methods

Participants

A total of 56 male participants from Ba and Lautoka region, 14 in each sport (Rugby, Soccer, Volleyball, Futsal), participated voluntarily in this study. There average age was 23.59±4.27years, body mass 71.96±10.10kg, height 176.71±6.82cm, and body mass index (BMI) 23.51±2.38 kg/m² (tabl. 1). The inclusion criterium had at least three-year playing experience at the university level. Exclusion criteria included participants with cardiorespiratory disorder and lower extremity musculoskeletal injury recorded in the last three months.

Research Design

This was a comparative cross-sectional study. All the tests were conducted during morning session in the physical education department's laboratory and indoor sports arena at Fiji National University, Fiji. This study was approved by the Fiji national university human research ethics committee with the approval (FNU-HREC-22-14) on 14th March 2022. All participants sign a written consent form before participating in this study.

Outcome Measures:

Anthropometric characteristics

Body height and body mass were measured by using stadio-cum-weighing scale with the participant standing in an erect position with bare feet.

Physiological Performance analysis

VO2max: The Multistage Fitness Test (MSFT) was used to measure the maximal oxygen uptake (VO2max). The MSFT was created in the early 1980s to assess the maximum oxygen consumption in children, adolescents, and adults. The test was developed to offer a useful and cost-effective prediction of maximum oxygen consumption in a field environment. According to research, the MSFT test is a reliable predictor of maximum oxygen uptake [12]. Participants in the MSFT test were instructed to run in a shuttle pattern toward and away from 20-meter areas in response to an audio cue (beep). The speed in the first minute was 8.5 km/hr and increased by 0.5 km/hr every minute — the participants were required to complete a level before the next beep was produced. Participants should complete as many shuttles as they can. If a participant fails to maintain the recommended pace for two consecutive shuttles or withdraws from the test owing to exhaustion, the test is terminated. Flouris et al. [13] formula was used to determine the maximum oxygen uptake.

Peak Inspiratory Flow (PIF), Peak Expiratory Flow (PEF), and Force Vital Capacity (FVC) were measured with the help of a portable electronic spirometer used to measure physiological measures s. Tests were conducted in laboratory settings. Participants demonstrated the experimental process and allayed their concerns. The participant conducted forced inhalation and exhalation maneuvers as advised by the American Thoracic Society while sitting on a chair with their nose plugged. Each participant used the spirometer's mouthpiece tube to make a maximal inhalation followed by a vigorous expiration until all air had been ejected. Each participant took a minimum of three tests, with the best three being used for further research. Verbal encouragement and motivation were used to get the best possible inhalation and expiration attempts from the participants. The maneuver was finished with a maximal inhale by the individual. The required data

Table 1. Anthropometric characteristics among Athletes from Random Intermittent Dynamic Type Sports.

Sports	N	Age (Year) Mean±SD	Body Mass (kg) Mean±SD	Body Height (cm) Mean±SD	BMI kg/m² Mean±SD
Rugby	14	24.21±3.99	79.31±9.96	179.07±4.40	24.69±2.63
Soccer	14	23.21±4.00	72.51±12.01	174.71±8.06	23.69±2.95
Volleyball	14	23.00±3.91	69.00±7.62	173.29±6.84	22.93±1.65
Futsal	14	23.93±4.96	67.01±4.33	171.79±5.06	22.72±1.41
Total	**56**	**23.59±4.27**	**71.96±10.10**	**174.71±6.82**	**23.51±2.38**

were extracted from the device that was displayed on the screen.

Physical Performance analysis

Explosive Power: The explosive power of lower limbs was measured by the double-leg vertical squat jump test. The participants were asked to stand firmly on the ground next to the Vertec, extend their arms as high as possible, and touch the highest vane. The stance height was recorded as being at this height. Participants jumped and touched the highest possible vane. The maximum vertical jump was determined using the difference between the standing reach and maximum jump height, and the result was converted to lower leg muscle explosive power. Each participant made three attempts, and the average of three jumps was calculated and used for further analysis [14].

Dynamic Balance: A functional Y Balance Test (YBT) was used to test dynamic balance. The YBT was developed to assess dynamic balance in the anterior, posterolateral and posteromedial planes. The YTB have an excellent interrater test-retest reliability (ICC=0.80-0.85) [15]. To execute the test, the participant was asked to stand barefoot with one leg in the middle of the platform and reach with another leg three times in the anterior, posterolateral, and posteromedial directions. Each trial's greatest reach distance was recorded. The trial had to be rerun if a person stumbled, raised his heel off the platform, or used any support. The absolute reach distance, which was used to analyze the overall performance of the YBT test was obtained by dividing the total of the maximal reach distance in each direction by three trials [15].

Flexibility test: The lower back and hamstring flexibility was measured using the sit and reach test. A standard sits and reaches box (40 X 40 X 34.5 cm) was used for the test. A scale was fixed on the top of the box. The participants were seated on the floor with their feet in a dorsiflexion position and knees fully extended shoulder-width apart. One hand was placed on the other hand, and the participant steadily extended their arms as forward as he could. At maximum reach, he holds for three seconds. The reach distance was recorded. The average score of three trials was used for further analysis in centimeters [16].

Agility Test: The agility was measured by the Illinois agility run test that Getchell developed in 1979 [17]. The test was carried out in the 10 x 5-meter defined area using eight cones. Four more cones were placed in the centre at a uniform spacing of 3.3 meters. The participant was told to lie down before the starting cone. When the command "GO." was given, the participant stood up and immediately sprinted 10 meters in front, 10 meters back, 10 meters in a zigzag pattern around four cones, and then 10 meters forward and back again toward the finishing cone. Time (in seconds) was recorded from the start to the end of the run [17].

Speed Test: The participant's speed was determined using a 20-meter dash test. This examination is a trustworthy predictor of acceleration, speed, and agility. Cones, a stopwatch, a measuring tape, and a floor with a 20-meter designation were required for this test. For this test, a maximum sprint of 20 meters will be necessary. The participant should run as fast as he can to finish this test. The two trails' average time (in seconds) to cover the 20-meter distance was recorded [18].

Statistical Analysis

Before analysis, the data were examined for missing data, outliers, normality using the Shapiro-Wilk test and homoscedasticity using the Bartlett criterion. It was found that the data for all measures were homoscedastic and had a normal distribution. Parametric tests were applied to analyze the data for inferential statistics. A one-way analysis of variance (ANOVA) test was performed to determine differences among athletes from random intermittent dynamic-type sports for physiological and physical performance measures s. Partial eta-squared was determined to see the effect. Cohen's d also calculated the effect sizes of the difference between groups. A significance level of 0.05 was used for the comparison between athletes from random intermittent dynamic-type. All analyses were completed in SPSS v-26 software (IBM Co., Armonk, NY, USA).

Results

Table 2 compares rugby, soccer, volleyball, and futsal players for physiological characteristics (VO2max, PIF, PEF, FVC). There were significant differences for VO2max ($F=65.84$, $p=0.00$, $\eta p2=.79$), PIF ($F=4.12$, $p=0.01$, $\eta p2=.19$), PEF ($F=100.27$, $p=0.00$, $\eta p2=.85$), and FVC ($F=16.50$, $p=0.00$, $\eta p2=.49$) for random intermittent dynamic type sports. Further, Post hoc (Tukey) was also applied to see where significant differences existed, and the effect size was also determined by Cohen J.

Table 3 shows the multiple comparisons among rugby, soccer, volleyball, and futsal players for physiological characteristics (VO2max, PIF, PEF, and FVC). The VO2max, PEF, and FVC show significant differences for multiple comparisons among athletes from random intermittent dynamic type sports, and these differences had a large effect size. Whereas PIF shows that rugby players have a large significant effect on soccer and volleyball players, soccer players have an insignificant effect on volleyball players, and futsal players have a small insignificant effect on soccer and rugby players while having a large significant effect on volleyball players.

Table 4 compares rugby, soccer, volleyball, and

Table 2. Changes in the body composition of the competitive runners before and after the tests

Dependent Variable	Players	Mean±SD	95% CI for Mean Lower	Upper	F	Sig.	Partial eta-squared
VO2max	Rugby	52.69±2.05	51.50	53.87	65.84	0.000*	0.791
	Soccer	47.86±1.17	47.18	48.53			
	Volleyball	43.20±1.39	42.40	44.00			
	Futsal	36.02±5.94	32.59	39.45			
PIF	Rugby	106.46±16.24	97.09	115.84	4.12	0.011*	0.192
	Soccer	118.45±21.80	105.86	131.04			
	Volleyball	128.91±17.92	118.56	139.26			
	Futsal	110.58±16.46	101.08	120.08			
PEF (L)	Rugby	4.00±.30	3.82	4.22	100.27	0.000*	0.849
	Soccer	3.41±.10	3.35	3.47			
	Volleyball	2.84±.22	2.73	2.97			
	Futsal	2.30±.38	2.08	2.52			
FVC (L)	Rugby	4.56±0.39	4.33	4.78	94.48	0.000*	0.487
	Soccer	3.76±0.18	3.65	3.86			
	Volleyball	3.28±0.21	3.16	3.40			
	Futsal	2.75±0.34	2.55	2.95			

PIF – Peak Inspiratory Flow, PEF – Peak Expiratory Flow, FVC – Force Vital Capacity; * - The mean difference is significant at the 0.05 level.

Table 3. Post-Hoc (LSD) and effect-size Analysis of physiological output values of athletes from random intermittent dynamic type sports.

Dependent Variable	(I) Players	(J) Players	Mean Difference (I-J)	Std. Error	Sig.	Effect Size	
VO2max	Rugby	Soccer	4.83*	1.24	.000	1.00	Large
		Volleyball	9.49*	1.24	.000	1.00	Large
		Futsal	16.66*	1.24	.000	1.00	Large
	Soccer	Rugby	-4.83*	1.24	.000	1.00	Large
		Volleyball	4.66*	1.24	.000	1.00	Large
		Futsal	11.84*	1.24	.000	1.00	Large
	Volleyball	Rugby	-9.49*	1.24	.000	1.00	Large
		Soccer	-4.66*	1.24	.000	1.00	Large
		Futsal	7.18*	1.24	.000	1.00	Large
	Futsal	Rugby	-16.66*	1.24	.000	1.00	Large
		Soccer	-11.83*	1.24	.000	1.00	Large
		Volleyball	-7.18*	1.24	.000	1.00	Large
PIF	Rugby	Soccer	-11.99	6.90	0.008	1.00	Large
		Volleyball	-22.45*	6.90	0.002	1.00	Large
		Futsal	-4.12	6.90	0.553	0.38	Small
	Soccer	Rugby	11.99	6.90	0.008	1.00	Large
		Volleyball	-10.46	6.90	0.135	0.10	Very Small
		Futsal	7.87	6.90	0.259	0.38	Small

Table 3 (continued)

Dependent Variable	(I) Players	(J) Players	Mean Difference (I-J)	Std. Error	Sig.	Effect Size	
	Volleyball	Rugby	22.45*	6.90	0.002	1.00	Large
		Soccer	10.46	6.90	0.135	0.10	Very Small
		Futsal	18.33*	6.90	0.01	1.00	Large
	Futsal	Rugby	4.12	6.90	0.553	0.38	Small
		Soccer	-7.87	6.90	0.259	0.38	Small
		Volleyball	-18.33*	6.90	0.01	1.00	Large
PEF (L)	Rugby	Soccer	.59*	0.10	.000	1.00	Large
		Volleyball	1.16*	0.10	.000	1.00	Large
		Futsal	1.70*	0.10	.000	1.00	Large
	Soccer	Rugby	-.59*	0.10	.000	1.00	Large
		Volleyball	.57*	0.10	.000	1.00	Large
		Futsal	1.11*	0.10	.000	1.00	Large
	Volleyball	Rugby	-1.16*	0.10	.000	1.00	Large
		Soccer	-.57*	0.10	.000	1.00	Large
		Futsal	.54*	0.10	.000	1.00	Large
	Futsal	Rugby	-1.70*	0.10	.000	1.00	Large
		Soccer	-1.11*	0.10	.000	1.00	Large
		Volleyball	-.54*	0.10	.000	1.00	Large
FVC (L)	Rugby	Soccer	.79*	0.11	.000	1.00	Large
		Volleyball	1.27*	0.11	.000	1.00	Large
		Futsal	1.80*	0.11	.000	1.00	Large
	Soccer	Rugby	-.79*	0.11	.000	1.00	Large
		Volleyball	.47*	0.11	.000	1.00	Large
		Futsal	1.01*	0.11	.000	1.00	Large
	Volleyball	Rugby	-1.27*	0.11	.000	1.00	Large
		Soccer	-.47*	0.11	.000	1.00	Large
		Futsal	.53*	0.11	.000	1.00	Large
	Futsal	Rugby	-1.80*	0.11	.000	1.00	Large
		Soccer	-1.00*	0.11	.000	1.00	Large
		Volleyball	-.53*	0.11	.000	1.00	Large

PIF - Peak Inspiratory Flow, PEF - Peak Expiratory Flow, FVC - Force Vital Capacity; * - The mean difference is significant at the 0.05 level.

futsal players for physical performance measures (power, dynamic balance, flexibility, agility, and speed). There were significant differences for power (F=16.50, p=0.00, ηp2=.49), dynamic balance (F=11.78, p=0.00, ηp2=.40), flexibility (F=28.92, p=0.00, ηp2=.63), agility (F=7.45, p=0.00, ηp2=.30) and speed (F=3.86, p=0.01, ηp2=.18) for random intermittent dynamic type sports. Further, Post hoc (Tukey) was also applied to see where significant differences existed, and the effect size was also determined by Cohen J.

Table 5 shows the multiple comparisons among rugby, soccer, volleyball, and futsal players for physical performance measures (power, dynamic balance, flexibility, agility, and speed). The power, dynamic balance, flexibility, agility, and speed show significant differences for multiple comparisons among athletes from random intermittent dynamic type sports. These differences distinguished (large, medium, small, and very small) effect sizes.

Discussion

This study comparing among athletes from random intermittent dynamic-type sports for physical performance measures and physiological characteristics. Multiple comparisons have been

Table 4. Comparison of Physical Performance Measures among Athletes from Random Intermittent Dynamic Type Sports.

Dependent Variable	Players	Mean±SD	95% CI for Mean Lower	Upper	F	Sig	Partial eta-squared
Power	Rugby	1770.43±77.30	1725.80	1815.06	16.50	0.001*	0.487
	Soccer	1632.71±115.73	1565.89	1699.54			
	Volleyball	1541.86±72.73	1499.86	1583.85			
	Futsal	1608.50±81.52	1561.43	1655.57			
Dynamic Balance	Rugby	82.20±3.87	79.97	84.44	11.78	0.012*	0.404
	Soccer	94.06±2.21	92.79	95.34			
	Volleyball	87.96±9.25	82.62	93.30			
	Futsal	91.04±4.08	88.68	93.39			
Flexibility	Rugby	25.14±4.70	22.43	27.86	28.92	0.001*	0.625
	Soccer	16.14±1.88	15.06	17.23			
	Volleyball	16.93±2.64	15.40	18.46			
	Futsal	17.29±1.27	16.55	18.02			
Agility	Rugby	14.15±0.53	13.85	14.46	7.45	0.011*	0.300
	Soccer	15.84±0.79	15.38	16.29			
	Volleyball	15.15±1.56	14.25	16.05			
	Futsal	15.37±0.68	14.98	15.76			
Speed	Rugby	3.31±0.28	3.15	3.47	3.86	0.014*	0.182
	Soccer	3.67±0.42	3.42	3.91			
	Volleyball	3.70±0.26	3.55	3.85			
	Futsal	3.47±0.39	3.25	3.69			

* - The mean difference is significant at the 0.05 level.

Table 5. Post-Hoc (LSD) and effect-size Analysis of physical performance output values of athletes from random intermittent dynamic type sports.

Dependent Variable	(I) Players	(J) Players	Mean Difference (I-J)	Std. Error	Sig.	Effect Size	
Power	Rugby	Soccer	137.71*	33.44	0.00	0.96	Large
		Volleyball	228.57*	33.44	0.00	1.00	Large
		Futsal	161.93*	33.44	0.00	1.00	Large
	Soccer	Rugby	-137.71*	33.44	0.00	0.96	Large
		Volleyball	90.86*	33.44	0.01	0.70	Medium
		Futsal	24.21	33.44	0.47	0.09	Very Small
	Volleyball	Rugby	-228.57*	33.44	0.00	1.00	Large
		Soccer	-90.86*	33.44	0.01	0.70	Medium
		Futsal	-66.64	33.44	0.05	0.63	Medium
	Futsal	Rugby	-161.93*	33.44	0.00	1.00	Large
		Soccer	-24.21	33.44	0.47	0.09	Very Small
		Volleyball	66.63	33.44	0.05	0.63	Medium
Dynamic Balance	Rugby	Soccer	-11.86*	2.09	0.00	1.00	Large
		Volleyball	-5.76*	2.09	0.01	0.83	Large
		Futsal	-8.83*	2.09	0.00	1.00	Large
	Soccer	Rugby	11.86*	2.09	0.00	1.00	Large
		Volleyball	6.10*	2.09	0.01	0.67	Medium
		Futsal	3.03	2.09	0.15	0.68	Medium

Table 5 (continued)

Dependent Variable	(I) Players	(J) Players	Mean Difference (I-J)	Std. Error	Sig.	Effect Size	
	Volleyball	Rugby	5.76*	2.09	0.01	0.83	Large
		Soccer	-6.10*	2.09	0.00	0.67	Medium
		Futsal	-3.07	2.09	0.15	0.21	Small
	Futsal	Rugby	8.83*	2.09	0.00	1.00	Large
		Soccer	-3.02	2.09	0.15	0.68	Medium
		Volleyball	3.07	2.09	0.15	0.21	Small
Flexibility	Rugby	Soccer	9.00*	1.11	0.00	1.00	Large
		Volleyball	8.21*	1.11	0.00	1.00	Large
		Futsal	7.86*	1.11	0.00	1.00	Large
	Soccer	Rugby	-9.00*	1.11	0.00	1.00	Large
		Volleyball	-0.78	1.11	0.48	0.15	Very Small
		Futsal	-1.14	1.11	0.31	0.48	Small
	Volleyball	Rugby	-8.21*	1.11	0.00	1.00	Large
		Soccer	0.78	1.11	0.48	0.15	Very Small
		Futsal	-0.36	1.11	0.75	0.07	Very Small
	Futsal	Rugby	-7.86*	1.11	0.00	1.00	Large
		Soccer	1.14	1.11	0.31	0.48	Small
		Volleyball	0.36	1.11	0.75	0.07	Very Small
Agility	Rugby	Soccer	-1.68*	0.37	0.00	1.00	Large
		Volleyball	-.99*	0.37	0.01	0.62	Medium
		Futsal	-1.22*	0.37	0.00	1.00	Large
	Soccer	Rugby	1.68*	0.37	0.00	1.00	Large
		Volleyball	0.68	0.37	0.07	0.31	Small
		Futsal	0.46	0.37	0.21	0.39	Small
	Volleyball	Rugby	.99*	0.37	0.01	0.62	Medium
		Soccer	-0.68	0.37	0.07	0.31	Small
		Futsal	-0.22	0.37	0.54	0.07	Very Small
	Futsal	Rugby	1.22*	0.37	0.00	1.00	Large
		Soccer	-0.46	0.37	0.21	0.39	Small
		Volleyball	0.22	0.37	0.54	0.07	Very Small
Speed	Rugby	Soccer	-.35*	0.13	0.01	0.39	Small
		Volleyball	-.39*	0.13	0.00	0.52	Medium
		Futsal	-0.16	0.13	0.23	0.12	Very Small
	Soccer	Rugby	.35*	0.13	0.01	0.39	Small
		Volleyball	-0.03	0.13	0.79	0.04	Very Small
		Futsal	0.19	0.13	0.14	0.26	Small
	Volleyball	Rugby	.39*	0.13	0.00	0.52	Medium
		Soccer	0.03	0.13	0.79	0.04	Very Small
		Futsal	0.23	0.13	0.09	0.45	Small
	Futsal	Rugby	0.16	0.13	0.23	0.12	Very Small
		Soccer	-0.19	0.13	0.14	0.26	Small
		Volleyball	-0.23	0.13	0.09	0.45	Small

* - The mean difference is significant at the 0.05 level.

made among rugby, soccer, volleyball, and futsal players for physiological characteristics (VO2max, PIF, PEF, and FVC). The VO2max, PEF, and FVC show significant differences for multiple comparisons among athletes from random intermittent dynamic type sports, and these differences had a large effect size. Whereas PIF shows that rugby players have a large significant effect on soccer and volleyball players, soccer players have an insignificant, very small effect on volleyball players, and futsal players have a small insignificant effect on soccer and rugby players while having a large significant effect on volleyball players. Most researchers have regarded VO2max as the best indicator of aerobic capacity. This single measurement indicates the functional capacities of the cardiovascular and respiratory systems and physiological performance. VO2max is one of the most important factors influencing the success of endurance performance. Different level's players have a distinguished level of VO2max. The hypothesis of this study was accepted as there was significant differences across athletes from sports characterized by random intermittence dynamic activity for physiological characteristics and physical performance measures.

Our findings were consistence with the findings of previous studies. Reilly et al. reported that elite soccer players have exceptional aerobic power with a VO2max range of 55-70 ml/kg/min [19]. There is a variation in aerobic power in soccer players. This variation is due to their playing position, as midfielders have much higher aerobic power levels for outfield players, whilst central defenders have the lowest values. Gabbett indicated that first-grade rugby players have a VO2max range between 45-55 ml/kg/min, whereas second-grade rugby players have 40-49 ml/kg/min [20]. The comparison between playing positions among rugby players showed that back players have greater aerobic power than forward players [21]. Boone et al. [22] found the maximal aerobic power values of 289 professional soccer players playing in the first league of Belgium in 2003-2010 to be 57.7±4.7 ml. kg/min. Mohammadi et al. [23] found the aerobic power of Iranian soccer players to be 52.78±0.98 ml. kg/min. Baroni and junior found that the mean values of VO2max in futsal players were 58.00±6.37 mL/kg/min [24]. Charitonidis et al. [25] revealed that the VO2max values were better in male volleyball players (56.32±6.36 ml/kg/min) than in female volleyball players (44.78±3.65 ml/kg/min). Insufficient aerobic capacity will negatively affect sports performance, especially at the end of the game. It should be observed that the athletes from random intermittent dynamic type sports differ statistically significantly. This suggests that the athletes' physiologies have changed due to the training connected with each sport. Tareq et al. found that the forced vital capacity in soccer players was 90.2±8.8, and in futsal players, 88.5±6.9 [26]. Mazic et al. [27] found that there were significant differences between the control group and other team players for FVC as rugby players (4.89±1.0), soccer players (5.69±1), volleyball players (5.29±1), and control group (5.58±0.6). Ostojic [28] found the FVC of professional soccer players playing in the national first league to be 5.6±0.8 lt. and amateur soccer players to be 5.4±0.9 lt. Tareq et al. [26] found that the peak expiratory flow in soccer players was 98.6±4.8, and in futsal players, 88.9±6.0, and there was a significant difference. A study by the West et al. showed that paralympic rugby players have PIF of 7.14±1.11 and PEF of 6.61±2.54 L/s. [29]. Mazic et al. [27] showed PFI average values for rugby players (9.21±2.23), soccer (10.33±2.51), volleyball (9.25±1.85), handball (9.21±2.23) and control group (11.17±1.43). Taylor et al. [30] reported the PIF 6.50±1.10 PEF 6.32±1.95 l/s in paralympic wheelchair rugby players. PEF 7.7±1.48 experimental group and 6.36±1.61control group for soccer players. The experimental group performed additional inspiratory muscle training for eight weeks with a commercially available respiratory muscle trainer [31]. Bostanci et al. [32] revealed no significant difference between the male (307.32±43.92) and females (304.91±44.81) for peak expiratory flow among athletes.

Comparing physical performance measures (power, dynamic balance, flexibility, agility, and speed) demonstrated significant differences among rugby, soccer, volleyball, and futsal players. The results showed that rugby players have higher power values than the rest, soccer players have higher power values than futsal and volleyball players, and volleyball players have lower power values than the other players. All of them also have significant differences. The power, dynamic balance, flexibility, agility, and speed show significant differences for multiple comparisons among athletes from random intermittent dynamic type sports. These differences have distinguished (large, medium, small, and very small) effect sizes.

Muscular power and strength are key attributes of rugby, soccer, volleyball, and futsal players due to the collision and contact factors of the games. All players must have well-developed power, dynamic balance, flexibility, agility, and speed to cope with the heterogeneous demands of the game [33]. A high level of muscular power rapidly enables players to perform more effectively during rucking, wrestling, tackling, jumping, smashing, sprinting, and changing direction [34]. A study showed that the peak power values of lower leg muscles for rugby players were found as 3603.80±144.63 (watts), and for soccer players, 3386.88±605.52 (watts) [35]. It showed that rugby players have more power than soccer players, consistent with our findings. A study showed that the average squat jump flight was 544.0±35.49 in male futsal players [36]; they also stated that their study showed lower values and further mentioned that these differences can be attributed to varying levels of training and competition [36]. A significant weakness in elastic-explosive strength training, which is essential for futsal play, maybe the cause. Rugby players have a higher degree of flexibility than futsal players, volleyball players, and soccer players. The present study findings identified the differences in sit and reach flexibility test. A study with volleyball players indicated that the average flexibility scores were 17.81±3.42 [37]. Another study reported that the sit-and-reach test score (Flexibility) was 18.21 for volleyball players [3]. These findings were consistence with our findings. Palaniappan & Deivendran [38] reported that stretching parameters have positive effects on jumping performance. Whereas Lee et al. [39] supported that sit and reach test positively correlates with the vertical jump scores. Rugby league "professional" players scored higher on agility tests than amateurs, according to research by Till et al. [40], but they included U14 players. Milanović et al. [41] study revealed no significant differences between soccer players and futsal players for the specific agility test.

Further, they reported that soccer players showed better results than futsal players. A study on volleyball players showed average agility values of 15.11±0.93 [37]. Another study showed that the mean agility score was 18.37 for volleyball players, resulting from the Illinois agility run test [3]. Rugby players can move quickly in attack and defense because speed is frequently cited as an essential physiological trait. Speed has also been connected to match the success and execution of game abilities like tackling [42]. A study showed that rugby back players are faster than forward players compared to 40-meter sprint [43]. Hansen et al. found rugby squad sprint data for 30 m 4.400.25 sec [44]. Crewther et al. [45] found 3.16±0.10 sec for 20 m sprint time for forward rugby players. Ferro et al. [46] demonstrated that the competitive soccer player's average time score was 3.8±0.1 sec for the 20 m speed test and their findings were consistent with others' findings over the 20 m speed test. Cometti et al. [47] reported that professional soccer players were faster than amateurs players compared with a distance of 30 m, but there was no significant difference. Tanyeri and Oncen [48] revealed that the average pre and post 20 m speed test scores were 3.46 0.164 and 3.39 0.162 sec, respectively, for futsal players). A study on volleyball players showed speed average values were 3.31±0.21 [37]. The study findings demonstrated that rugby, soccer, volleyball, and futsal have similar physical performance characteristics. It is unknown whether these differences were brought about by a particular training regimen or physical adaptation to the sports type. A possible explanation for this research findings could be observed differences in physical performance characteristics among players from random intermittent dynamic sports.

This study has some limitations when performing functional tests to measure players' performance—first, this study design. A cross-sectional study design was adopted to conduct this study. There was no cause-and-effect relationship determined. Second, the study recruited only male participants. The generalization of the result is limited. Third, the sample size for the present study was limited. If the sample size is huge, the sampling error will be less. Fourth, few performances assessment tests. Players are more familiar with these tests, which may lead them to perform movements requiring less energy. The physical performance tests (MSFT, VC, PIF, PEF, FVC, vertical jump, YBT, sit and reach Illinois agility, and 20-meter dash) should be used with great caution regarding evaluating rugby, soccer, volleyball, and futsal players' performance. Indoor and outdoor modes of test, time, and location of the test should be considered when generalizing the result of the present study.

Conclusions

This study revealed important information about the effect of various intermittent dynamic activities on physiological characteristics and physical performance measures. There are significant differences among athletes from random intermittent dynamic type sports for physiological and physical performance characteristics. Additionally, this information can be utilized to make training suggestions and monitor athlete's progress afterwards. While constructing the training program, morphological and functional factors should be considered based on the nature of activities.

Conflict of interest

There is no conflict of interest among authors.

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ORIGINAL ARTICLE

The effect of exercise using auxiliary tools in learning the forehand and backhand skills of female tennis students

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

Abstract

Background and Study Aim The present study investigates the effect of exercise using auxiliary tools. It should facilitate learning process of the forehand and backhand skills of female tennis students of physical education and sports. It can also be used by workers in the field of performance and different motor responses.

Material and Methods An experimental method with two group pretest and posttest design approached the 20 volunteers of female sports students (age 19±2), who had participated in a training course. The sample is divided into 2 groups of experimental and control according to the score of the forehand and backhand tests and measurements. Analyses were performed using statistical software SPSS 23 (Statistical Package for social science) program. The following variables were calculated using: Arithmetic mean, Standard deviation, Simplex correlation coefficient (Pearson), T-test for related means.

Results The study showed a significant value ($p=0.001$, $p<0.05$) in the acquisition of the forehand and backhand skills after post-test assessment when compared to pretest. However, significant differences emerged in developing some basic tennis skills. The special exercises with auxiliary tools made a remarkable development in all basic skills.

Conclusions Coaches play a key role in use of suitable equipment in tennis teaching programs. Voluntary participation in such tests provides effectiveness feedback on teachers teaching and adequacy of performance acquisition gained by learners. This study will encourage teachers to use special exercises with auxiliary tools in learning and acquiring basic skills in games and sports activities.

Keywords: exercises with auxiliary equipment, tennis skills, teaching method.

Introduction

Play tennis, it means deploying strategies to progress and excel: knowing more to do better. Thus, the purposes and objectives can be different according to the individuals: the physical will be privileged for some, the technique or the tactics for others, finally for some the relational will be essential. As a result, there are many learning strategies: by observation and deduction, by imitation, by trial and error, with the help of a loved one or an instructor. However, nothing replaces experiences that build up knowledge and knowledge that can be used later [1]. According to Sève et al. [2] excellence requires training embedded in structured and formalized practices. They aim to develop motor and decision-making skills by offering individuals the opportunity to practice under usual conditions, so as to allow errors and promote progress. Talent development models prescribed the training of young people as a linear process. Thus, the training is centered on the requirements of the task to be performed: instructions from the coach, movements of the players, type of ball or racket, amplitude of movement of a given joint which amplifies the sources of information allowing players to achieve their goals [4]. However, the beginnings of sports practice motivated by the love of sport. As athletes develop their skills, linear models prescribe disciplined practice to hone sport-specific skills, then applied in competition [5].

In coaching, by Regan [6] manipulation of constraints is nothing new, coaches have always used tasks and environments in seemingly similar ways. He confirms that developments in psychological theory inform best practice in skill acquisition. Far from being trained solely by the prescriptive transmission of experts, coaches must explore ecological and implicit approaches to developing the skills of tennis players. In their goals and interventions, coaches should develop the whole athlete. Training for well-being must take into account the emotional, personal, cultural and social identity of each athlete and how this identity influences athletic development and athletic performance [7].

In economic power, coaches participate in the circulation of symbolic capital within the bourgeoisie. The recommendation is decisive in the career of a coach, they need to draw their legitimacy and authority from fields and worlds that are largely

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autonomous and desirable for their students [8]. When it comes to coaching children, the relationship must be negotiated both with the student and his parents. Indeed, it is a question of arousing fulfillment, interest in tennis and self-confidence. For parents, sports practice is part of both educational strategies and a process of toughening up their son, making him more autonomous, physically and psychologically tough, and tenacious in upsetting situations. Also, endowed with a quality associated with the practice of competitive sport, which the American upper classes call the drive [8]. In this context, the coach can use different strategies to impose task-related constraints [4]. Environmental constraints can be both social and physical. Player development is influenced by the training climate. On the social level, the coach can establish two types of environment on the social level: a self-centered environment or a task-centered environment [9]. In terms of training, it is important to teach coaches how to develop programs and organize sessions whose content and frequency are specially adapted to children [10]. In cases, Pankhurst [11] shows a slowness in integrating new teaching strategies into coach education programs, which means that coaches do not have guidance on which to base their design of their daily training programs for players.

Today, tennis sport; It is an Olympic sport that is embraced by the world and that at the same time arouses excitement and admiration to do and watch. In this sport, it is known as a sport that includes aerobic and anaerobic loads and sudden changes of direction, as well as requiring a high level of basic motor features such as strength, speed, endurance, flexibility and coordination, and athletic performance [12]. Moreover, basic forehand and backhand technical skills are the main requirements that must be mastered in playing tennis. Physical condition and intellectual intelligence were found to be the factors that affect the quality of tennis [13]. In this study, we tried new teaching methods (using some exercises with auxiliary tools) in learning basic tennis skills. At Physical Education College and Sports Sciences for girls at the university of Baghdad, what is the effect of using of using some exercises with auxiliary tools on acquisition of the forehand and backhand tennis skills for female students? Are there statistically significant differences in measurements dimensional between the first and the second experimental group in developing some tennis skills?

Material and Methods

Participants

The research involved a cohort of 20 students (STs) female (13.33 %), from total 150 STs (100 %) studying in physical education college and sports sciences for girls. All participants in this study were volunteers. The group of participants consisted of the third year. The ages of the participants varied from 17 to 21 years old and the mean age was 19 (*SD* = 0.43). All were aged between (19 ± 2 years) registered in the third year, by the master's degree in physical education. The research sample was divided randomly into two groups of 10 students for each group, where the first group applied the experimental group, and the control group (see Table 1). In this study, we chose the experimental approach to ensure internal and external validity of the results. In order to achieve the objective, this approach was used with two equivalent groups.

Measures

This quantitative study used several research methods to access the required research data and results, which are (scientific sources and references, tests and measurement). The tools and devices used: (tennis court, ten tennis balls, tennis rackets, signs, stopwatch, two whistles, tape measure, adhesive tape). After reviewing the tennis academic curriculum and scientific references, the tests and measurements was presented to a group of ST. The measurement of the front and back strokes of a tennis player: (1) the tennis court is planned at one side as shown, (2) a rope shall be fixed at both ends of the two legs of the net, parallel to it, at a height of 2 m from the ground and 1.6 m from the net (3) parallel lines are drawn between the transmission line and the baseline so that the distance between the line equals 1.7 m.

Also, after identifying the forehand and backhand skills for the students of the research sample, performance description and appropriate tests for these skills were fixed and then presented to a group. The performance description and the tests that have been approved are: (i) the player stands on the center mark while the coach stands in the facing half of the court on the center plans, with a box for tennis balls; (ii) the coach hits the ball behind the transmission line, where he moves from his place to take the appropriate position and hit the ball in front, and then background strikes to pass over the net and down the rope. It then falls

Table 1. The research sample for the two experimental groups

Variable	Total number	Group	Experimental
The forehand and backhand tennis skills	10	First	Experimental (1)
	10	Second	Control (2)
	20		Total

in the areas indicated by the numbers in the facing half, trying to achieve the highest score each time in the area Number (5); (iii) the player repeats the previous performance for 5 consecutive attempts to get adequate training for the test; (iv) the test begins with the player performing (10) times in the same way; (v) in all attempts, the coach hits the ball in a consolidated and legal manner so that it is as similar as possible to the balls in the actual play situations; (vi) the player has the right to start with the front or background kicks. The basic skills tests used in the current research are standardized tests and appropriate for the research sample, as they have been applied in previous and similar studies that have been touched upon. Thus, data were collected through the rating score (1) a ball that passes over the rope is counted as half the degree zone where it falls; (2) balls touching the rope at the beginning of the net bounce, and are considered a failing attempt; (3) a player's score is the set of points she gets after hitting ten balls using the front ground kick method and then hitting ten balls using the background kick method.

Procedures

First of all, the permission was granted by the director of university of Baghdad and students to realize the current study. Then, the research procedures for experiment were implemented in a pre and posttests, and there was an educational plan for each of them during (9) weeks. Before conducting the pretests, the researcher started the selection process, recording students' names. Then, he delivered an educational unit detailing the test performance method while explaining and clarifying the test on the first week. In addition, the researcher conducted pretests on the research sample members/group. Later, the implementation of the educational curriculum put forward by the researcher proceeded. It comprises: (1) the skills were acquired in the lecture, as prescribed in the educational curriculum which is consistent with the warm-up activities, the physical exercises, the educational activity, and the closing section. However, in practice, differences were revealed as the experimental group used special exercises backed up by auxiliary tools in the learning process of the forehand and backhand tennis skills for female students; (2) the experimental group used special exercises with auxiliary tools in the learning process of the forehand and backhand tennis skills for female students. The educational curriculum that consisted of 16 educational units, was covered over a two-month period: each group was assigned two educational units per week, while each educational unit at (60) minutes period allotted as follows: (i) the preparatory section (15 minutes); (ii) the man section (40) minutes: (10) minutes academic, and (30) minutes for practice; (iii) the final section (10) minutes. After two months, the post-tests were conducted under the same pretest conditions. Then, the researcher carried out the tests as to the forehand and backhand skills.

Statistical Analysis

Analyses were performed using statistical software SPSS 23 (Statistical Package for social science) program. The following variables were calculated using: Arithmetic mean, Standard deviation, Simplex correlation coefficient (Pearson), T-test for related means.

Results

The effect of using exercises with auxiliary tools on acquisition of the forehand and backhand

In order to investigate the effect of using some exercises with auxiliary tools on acquisition of the forehand and backhand tennis skills for female students, the values of the two groups in the present study were compared in the pre-test and post-test. For statistical analysis, parametric statistical method was used, the results of which are illustrated in table 2. According to the test results, some exercises with auxiliary tools enabled participants to make significant progress in the area of the forehand and backhand tennis skills, such that the performance from pre-test to post-test were significantly improved (P = 0.001). In the case of performed forehand and backhand tennis skills, the difference between the pre-test and post-test was statistically significant (P <0.05). Also, significant differences were found in favor of the post-test, it was observed that the experimental group influenced by the exercises with auxiliary tools. Moreover, the results indicate that the progress of the subjects from the pre-test stage to the performance test is statistically significant (P = 0.001). For this reason, exercises with auxiliary tools have a significant effect on acquisition of the forehand and backhand tennis skills for female students.

Table 2. The statistical differences in developing forehand and backhand tennis skills

Basic skills	Measuring unit	Pretest		Post test		Sig	Calculated (t) value
		sd	p	sd	p		
Forehand	Score	18.800	.83666	26.800	1.48324	0.001	1.58114
Backhand	Score	20.6667	27.6667	1.21106	1.86190	0.001	2.28035

Note: * Significant when the error ratio ⩾ (0.05)

Discussion

To provide a training quality in terms of teaching practice for student-trainees that meet the challenges in learning forehand and backhand and performance. Thus, the purpose of this research was to know the possibility of the sample to apply exercises backed up by auxiliary tools are believed for a successful teaching and training in tennis performance and motor skills. According to our results, there are significant differences between the results of the basic skills tests, before and after, for the two experimental and control groups. Therefore, this corresponded to the opinion of experts and specialists in the field of motor learning, who emphasized the importance of exercises with auxiliary tools in responsiveness to the performance of a particular skill. Thus, the changes that occur in the behavior of the learner have an impact on know-how in order to acquire other skills. Also, the educational program developed by the researcher (the exercises performed in the educational teaching and the use of auxiliary tools) has an important role in acquiring and refining the skill of the forehand and backhand. In this field Kilit et al. [14] investigate the acute effect of different stretching methods on speed and agility performance in young tennis players according to conditioning level. They concluded that the acute effect of static stretching had a negative effect on agility and sprint performances. They suggest that dynamic and static dynamic stretching might be use for the performing better performance in acceleration, speed and agility skills during the warm-up session in young tennis players [14].

The researcher also attributes the learning of the two skills to the adequacy of the teaching units to perform the two skills and the inclusion of the exercises. Also, the use of auxiliary tools effective time management. therefore, the diversification of the exercises and their organization, the demands of play and the variety of movements will help to gain experience and optimize performance [15]. Here we can say that one of the fundamentals of the learning process is the development phase. in this context, the teacher must respect the learning stages and focus on performance towards the consolidation phase. Learning and teaching skills are influenced by the choice of strategy and instructional technique used with apprentices [16.17]. Thus, according to Vickers [18] it becomes essential for coaches to set up appropriate and different environments for children 10 and under, for the following reasons: (i) we know that children like to have fun and be in the presence of adults; (ii) coaches need to change activities frequently to keep children motivated; (iii) children learn mainly by reproducing what they see; (iv) children like to be surrounded by their friends, even if they do not necessarily have the same skills as them. Gallo-Salazar et al. [19] proposes to analyze the effects of 2 tennis matches on the same day on the physical performance of young tennis players. Physical impairments occurred in neuromuscular performance variables involving lower (jumping, sprinting, and change of direction) and upper (isometric strength and range of motion) limbs the day after playing a competition with 2 consecutive matches on the same day. These alterations in neuromuscular and sport-specific performance need to be taken into consideration when planning tournament schedules for young tennis players, as well as preparing match and recovery strategies [19].

Moreover, it can be said that the learning was the result of following the right method, providing regular presentation and explanations, and offering feedback to the learner, which stimulate motivation and arouse their passion and the desire to act. thus, for significant progress, the basic rule in learning motor skills is to seriously consider exercise attempts and their diversification [20]. In this study, the sample focused on repetition of skill performance, which is an effective process for ensuring performance. it appears that the repetition of motor performances is a prerequisite for high-level motor learning. Thus, children like to move, and tennis is a movement game in which players must use a variety of different skills in a dynamic environment. Waiting behind each other to be able to hit a ball [11]. According to recommendations from several studies [10], the amount of physical activity should be proportional to children and adults.

On the other hand, the mental rehearsal that accompanies the physical rehearsal by following an integrated action plan for each skill facilitates the process of memorization. Generally, the learner is forced to reconstruct an action plan for each skill in each performance due to overlapping skills. Then, in practicing the drill technique, the learner repeats the skill action plan in the initial repetitions to apply that plan repeatedly in further drill attempts. The process of learning an action plan enriches the process of acquiring performance and helps develop the skill of storing and retrieving information from memory in order to give solutions to the tasks assigned to the learner. Tennis is an open-skill dynamic sport in which players over a limited period of time have to process and integrate complex visual information (VT). Bonato et al. [21] suggest that VT was effective to improve on-court tennis performance in junior. In multiple comparison test, they showed significant improvements in speed during second serve were found. Moreover, the time course between the split step and shoulder rotation in forehand, backhand, and return to serve improved significantly. Changing game conditions dictate that decision-making and action must be time-sensitive. The perception of information sources is the fit between the characteristics of the player and the properties of the task to be performed. According to

Dana et Gozalzadeh [22], the use of mental imagery improves the precision of the serve in tennis. Their research aimed to determine the effects of visual imagery on the forehand, backhand and serve in novices. The results were able to demonstrate that all groups showed an improvement in accuracy. Miles and al. [23] focusing on ball sports highlighted the importance of the realism of the sports environment in which the learner finds himself. Thus, Milazzo et al. [24] shown that video-based perceptual training improves cognitive and perceptual skills resulting in decrease in decision time and increase in decision's accuracy in simulations and field. Furthermore, the benefits of explicit approaches in early stage of learning to promote rapid acquisition of knowledge is highlighted. On the other hand, it is suggested that implicit approaches will be more conducive to the experts to ensure that they "reinvest" their knowledge in stressful situations. Finally, it is envisaged that guided approaches are relevant alternatives to explicit and implicit approaches.

This corresponded to what had been indicated by the literature, in the exercise, the individuals must recall the program and identify it before each movement, because they produce different movements from one attempt to another. Thus, in exercises, they can use the same program (without maximum modification) for a series of motor attempts Finch et al. [25]. Moreover, the ability to achieve a goal is limited by the conditions of the task execution. Thus, the behavior of the player will be different if he is asked to play five groundstrokes, taking care to keep the ball in play, before triggering an attack shot. If he performs this attack with a forehand, he scores a point [4]. Therefore, in individual sports, the athlete is in constant interaction with his coach during training and competition. Thus, the coach-trainee relationship, the behaviors of the coach or the leadership of the coach have an effect on the well-being and the performance of the athletes [26, 27]. In research contributing to an evolutionary epistemology of junior tennis training, Gowling [5] confirms that young tennis players focus on winning, which can influence their attitude towards learning and reduce their enjoyment of competition. To do this, the situated activity approach makes it possible to understand how individuals adapt to the modification of the situation in which they act. She apprehends their explanations and judgments on the situation and unexpected events in order to adjust to them [2]. Visioli, Petiot et Ria [28] confirm in their study that a subject will have more pleasure when learning a movement when it is done in the form of a game.

Conclusions

The forehand and backhand skills are among the most important basic skills in tennis, as most scientific sources confirm the similarity of the course of these two skills in terms of performance and different motor responses. They are at the core of the tennis learning process as mastering these two skills will quickly help develop and build up other skills. According to the results reached by the researcher, it was concluded that:

- the specific exercises backed up by the auxiliary tools that were used on the research sample helped them master the tennis forehand and backhand tennis skills;
- the auxiliary tools produced a significant effect on the learning outcomes of the forehand and backhand skills by the research sample.

In light of the researcher's conclusions, the researcher recommends the following: Stressing the necessity of using special exercises with auxiliary tools in learning and acquiring basic skills in games and sports activities owing to their effective role in the learning process, based on the significantly inherent advantages in this educational method. In addition, the urge to employ various up-to-date educational methods that make up for traditional ones. Finally, proceed with the learning process by starting with the easy skills to acquire more difficult ones to ensure smooth progression.

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ORIGINAL ARTICLE

Blood types and fitness capability of physical education students: a non-parametric analysis

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

Abstract

Background and Study Aim The study describes the association of blood types and physical fitness capability of physical education students.

Material and Methods A non-parametric analysis was used in the study employing chi-square with the Cramer's V analysis to provide the likelihood relationship between variables. Using the simple random sampling, there were 263 participants composed of 198 (75.3%) females and 65 (24.7%) males. The samples were all students from physical education subject with the age ranged from 17-34 years old.

Results The finding showed that among the physical fitness capability of the PE students, only anaerobic and flexibility fitness have positive association to blood types. Further, anaerobic fitness has the likelihood to be more advantageous within the A blood type with 57.1%. While flexibility fitness is seen in blood type O with a likelihood association of 79.1%, A with 60.7%, and B 55.3%. Moreover, this implies that PE students' physical fitness capability such as anaerobic and flexibility fitness are potentiality associated or related to blood types most specifically to "A" and "O." Thus, in any fitness related physical activity, blood type must be considered in the selection process especially if instills high intensity exercises producing without oxygen and muscle range extension.

Conclusions It has been concluded that physical fitness capability of an individual can be attributed or influenced by the type of blood he/she possesses. Thus, in the context of sports and dance competition that requires specific physical fitness level, it is recommended to consider blood types of a person.

Keywords: blood types, fitness capability, physical education, non-parametric analysis

Introduction

Physical activity has been the venues for developing and promoting fitness of the individuals. Thus, physical fitness is always been linked to individuals' capability to perform physical activity [1] and some studies relate it to selective attention and concentration [2, 3, 4]. However, not all individual is capable in engaging and performing in any physical activity. Oftentimes, comparison between individuals in terms of capability in performing physical activity can easily be uttered and/or identified by others. Usually, the reasons behind it can be seemingly associated to "it runs from the blood" and "it's an innate talent". Thus, it somehow elaborates the relationship of blood types and physical fitness capability in engaging in physical activity.

During COVID – 19 pandemics, there are studies that had proven that physical fitness level of an individual increase specifically on the body mass index, flexibility, cardiovascular endurance, muscular endurance, and strength in performing home quarantine – based rhythmic exercises [5] and housework – based exercise (household chores) and conventional exercise program given to the young adults [6]. Even before pandemic, there are several studies already proved that physical fitness of an individual can be augmented if certain interventions will be provided and/or facilitated. It has showed that students' participation in physical activity increases its fundamental movement skills [7] and when there are physical resources provided, internal regulation is clear, students' intentions is strong and when they feel supported and motivated [8].

However, there is a dearth in study that can explain the relationship and/or association between blood types and physical fitness of the students. Most of it were just implied studies. Such as blood types are usually associated to personality and IQ of a person [9, 10]. Recently, there is a study that proves the relationship between blood types and movement capability in physical activity. It was explained that blood type is a predictor of movement capability in terms of flexibility, speed, accuracy, and endurance of an individual [11]. Moreover, another study explained that people with blood type "O" and positive RH have the higher risk or chance in terms of increasing his/her body mass index (BMI) [12]. Though, the level of association were not thoroughly elaborated in the above studies. Thus, this study is eager to understand the link between the two variables and provide more evidences on its relationship.

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Materials and Methods

Participants

Using the simple random sampling technique, there were 263 participants composed of 198 (75.3%) females and 65 (24.7%) males. The samples were all students from physical education subject with the age ranged from 17-34 years old. The participants are all physical education students in one of the medical universities in Cebu, Philippines.

Research Design

The study utilized a non – parametric descriptive research design. Descriptive was used to describe the students' age, gender, and blood types. Moreover, it explained and described the level of fitness capability of the students in terms of the flexibility, aerobic, speed, agility, anaerobic, and power. In the same vein, Chi - square and Cramer's V were employed to surface the potential likelihood of blood types to fitness capability of the students. Valid instruments were used in the study. First part of the instrument is the profile and blood classification of the students. While, the second part of the instrument are the series of fitness tests that are commonly used by the PE instructors in the university to test the students' fitness capability level. This instrument has been used by PE instructors of the university in many years. The different tests were adopted from the American College of Sports Medicine [13] for registering baseline fitness capability of students and these tests were used in many researches such as 12-minute run for aerobic fitness [14], 40-yard sprint for speed fitness [15], 300- yard shuttle for anaerobic fitness [16], hexagon test for agility fitness [17], vertical jump for power fitness [18], and sit and reach for flexibility fitness [19]. Moreover, these tests have been indigenized by PE teachers to be more applicable in the context of Filipino skill test. Indigenization of the instruments happened during the giving of the instructions of the concept of the test, using the language wherein the participants can understand fully the test, few of the materials or equipment for the test were modified based on the availability of the school's materials (e.g., instead of sports pistol, whistle was used), and the setting of the test were slightly modified.

Statistical Analysis

Microsoft word excel was used in storing and analyzing of the data. Descriptive statistics were used in the profile, blood types and fitness capability levels of the participants. Then, chi-square with the Cramer's V analysis to provide the likelihood relationship between variables.

Results

Below are the results of the study presented in tables.

Table 1. Profile of the Participants (n=263)

Variable	Category	Frequency	Percentage
Age	17 years old	4	1.5
	18 years old	117	44.5
	19 years old	128	48.7
	20 years old	10	3.8
	21 years old	2	.8
	24 years old	1	.4
	34 years old	1	.4
Sex	Male	65	24.7
	Female	198	75.3

Table 1 presents the profile of the participants in terms of age and sex. It can be observed that the participants of the study were mostly 19 (48.7%) and 18 (44.5%) years of age. This is so, since they are all tertiary (1st year) students in a private university of Cebu, Philippines. It is believed that this age range (young adults), their engagement in physical activity have greatly diminishing or declining [20]. Further, the participants are mostly female (75.3%) which according to the study that women are greatly influenced by their parents in terms of the engagement in physical activity [21].

Table 2. Participants' Blood Types

Blood Category	F	%
Blood Type "A"	46	17.50
Blood Type "B"	77	29.27
Blood Type "AB"	43	16.35
Blood Type "O"	97	36.88
Total	263	100

Blood Type has been analyzed using frequency and percentage distributions. It has been revelled in Table 2 that among the 263 participants, the sample has been mostly composed of those who belong to "O" blood type, f=97, 36.88%. This has been marginally followed by the Blood Type "B" group, f=77, 29.27%. A lesser distribution of the sample composed blood types "A" and "AB", f=46, 17.50% and f=43, 16.35%, respectively. Apparently, in the Philippines blood type "O" and blood type "A" are the dominating blood categories among the Filipino people [22].

Table 3 presents the descriptive analysis of the participants in terms of their physical fitness capability. In terms of their flexibility fitness level, it has been indicated that most of the participants have a very good capacity to extend their range of motion in performing the flexibility test with a mean of 73.68 and standard deviation of 15.09. This further implies that the participants' flexibility fitness capability at the start of the study is already high. Power on the other hand, posited a below average

Table 3. Descriptive Measures of the Physical Fitness Capability of the Participants (n=263)

Fitness Component	M	SD	Interpretation
Flexibility	73.68	15.09	Very Good
Power	36.22	14.61	Below Average
Agility	36.45	7.32	Excellent
Speed	7.51	2.01	Poor
Anaerobic	15.99	6.09	Below Average
Aerobic	1476.99	358.45	Poor

Table 4. Chi – square Analysis between the Blood Types and Physical Fitness Capability

Variable	Computed Chi – square	df	p-value	Significance	Result
Blood Type					
Aerobic	9.248	12	.682	Not Significant	Accept Ho
Speed	9.104	12	.684	Not Significant	Accept Ho
Agility	10.174	9	.337	Not Significant	Accept Ho
Anaerobic	22.704	12	**.030**	Significant	Reject Ho
strength	15.862	18	.602	Not Significant	Accept Ho
Flexibility	21.645	12	**.042**	Significant	Reject Ho

result with a mean of 36.22 and standard deviation of 14.61. This means that the participants' capability to resist resistance in lifting heavy objects displayed low level. While, participants in terms of their agility signifies excellent result with a mean of 36.45 and standard deviation of 7.32. This can be indicated that participants of the study have self – acquired efficiency in terms of body coordination while moving. However, participants' speed yielded poor result with a mean of 7.51 and standard deviation of 2.01. The result implies that the participants have low level in terms of movement displacement that requires time and distance. Similarly, in the account of anaerobic fitness level of the participants, it can be interpreted that the result is below average with a mean of 15.99 and standard deviation of 6.06. The result implies that at the start of the study, participants are not good in high intensity interval training and/or exercise that does not required so much oxygen. Lastly, the participant's aerobic fitness level is interpreted as poor with a mean of 1476.99 and standard deviation of 358.45. This can be interpreted that the participants at the start of the study cannot endure prolonged displacement of movements with respect to time. Overall, the participants fitness capability varies in the different fitness components that might have affected the results of the association between two variables.

Table 4 presents the association of blood types to the physical fitness capability of the participants in physical activity. Among the 6-fitness capability, only two (2) components were associated to blood types. It was found out that anaerobic fitness capability is associated to blood type with p - .030. Anaerobic fitness are exercises or physical activity that requires high intensity training and does not need too much oxygen in producing body movements. Some examples of anaerobic physical activity are weightlifting, jumping, sprinting, and biking. While, flexibility, on the other hand is the extent of the range of motion to reach in the next step, showed a good association with blood type with the p - .042. Some of the flexibility physical activity are gymnastics, ballet, dancing, and other activities the uses the extension of muscles or muscle groups.

The table 5 explains the likelihood ratio analysis of each of the blood type to fitness capability specifically on anaerobic fitness in physical activity. It was shown that blood type "A" is likely has the most potential in anaerobic fitness component which has 57.1% likelihood ration which is interpreted as above average. The result reveals that among the 4 types of blood, blood type "A" has the highest attribution or association to anaerobic fitness capability.

The table 6 shows the likelihood ration of blood type to fitness capability specifically on flexibility fitness component. Blood type O has the highest likelihood ration of 79.1% which is interpreted above average and followed by A (60.7%) and B (55.3%). It explains that blood type O is the most flexible among the blood types. Flexibility is described as the movement range of a person which can be commonly seen in some exercises such as splits, bridge stand, one- leg stand, high kicks and many more.

Discussion

The association of blood type and physical fitness capability is not been explored based on the literature review of the study. Physical fitness is

Table 5. Likelihood Ratio Analysis of Blood Type to Anaerobic Fitness Capability

Chi-square 26.240, p-value .010, Likelihood value 27.340, p – value .007	Anaerobic					Total
	P	BA	A	AA	E	
Blood Type						
A						
Count	5	0	4	16	3	28
% within Blood Type	17.9	0	14.3	57.1	10.7	100
% within Anaerobic	21.7	0	10.5	35.6	12.0	19.4
B						
Count	5	9	14	9	10	47
% within Blood Type	10.6	19.1	29.8	19.1	21.3	100
% within Anaerobic	21.7	69.2	36.8	20.0	40.0	32.6
AB						
Count	7	2	9	4	4	26
% within Blood Type	26.9	7.7	34.6	15.4	15.4	100
% within Anaerobic	30.4	15.4	23.7	8.9	16.0	18.1
O						
Count	6	2	11	16	8	43
% within Blood Type	14.0	4.7	25.6	37.2	18.6	100
% within Anaerobic	26.1	15.4	28.9	35.6	32.0	29.9
Total						
Count	23	13	38	45	25	144
% within Blood Type	16.0	9.0	26.4	31.2	17.4	100
% within Anaerobic	100	100	100	100	100	100

mostly associated to cognitive function [23], body composition indices [24], movement capability [11], academic performance [25, 26], self-control [27], and school and neighbourhood [28]. While, blood types were associated to stress [29], personality [10], cognitive impairment and dementia [30], behavior [31], and career development and organizational practices [32]. Thus, the study explained the association of the two variables and provided evidences to support the claims.

In terms of the distribution of blood type among the participants in Table 2, most of them are in blood type "O". Identifying the blood type of the participants had been carefully selected in the study so that there are enough representations of the different blood types. Further, to directly explain its association to the physical fitness capability of the participants. However, Philippines is dominantly blood type "O" and "A" [22]. Further, it is not only in the Philippines that "O" blood type is prevalent but also worldwide [33]. It is believed that this blood type has the potential in fighting against human pathologies [34], such as cancer [35], cardiovascular disease [36], diabetes [37], and venous thrombosis [38]. Thus, the representation of blood type "O" in this study might have affected the results of the study. However, this can be considered as the limitation of the study and a new area or topic for research.

Subsequently, Table 3 presents that the participants differ in their physical fitness capability in terms of the 6-fitness components as their baseline assessment in their fitness level. In the physical fitness capability, 4 out of six components such as power, speed, aerobic, and anaerobic are in poor level while 2 out of six components such as flexibility and agility are in high level. This implies that the participants of the study are more flexible and agile. Flexibility is the extent of the range of motion to reach next step while agility projects strong body coordination with respect to time [39]. Moreover, the participants of this study are likely to be capable on exercises that requires stretching, muscle extension, exhibiting sequencing, fractionating, and isolating their movements in the selective capacity.

In the Chi – square analysis of the association of blood types and fitness capability of the participants as presented in Table 4, it was found out that among the six (6) physical fitness components only anaerobic fitness and flexibility fitness were associated to blood types. Anaerobic fitness capability of the participants is significantly associated to blood type with p-.030. Anaerobic exercise is defined as a very short duration but intense physical activity and been fuelled and independent on inhaled oxygen

Table 6. Likelihood Ratio Analysis of Blood Type to Flexibility Fitness Capability

Chi-square 31.460, p-value .002, Likelihood value 30.506, p – value .002	Flexibility					Total
	P	BA	A	AA	E	
Blood Type						
A						
Count	1	0	9	17	1	28
% within Blood Type	3.6	0	32.1	60.7	3.6	100
% within Flexibility	50.0	0	18.4	20.2	100	19.4
B						
Count	1	2	18	26	0	47
% within Blood Type	2.1	4.3	38.3	55.3	0	100
% within Flexibility	50.0	25.0	36.7	31.0	0	32.6
AB						
Count	0	5	14	7	0	26
% within Blood Type	0	19.2	53.8	26.9	0	100
% within Flexibility	0	62.5	28.6	8.3	0	18.1
O						
Count	0	1	8	34	0	43
% within Blood Type	0	2.3	18.6	79.1	0	100
% within Flexibility	0	12.5	16.3	40.5	0	29.9
Total						
Count	2	8	49	84	1	144
% within Blood Type	1.4	5.6	34.0	58.3	.7	100
% within Flexibility	100	100	100	100	100	100

as an energy source in performing physical activity [40]. Sprinting, power lifting, high-intensity interval training and others are examples of anaerobic fitness exercises. In engaging in anaerobic exercises allows the increase in lactate and metabolic acidosis in the body [41]. It is believed that anerobic exercises can benefit the cardiovascular system of the body and decrease cardiovascular diseases [42]. Moreover, anaerobic exercise has positive influence on lipid profile and effective for weight loss [43]. The association of anaerobic fitness to blood type implies that performance in HIIT physical activity can be influenced by the types of blood the person possesses. Thus, physical activity that involves anaerobic fitness such as in sports competition, blood types must be considered.

Flexibility, on the other hand, is the capability of the body to extent in certain range of motion (ROM). Engaging in flexibility exercises prevent the chance of getting injury, correct muscle imbalances, develop good posture, and increase the joint range of motion [44]. Further, long - term engagement in flexibility/stretching exercise allows long – term muscle elastic changes which in a way increases the range of motion and decreases muscle – tendon injury [45]. Moreover, regular stretching/ flexibility either before or after an exercise elevates the maximal voluntary contraction, contraction velocity, eccentric and concentric contraction force, counter-movement jump height, and 50-yard dash time of the individuals [46]. With the positive association of flexibility to blood type with p-0.042, it implies that flexibility capability of an individual can be attributed to blood type. Thus, in physical activity engagement that involves flexibility, blood type of a person must be considered especially in sports and dance competitions.

Table 5 presents the likelihood ratio analysis of blood type to anaerobic fitness capability of the participants. Among the blood types only "A" blood type is associated to anaerobic fitness of the participants with the likelihood ration of 57.1%. Though, the likelihood ration is not that high but it is enough to show its positive relationship. It might be also that at the baseline assessment of the participants in terms of their level of anaerobic fitness is below average *(M=15.99, sd=6.09)* that has affected the viability of the association. There might be changes in the association if the baseline assessment of the participants on anaerobic fitness is high. This will be another area to be explored particularly on its fitness level. Moreover, this association implies that individuals with blood type "A" has the potential to excel in exercises or physical activities that requires intense but short duration physical activity such power lifting, sprinting, and other high – intensity interval training exercises. This further implies to the sporting events, that choosing athletes that requires anaerobic exercises such weight lifting, sprint, long jump, javelin throw, discus throw, cycling and many others, blood type "A" must be considered.

On the other hand, flexibility fitness capability is associated to blood type "0" with the likelihood ration of 79.1%, blood type "A" with 60.7%, and blood type "B" with 55.3%. The results present that most of the blood types are associated to flexibility except for blood type "AB" with the likelihood ration of 26.9%. In the distribution of participants in terms of blood type, blood type "AB" had the lowest participation among the participants. This might be the cause why it does not show good association to flexibility fitness. Thus, this is also considered as the limitation of the study. However, it is clearly shown in the results that the viability of the relationship or association of blood type "O" to flexibility fitness capability of the participants is indeed very high. In other studies, it was explained that blood type "O" excels in endurance performances such as running event and believed to have a strong survival instinct than other blood types [47]. Further, "O" blood type is believed to have a better association to concentration index in the performance of sports [48]. Thus, the study proves that blood type "O" individuals potentially have the edge and ease in performing physical activity that requires extension of joint muscles and/or stretching. Being flexible allows individual to prevent muscle injury and have sense of good balance and posture. This indicates that the capability of the individuals most specifically those with blood type "O" can be seen to excel in physical activities either in sports or dance such as gymnastics, diving, surfing, combative sports, figure skating, dance, cheerleading, pole vaulting, skiing, etc. Further, selecting players or athletes that requires flexibility, blood type "O" must be considered.

The study provides significant explanation on the relationship or association of blood types to physical fitness capability in performing physical activity. Though, not all fitness capability were associated to blood type but it provides good grasp of understanding and knowledge that blood type can be a determining factor in the fitness capability of an individual in performing physical activity especially on an anaerobic and flexibility fitness capability. Further, this can somehow elaborate that the capability of an individual in performing physical activity can be traced and attributed to blood types.

Conclusions

It has been concluded that physical fitness capability of an individual can be attributed or influenced by the type of blood he/she possesses. Thus, in the context of sports and dance competition that requires specific fitness level, it is recommended to consider blood types of a person.

Conflicting Interest

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ORIGINAL ARTICLE

Evaluation of respiratory function indicators of elite athletes in academic rowing using the method of computer spirography

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Abstract

Background and Study Aim In modern sports, the research and study of the functional capabilities of athletes' breathing is relevant. The analysis of individual results made it possible to form an idea about the respiratory functions of athletes. Among elite athletes, parameters of respiratory functions are significantly higher than the norm, so their interpretation relative to the general healthy population is inadequate. The purpose of the study is to determine lung volumes and dynamic parameters of the respiratory act and their difference in height and weight categories, respectively.

Material and Methods The study involved 22 elite athletes aged 19-24 took part in the study. Testing of all athletes was carried out during the period of preparation for the competition The following research methods were used: method of anthropometry; method of computer Spirometry (was used to assess the functional state of reserve possibilities of the external breathing of athletes by absolute indicators). The studied material was processed by the methods of mathematical statistics using the "Statistica 6.0" software and MS Excel. Athletes were divided into three groups of height categories: group-A (190 cm and above), group-B (180-189 cm), group-C (170-179 cm) and three weight categories: group-D (90 kg and above), group-E (80-89 kg), group-F (70-79 kg).

Results Studies have shown that the absolute values of respiratory functions in athletes with significant hight and significant body weight are higher than in athletes with short height and insignificant weight. Real indicators of respiratory functions in most athletes are within the normal range. The highest actual indicators of respiratory functions are observed in the group of athletes with average height and average body weight. Also, in elite athletes with average height and average body weight, individual actual indicators are practically the same.

Conclusions Planning and construction of the training process requires knowledge of absolute and actual indicators of respiratory functions. The conducted research made it possible to establish the level of functional reserves of power and mobilization functions of breathing in elite-level rowers. The results allow effective planning of physical activity during training.

Keywords: lung volumes, respiratory system, elite athletes

Introduction

Modern sports science research is impossible without training planning knowledge. Bubka et al. [1], Naglak [2], Platonov [3] stated that training planning is related to physical, technical-tactical and psychological training. According to other scientists [4, 5, 6] when planning physical activity, it is necessary to take into account the current state and functional capabilities of the athlete's body systems. In the scientific literature [7, 8, 9, 10, 11, 12] it is proposed many methodological approaches and a list of parameters that largely reflect the functional fitness of athletes who specialize in various sports.

Malikov et al. [6] emphasized that today it is extremely necessary to expand and practically implement new innovative methods of functional research that would satisfy the demands of modern requirements. Bazzucchi et al. [13] note that information about the functional state of an athlete's body is necessary for timely obtaining data on determining the level of training, and is one of the necessary conditions for achieving high results in sports. As Bourgois [14] notes, it is no less important to study quantitative indicators of the functional capabilities of the respiratory system of the athletes' body, which allow establishing the most promising approach to improving physical fitness. This problem arises when training athletes who specialize in cycle sports, including academic rowing [15]. Pengcheng et al. [16] emphasize the parameters of functional indicators, namely the respiratory functions of elite athletes, as they are important in the process of planning the training load. Okun et al. [17] established that the construction and planning of the training process of rowers depends on the assessment of the functional capabilities and dynamics of the performance of the

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athlete's body.

Omelchenko [18] indicated the need to use modern innovative research methods, primarily cardiointervalography. The received data and the analysis of the athlete's functional capabilities allow from a scientific point of view to make adjustments to the physical load in the training process of training athletes. Also, the results of functional capabilities provide an opportunity to increase the specialized focus of physical activity. In addition, these data make it possible to form a complete structure of the functional support of athletes according to their individual capabilities.

According to the research of other [4, 15, 19], in sports with a predominant manifestation of endurance, the functional state of the external respiratory system plays an important role. Determining the level of the functional state of the respiratory system is extremely important for rational planning and control of functional capabilities.

In the practice of sports, such methods include computer Spirometry, which allows you to explore the functions of external respiration, including the measurement of volumetric and speed indicators of respiration. Evaluation of the results of a computer spirographic study allows you to compare the actual values of respiratory parameters with the normative («ideal»), to assess the level of functionality of the respiratory system or its disorders. Recently, in sports, the study of respiratory functions by the computer Spirometry method has been of great importance in cyclic endurance sports (rowing, cycling, swimming, cross-country skiing, triathlon, etc.). Analyzing the data obtained in the process of the computer Spirometry method, sports physicians and coaches can obtain information not only on the absolute indicators of the respiratory system, but also on the reserve respiratory capabilities of athletes, taking into account various factors (age, gender, weight, height, specifics of the sport, psychological the physical state of the organism, natural climatic conditions, etc.). Thus, the study of the parameters of the respiratory system of rowers using the computer Spirometry method is relevant.

It is assumed that obtaining data on the reserve capabilities of external breathing of rowers athletes will allow to establish identity or differences according to the absolute indicators of the dynamic parameters of the respiratory act.

Material and Methods

Participants

22 elite athletes aged 19-24 took part in the study. The average sports experience was 7.2 years. This study was conducted by the Declaration of Helsinki and was approved by the Ethics Committee of University. All participants had provided written informed consent.

Research Design

The method of computer Spirometry was used to assess the functional state of reserve possibilities of the external breathing of athletes by absolute indicators:

- tidal volume (VT) – the volume of air inhaled or exhaled during each respiratory cycle;
- inspiratory vital capacity ($VC_{inspiratory}$) – the largest volume measured on complete exhalation after full inspiration;
- inspiratory reserve volume (IRV) – the maximal volume of air inhaled from end-inspiration;
- expiratory reserve volume (ERV) – the maximal volume of air exhaled from end-expiration;
- breathing rate (BR) – the number of breaths in a minute;
- minute ventilation (MV) – breathing rate × tidal volume – the total volume of air entering the lungs in a minute;
- forced vital capacity (FVC) – the total volume of air that can be exhaled during a maximal forced expiration effort;
- forced expiratory volume in one second (FEV1) – the volume of air exhaled in the first second under force after a maximal inhalation;
- maximal voluntary ventilation (MVV) - a pulmonary function test that measures the maximum amount of air a person can inhale and then exhale with voluntary effort.

In the process of calm breathing, the spirogram (the graph of changes in the volume of inhaled and exhaled air) and the pneumotachogram (the graph of changes in the speed of the air flow over time) of the athlete's breathing are recorded in real time.

An idea about the functions of external breathing during Spirometry is formed on the basis of the analysis of lung volumes and dynamic characteristics of the respiratory act. Each of the spirographic indicators is compared with its proper value, which is calculated according depending on gender, age, and height and body weight. The actual indicators are taken as 100%, and the actual values obtained in the research process are displayed as a percentage of the proper ones.

Statistical Analysis

Statistical analysis of the obtained data was performed using licensed MS Excel and "Statistica 6.0". The main indicators of mathematical statistics were: $\bar{X}$– mean, SD – standard deviation, CV – coefficient of variation. A calculation was used to compare indicators between groups t_{score} – student's, the level of significance was taken as $p<0.05-0.001$.

Results

The parameters of the main lung volumes and dynamic parameters of the respiratory act of rowers are given in table 1. The results of the study were

Table 1. Indicators of the main lung volumes and dynamic parameters of the respiratory act

Indicators / Group	Mathematical statistics	Basic lung volumes: VT (L)	$VC_{inspiratory}$ (L)	$VC_{inspiratory}$%	IRV (L)	IRV%	ERV (L)	ERV%	Dynamic parameters of the respiratory act: BR, (mov/min)	MV, (L/min)	FVC (L)	FVC%	FEV1 (L)	FEV1%	MVV (L)	MVV%
Growth categories (sm)																
Group-A (n=10, 195.4±4.2)	X̄	1.1	5.6	91.8	2.6	89.7	2.6	89.7	17.9	18.2	5.4	89.6	4.6	91.0	170.5	83.9
	±*SD*	0.3	0.3	6.4	0.5	15.9	0.5	15.9	4.2	5.1	0.4	7.6	0.4	6.8	19.7	11.1
	V	26.2	6.2	7.0	17.2	17.7	17.2	17.7	23.4	2.2	7.1	8.5	7.6	7.5	11.5	13.2
Group-B (n=7, 184.7±2.2)	X̄	0.9	5.7	102.7	2.6	98.6	1.6	98.0	12.7	13.8	5.4	99.3	4.3	92.6	156.0	85.9
	±SD	0.2	0.6	7.67	0.4	13.1	0.2	12.9	5.1	3.4	0.4	4.9	0.3	5.2	12.0	5.3
	V	22.4	10.0	7.5	14.2	13.3	12.5	13.1	39.9	24.5	7.5	4.9	6.9	5.6	7.7	6.2
Group-C (n=5, 176.0±2.0)	X̄	0.7	4.6	89.6	2.8	129.0	1.5	83.8	17.3	12.8	4.1	79.6	3.4	80.6	120.8	81.0
	±SD	0.1	0.5	7.3	0.6	28.0	0.2	27.8	1.3	2.5	0.8	11.3	0.6	15.5	19.7	24.0
	V	19.5	10.0	8.1	21.1	21.7	15.1	33.2	7.6	19.6	18.5	14.2	18.6	19.3	16.4	29.6
$p_{A,B}$		0.76	0.25	3.09	0.05	1.26	0.66	1.04	2.19	2.09	0.02	3.19	2.10	0.54	1.89	0.48
$p_{B,C}$		2.09	3.75	3.01	0.77	2.26	0.13	1.06	2.28	0.62	3.48	3.66	2.97	1.66	3.55	0.44
$p_{A,C}$		2.84	4.54	0.57	0.73	2.91	0.69	0.42	0.38	2.73	3.60	1.79	4.07	1.43	4.60	0.26
Weight categories (kg)																
Group-D (n= 8, 94.8±4.2)	X̄	1.2	5.8	95.0	2.7	93.6	1.5	83.3	16.9	18.9	5.5	91.5	4.6	90.1	167.4	82.6
	±SD	0.3	0.5	9.5	0.5	16.8	0.3	18.5	4.8	5.8	0.4	8.4	0.4	5.9	22.6	10.6
	V	23.1	8.8	10.0	16.7	18.0	20.4	22.2	28.6	30.6	7.7	9.2	8.6	6.5	13.5	12.9
Group-E (n=7, 84.9±3.3)	X̄	0.9	5.3	97.3	2.6	100.0	1.6	103	17.5	14.9	5.1	93.9	4.2	91.3	137.4	79.0
	±SD	0.1	0.5	8.6	0.3	13.1	0.3	17.7	2.6	2.2	0.4	7.6	0.4	10.5	28.5	12.3
	V	14.9	9.5	8.9	11.4	13.1	16.4	17.2	14.8	14.8	8.5	8.0	10.1	11.5	20.7	15.6
Group-F (n=7, 76.7±1.8)	X̄	0.8	4.9	92.0	2.6	111.9	1.4	76.9	13.8	12.4	4.6	85.7	3.9	85.9	142.7	90.1
	±SD	0.2	0.5	7.4	0.5	29.8	0.5	32.7	4.9	3.1	0.8	11.8	0.7	11.9	19.7	17.6
	V	21.7	11.0	8.1	18.7	26.6	35.8	42.6	35.1	24.7	18.4	13.7	17.1	13.9	13.8	19.6
$p_{D,E}$		2.80	1.79	0.49	0.55	0.82	0.70	2.11	0.30	1.85	1.90	0.57	1.78	0.26	2.24	0.61
$p_{E,F}$		3.39	3.22	0.69	0.47	1.43	1.09	0.75	1.22	2.77	2.43	1.08	2.54	0.86	2.27	0.98
$p_{D,F}$		1.11	1.46	1.23	0.03	0.96	1.52	1.96	1.76	1.71	1.23	1.54	1.17	0.90	0.40	1.37

Note: VT - tidal volume, $VC_{inspiratory}$ - inspiratory vital capacity, $VC_{inspiratory}$ % - actual indicators inspiratory vital capacity, IRV - inspiratory reserve volume, IRV% - actual indicators inspiratory reserve volume, ERV - expiratory reserve volume, ERV% - actual indicators expiratory reserve volume, BR – breathing rate, MV - minute ventilation, FVC - forced vital capacity, FVC % - actual indicators forced vital capacity, FEV1 - forced expiratory volume in one second, FEV% - actual indicators forced expiratory volume in one second, MVV - maximal voluntary ventilation, MVV%- actual indicators maximal voluntary ventilation; X̄ – mean, SD – standard deviation, CV – coefficient of variation; ▇ - significant differences t score – Student's as p<0.05-0.001

analyzed by groups of growth categories (group-A, group-B, group-C) and weight categories (group-D, group-E, and group-F).

The VT indicators of rowing athletes of two categories are directly dependent - the higher the height and weight of the athlete, the higher the VT indicator. Note that VT indicators in each group are heterogeneous, as evidenced by the coefficient of variation. According to score - Student's t-test, the reliability of differences (p<0.05) in height category between group-A and group-C, in weight categories between group-D and group-E, between group-E and group-F is monitored.

In the $VC_{inspiratory}$ indicators, there is no dependence with height and weight categories, it is practically the same in all groups of rowing athletes. However, there are significant differences according to score - Student's in growth indicators. It is important to note that this indicator characterizes the functional capabilities of the external breathing apparatus. The value of FVC depends on both the size of the lungs and the strength of the respiratory muscles. The $VC_{inspiratory}$ structure consists of IRV and ERV, which characterize the potential capabilities of the external respiratory system and can indicate the strength of the respiratory muscles.

In rowers of all groups, the actual indicators of FVC%, IRV% and ERV% are normal and correspond to the average level of functional reserves. At the same time, in groups by growth categories, the lowest level of functional reserves of $VC_{inspiratory}$% y according to this indicator is observed in group-C and the highest in group-B. In groups by weight categories, the lowest level of functional reserves is observed in group-F, and the highest in group-E. So, the best level of functional reserves according to the actual indicators of $VC_{inspiratory}$% of the appropriate indicators was demonstrated by rowers with average height and body weight, and the worst by rowers with short height and insignificant body weight. In group-C and group-F athletes, a significant percentage of actual IRV% indicators were determined. The obtained indicators testify to the high potential of the external respiratory system of our subjects in groups with low height and low body weight. Rowers of group-A and group-D had the lowest actual IRV% (89.7% and 93.6%, respectively), namely rowers with high height and overweight. We conclude that inspiratory muscles are the most trained in rowers with short height and low body weight, and the least trained are in rowers with the highest height and the largest body weight. The actual ERV% is within the normal range in all groups. The highest actual ERV% indicators among height categories were determined in group-B, the lowest in group-C, among weight categories the highest in group-E, the lowest in group-F. This indicates the most powerful and trained exhalation in rowers of average height and average body weight. The least powerful exhalation was observed in rowers of short stature and the lowest body weight. We note that significant differences according to t_{score} - students were determined in the actual IRV% indicator between group-A and group-C ($p<0.05$). The coefficient of variation in $VC_{inspiratory}$ indicators has no differences, in were determined in the IRV and ERV indicators differences. With the most significant differences in athletes with short height (group-C) and low body weight (group-F).

Analyzing the dynamic parameters of the respiratory act (table 1), BR in groups of rowing athletes is within the normal range and ranges 12.7-17.9 mov/min. The lowest indicators were determined in group-B and group-F. Such indicators testify to the efficiency of breathing of rowers. We note that there are intragroup differences in BR indicators, as evidenced by the coefficient of variation, which ranged 14.8-39.9%, with the exception of group-C, the smallest growth category.

The value of MV in rowers varies within fairly wide limits 12.4-18.9 L/min. The results presented in table 1 indicate a proportional increase in these indicators relative to the height and body weight of the rower athlete. The largest MV is observed in group-A from the height category and in group-D from the weight category, and the smallest in group C from the height category and group-F from the weight category. Significant intragroup discrepancies of MV indicators were established, as the coefficient of variation ranged – 14.8-30.6%.

The FVC indicators in groups of rowing athletes are practically the same and are within 4.1-5.4 L, and her actual FVC% indicators were determined at the level of 79.6-99.3%, which correspond to age norms. We note that the actual indicators of FVC% are the best in group-B and group-E, that is, with average indicators of body height and body weight of rowers. The lowest actual indicators of FVC% in rowers were determined in group-C and group-F with the smallest height and insignificant body weight. We point out the fact that significant differences according to t_{score} – Student's at $p<0.01$ were determined in growth categories: FVC – between group-B and group-C, between group-A and group-C; actual indicators of FVC% – between group-A and group-B, between group-B and group-C.

The FEV1 indicators in groups of rowing athletes are practically the same and are within 3.4-4.6 L, the actual FEV1% indicators were determined at the level 80.6-92.6%. We note that FEV1 indicators decrease in each height and weight category, the higher the height and weight category, the higher the indicators. Discrepancies between the results of FEV1 and their actual FEV1% in group-C and group-F were established, which indicates a significant range with low height and insignificant weight of rowers. There were no significant differences between the groups. It was established that the best bronchial patency according to the actual FEV1% is observed in rowers with average height and average body weight, and the worst - with short height, and insignificant body weight.

MVV characterizes not only the potential capabilities of the external breathing apparatus, but also the degree of mobilization of these capabilities. In rowers, MVV and its actual values MVV% is within the normal range. There is a decrease in MVV in groups of height categories, namely, the smaller the height, the lower the indicators. In group-C, they are the lowest. In group-A and group-C growth categories, in group-D, group-E, group-F there are intra-group differences in the coefficient of variation. There was a significant difference between group-A and group-B, between group-A and group-C according to t_{score} - Student's at $p<0.01$.

Figure 1 shows the individual indicators of

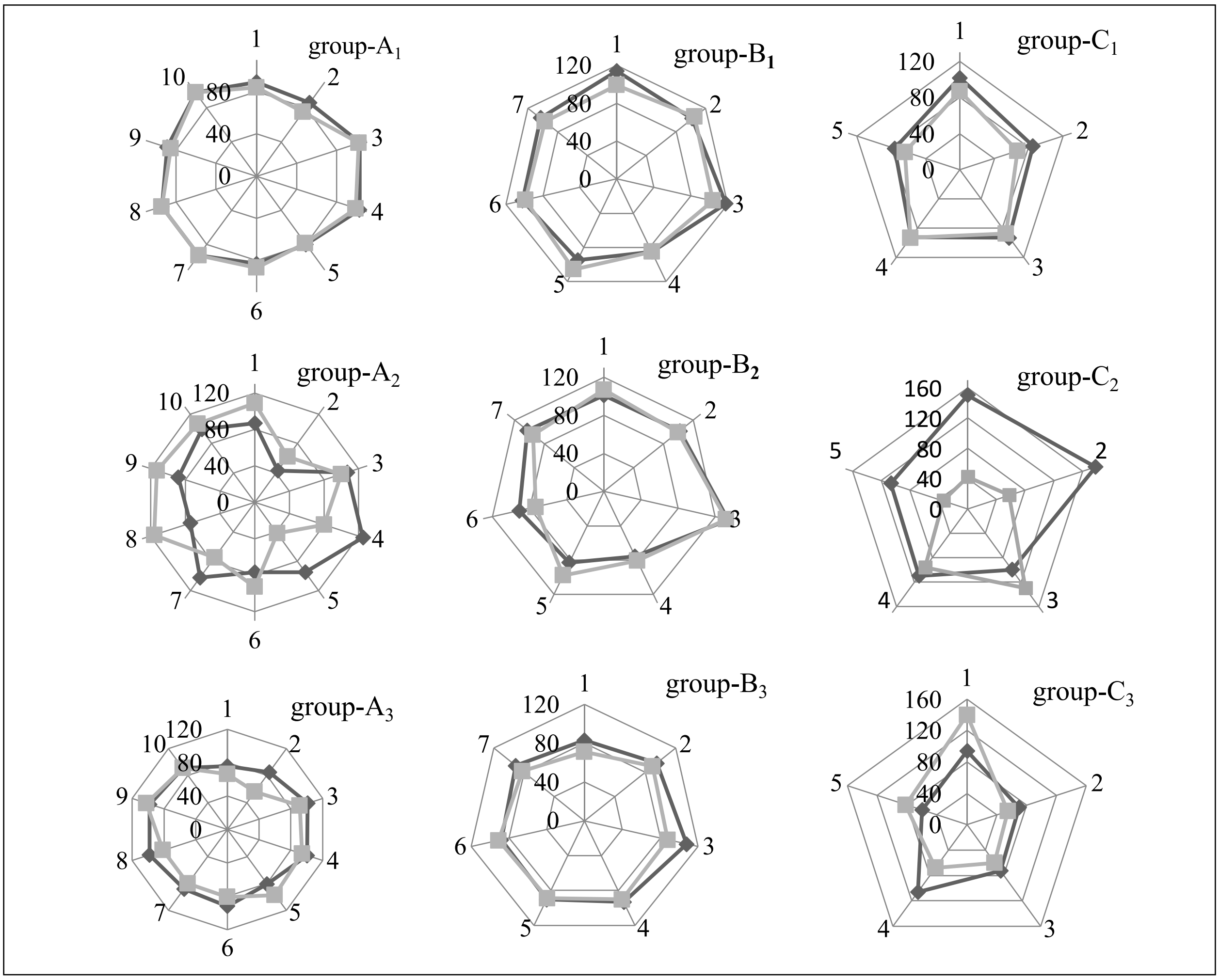

Figure 1. Individual actual indicators of reserve breathing capabilities of rowers athletes of growth categories: group-A$_1$, group-B$_1$, group-C$_1$ —— individual actual indicator VCinspiratory %, —— individual actual indicator FVC%; group-A$_2$, group-B$_2$, group-C$_2$ —— individual actual indicators of IRV%, —— individual actual indicators of ERV%; group-A$_3$, group-B$_3$, group-C$_3$ —— individual actual indicators of FEV1%, —— individual actual indicators of MVV%; 1-10 athlete.

the reserve capabilities of the respiratory system of athletes, taking into account growth data. In group-A$_1$, group-B$_1$ and group-C$_1$, the actual indicators of VC$_{inspiratory}$% and FVC% of rowing athletes are presented, which indicate the following: individual data of athletes of group-A$_1$, group-B$_1$ and group-C$_1$ are within 75%-102% and have no significant differences. Almost the same indicators of VC$_{inspiratory}$% and FVC% in all group-B$_1$ rowers.

The actual indicators of IRV% and ERV% of rowers are shown in figure 2 (group-A$_2$, group-B$_2$ and group-C$_2$). It should be noted that the greatest differences are observed in group-A$_2$ rowers in ERV% indicators and in IRV% indicators. In group-B$_2$ rowers, slight differences in these indicators are observed, in group-C$_2$ the difference in indicators is significant in ERV%.

In Figure 2, group-A$_3$, group-B$_3$ and group-C$_3$ show the actual indicators of FEV1% and MVV%. In the athletes of group-A$_3$ and group-B$_3$, there are no large differences between the indicators of athletes, which are within 60-100%, and in group-C$_3$, and vice versa, there are quite significant differences – 50-100% in FEV1% and even greater in indicators of MVV% – 44-140%.

Figure 2 presents individual indicators of the reserve capabilities of the respiratory system of athletes, taking into account weight categories. In group-D$_1$, group-E$_1$ and group-F$_1$, we do not observe significant differences in the indicators of VC$_{inspiratory}$% and FVC%, they are within 80-100%.

There are differences in rowing athletes in IRV% and ERV% indicators (figure 2; group-D$_2$, group-E$_2$, and group-F$_2$). In group-D$_2$, the IRV% range 42-107%, the ERV% range 62-107%. In group-E$_2$, the IRV% indicators are 80-130%, and the ERV% indicators are 70-130%. IRV% indicators in group-F$_2$ have the largest differences 75-178%, and ERV% indicators 34-116%.

Figure 2 shows individual actual FEV1% and

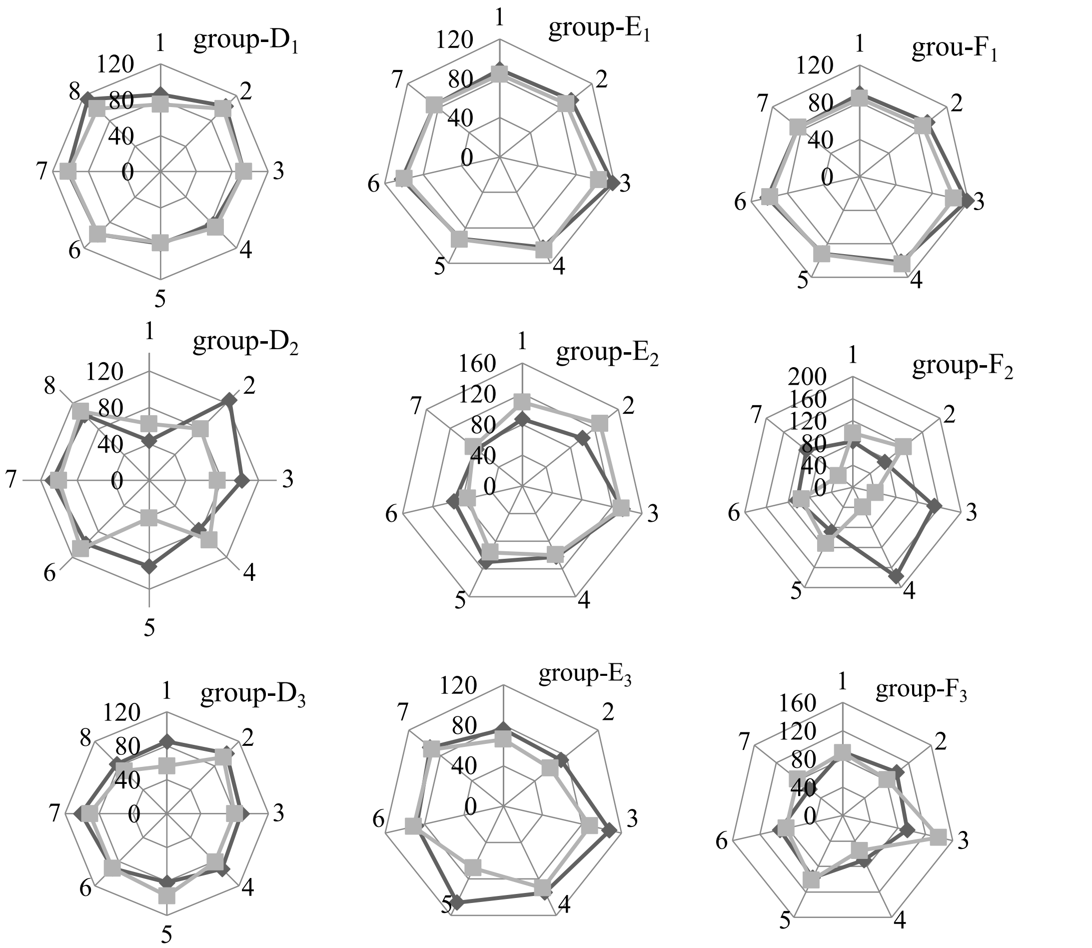

Figure 2. Individual actual indicators of the reserve capabilities of the respiratory system of athletes, taking into account weight data in %: group-D_1, group-E_1, group-F_1 - —— individual actual indicator VCinspiratory%, —— individual actual FVCindicator%; group-D_2, group-E_2, group-F_2 – —— individual actual IRV%, —— individual actual ERV%; group-D_3, group-E_3, group-F_3 – —— individual actual indicators FEV1%, —— individual actual indicators MVV%; 1-8 – an athlete.

MVV% indicators in group-D_3, group-E_3 and group-F_3. The results indicate slight differences in these indicators of group-D_1 and group-E_1. In the FEV1% indicator, group-D_3 ranged 81-94%, group-E_3 ranged 60-106%; in the MVV% indicator group-D_3, the discrepancy was 56-97%, group-E_3 – 60-90%. A significant discrepancy was determined in group-F_3 in FEV1% –55-102%, in MVV% – 55-140%.

Discussion

Assessment of the state of external breathing functions is an important study that allows observing the proper and actual performance of athletes. The results of studies of the functional state of external breathing, namely the main lung volumes and dynamic parameters of the breathing act of rowers, were not previously the subject of detailed scientific studies taking into account height and weight categories. This fact makes it impossible to compare the obtained data with other categories of athletes.

Numerous studies have proven that there is a relationship between respiratory functions and an athlete's anthropometric indicators, namely athlete's weight and athlete's height [20, 21, 22]. It is also natural that athletes who are mainly engaged in endurance show changes in indicators of the functional state of the respiratory system, namely adaptive changes in spirometric indicators - FVC, $VC_{inspiratory}$, FEV1 [15] In the studies of Durmic et al. [23] noted the presence of a high correlation dependence of body weight indicators with respiratory function indicators of elite athletes, and the highest was observed between body weight indicators and MVV.

Our studies confirm this dependence in VT (1.1±0.3 and 1.2±0.3), $VC_{inspiratory}$ (5.6±0.3 and 5.8±0.5), ERV (1.5±0.5 and 1.6±0.5), MV (18.2±5.1 and 18.9±5.8), FVC (5.4±0.4 and 5.5±0.4), FEV1 (4.6±0.4 in two cases), MVV (170.5±19.7 and 167.4±22.6). The IRV indicator was the largest in group-C rowing athletes with the smallest height (2.8±0.6), almost the same indicators in group-D, group-E and Group-F weight categories of rowing athletes. Indicators of the efficiency of breathing of athletes, namely BR, indicate the most economical processes in group-B rowing athletes with average height and group-F with the smallest body weight (12.7±5.1 and 13.8±4.8).

It was established that most of the indicators of the dynamic parameters of the respiratory act (BR, FVC, FEV1, MVL) are within the normal range, while the indicators of the main lung volumes exceed the normal indicators (VT, $VC_{inspiratory}$, IRV) and naturally increase with increasing anthropometric indicators. The actual indicators of respiratory functions of the main lung volumes according to the results of our research, the best level of functional capabilities according to the actual $VCi_{nspiratory}$% have group-B rowers with average body height (97.3±8.6) and group-E with average body weight indicators (102.7±7.7). The most trained muscles during inhalation according to the IRV indicator, in group-C rowers with the smallest body height (129.0±28.0) and group-F rowers with the smallest body weight (111.9±29.8). The most trained muscles during exhalation according to the ERV index in group-B rowers with average body height (98.0±12.9) and group-E rowers with average body weight (103.0±17.7). The actual parameters of bronchial patency during maximal rapid exhalation after deep inspiration (FVC%) and total bronchial patency and lung elastic properties (FEV1) are the best in group-C rowers and group-E rowers of average height and weight categories (99.3±4.9 and 93.9±7.6; 92.6±5.2 and 91.3±10.5). The actual dynamic indicator of MVV% is the highest in group-C of the medium height category (85.9±5.3) and in group-F of the insignificant weight category (90.1±17.6).

Individual scientific results are subject to scientific discussion. This is due to the fact that sufficient differences in the coefficient of variation were determined. Significant differences in the indicators of the main lung volumes of rowers athletes of the highest and group-C of the lowest growth category were determined in group-A and group-C (VT, IRV, IRV%, ERV, ERV%; V=15.1-33.2%). Identical results were obtained in weight categories, group-D and group-F (VT, IRV, IRV%, ERV, ERV%; V=16.4-42.6%). In the indicators of the dynamic parameters of the respiratory act, such a pattern was determined in rowers group-C and group-F with the smallest height and insignificant body weight (V=4.2-29.6% and V=17.1-35.1%).

It has been established that rowing athletes have one of the high indicators of the main lung volumes and dynamic parameters of the respiratory act, which are higher, the higher the athlete's weight, height and qualifications. The data of our study of individual lung volumes and dynamic parameters of the respiratory act (FEV1/VC, MVV) are consistent with the study of Lazovic et al. [22] and Pezelj et al. [24], and in some indicators they are lower (VC, FVC, FEV1). This can be explained by the fact that the level of sports professionalism of Ukrainian rowers is inferior to the level of Finnish rowers, who belong to the sub-elite senior and elite senior group of rowers. Also, the results obtained in our study can be compared with the data of Omelchenko [18], Lazovic et al. [22] and Pezelj et al. [24], in which it is shown that rowers with lower indicators of height and body length also have lower indicators of respiratory functions (VT, IRV, ERV, MV, BR, FVC, FEV, MVV). Note that the data of our study are slightly lower than the data of Vovkanych et al. [25] and Ahsan and Mohammed Feroz [26] in the indicators of the main lung volumes by an average of 16%. An exception is the IRV indicator – the volume of air that a person can inhale additionally after a calm inhalation. This indicator is the same in both studies and is 2.6 liters. The research data of Ichiba et al. [27], on the contrary, are lower than the indicators of our study in the main lung volumes by 28-50%. In the indicators of the dynamic parameters of the breathing act of athletes, the data of our study coincide with the data of Çelik et al. [28] in the FVC indicator and are 4.6 liters. In other indicators of dynamic parameters (FVC, FEV1, MVV), our data coincide with the data of Ozmen et al. [29], Çelik et al. [28] and are slightly lower than the indicators of studies by Pezelj et al. [24], Vovkanych et al. [25], Ahsan and Mohammed Feroz [26], Ozmen et al. [29], Lazovic-Popovic et al. [30]. In the MVV indicator, these data are lower than the data of other authors by an average of 25%. Indicators of FVC, FEV1 from our study exceed the data of Komici et al. [31] by 21%.

Comparing the results with athletes involved in speed-power and strength sports with the studies of Lazovic et al. [24] confirmed that groups of athletes training for endurance had higher VC, FVC, MVV indicators compared to others. The results of our research are confirmed by the research of Vovkanych et al. [25], where the indicators of the main lung volumes (VT, VC, IRV, ERV) are within the same limits. These indicators are almost identical, except for the VT indicator, in which it is slightly higher in biathletes than in other studies. Other indicators of lung volumes are within the same limits. VT indicators are within 0.7-1.6 l, VC – 4.9-6.2 l, IRV – 2.6-3.1 l, ERV – 0.9-1.6 l. Indicators of the dynamic parameters of the respiratory act (BR, MV, FVC, FEV1, MVV) in the studies of Omelchenko [18], Lazovic et al. [22], Pezelj et al. [24], Vovkanych et al. [25], Ozmen et al. [29] are in the same ranges. They are: FVC - 4.3-5.9 l; FEV1 – 3.8-4.9 l; MVV - 142-180 liters. The exceptions are the indicators from the study [26], where the FVC indicator is 25% higher than the average indicators of other studies. FEV1 is also highest in groups of athletes who train for endurance [24] and in rugby players and football players. The MVV indicator is the largest in rugby players and football players [26] and is 207 L, which is 24.6% more than these indicators in groups of other athletes.

We supplemented the data on indicators of the main lung volumes and dynamic parameters of the respiratory act of rowers of height and weight categories. Presented individual indicators of the reserve capabilities of the respiratory system of athletes taking into account height and weight categories. Made an analysis, determined the differences in height and weight categories, respectively. These indicators are extremely important for timely obtaining data on the determination of the training level of athletes and are a necessary condition for achieving a high sports result.

Conclusions

The study of the absolute parameters of lung volumes and dynamic parameters of the respiratory act using computer Spirography made it possible to establish a high level of functional reserves of power and mobilization of respiratory functions of elite rowers.

The absolute values of the respiratory functions of athletes who have significant height and significant body weight are higher than those of athletes with short height and insignificant weight (VT, $VC_{inspiratory}$, ERV, BR, MV, FEV1, MVV). The actual indicators of respiratory functions in most athletes are within the normal range. The highest actual indicators of respiratory functions are observed in the group with average height and average body weight of athletes ($VC_{inspiratory}$%, ERV%, FVC%, FEV1%). In elite athletes with average height and average body weight of athletes, individual actual indicators of $VC_{inspiratory}$% are practically homogeneous, significant discrepancies are observed in other indicators.

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Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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