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ORIGINAL ARTICLE

A biomechanical examination of the inclusion of active flexibility in artistic gymnastic movements requiring mobility

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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 the study is a biomechanical examination of the inclusion of active flexibility in artistic gymnastic movements requiring mobility (muscles' ability to stretch), flexibility and other motor abilities such as force, power, etc.

Material and Methods The study included 17 girl gymnasts aged 7-9 years old, with a body height of 140.7±10.2, weight of 34.1±6.4, and a body mass index of 17.6±3.0. Data collection in the study was made by using performance tests developed by FIG such as a Forward-Backward Split, Side Spit, Arm-Trunk Angle Backward, Trunk Bent Forward, Leg Raise forward, Leg Raise Sideward, Bridge, Standing long Jump, Lift Trunk Forward-60secs, Angle Degree of the Leg Split Position in Cartwheel, and Arm-Upper Body Angle Backward in Bridge Technique. The Kinovea 0.8.15 program was used in the data analysis of the variables in the study. The SPSS 24 software program was used for the data analysis. Percentages of the angle degree calculated by the formula "%= (angle^0 of the mobility in functional movement / angle^0 of the active flexibility) *100" were found.

Results Results indicate that active flexibility was 90% functional in the leg raise sideward, 90% in the leg split during execution of the cartwheel, 17.5% in the bridge technique, and completely functional for the flexibility ratio expressed in the leg raise forward technique. In the analysis of the various elements of the similar biomechanics, the anatomic structure and similar body planes, it was concluded that active flexibility expressed in the movements required a mobility of around 65-75%.

Conclusions: It was determined that the functionality rate of the techniques requiring active flexibility and requiring mobility of the same biomechanical and anatomical structure was around 65-75%. Therefore, to execute 100% of the flexibility in action (during active elements) as it is in a passively or actively, it may significantly increase force, motor control, dynamic balance, coordination etc., in the large range of motion.

Keywords: functional flexibility, range of motion (ROM), biomechanics, techniques.

Introduction

Artistic gymnastics is a branch characterized by the difficulty degree of elements, which is determined according to biomechanical features. One of the many reasons for these difficulties is involvement of more than one motor ability in the same movement and execution of the movements in different body planes [1, 2]. This makes it more difficult to determine the dominance of the motor abilities in each movement on artistic gymnastics. However, despite the mix and unclear definitions found in the literature, it is not very difficult to determine the inclusion of general motor abilities such as power, speed, endurance and flexibility in each movement. However, there is no clearly defined mobility; a skill that can be defined as the ability to move actively through a range of motions [3, 4]. This means that mobility is a way of functional flexibility. Accordingly, it is an inevitable fact that mobility combines flexibility with motor skills such as force, power, etc. In artistic gymnastics, the essential element of active flexibility is that it leads to maximal performance if it works in coordination with other motor skills [5, 6].

When more than 800 gymnastics techniques are analyzed, results have shown that dominance or importance of mobility is found as a fourth and flexibility as a fifth motor ability, led by coordination, strength, and speed [7]. However, execution of the routines, which includes coordination, means inclusion of both mobility, flexibility and other motor abilities [8]. Furthermore, execution of the elements such as a side split, forward-backward split, or arm trunk angle, require flexibility [2, 3]. On the other hand execution of the elements such as a straddle jump, wolf jump, stag leap, split leap, turn variations, etc., require high active flexibility at the same time when force is the dominant skill in a certain movements. Thus, execution of the elements requiring high force and active flexibility at the same time, may be called mobility or functional flexibility (muscles' ability to stretch) [1, 2, 8]. Flexibility can be defined as the range of motion of a body joint [9]. As it can be seen, it is not including the range of motion which is expressed during movements that require force. It means that a combination of flexibility and motor skills similar to force that reveals mobility.

Alternatively, coordination, the most crucial ability in artistic gymnastics, includes a combination of the different movements at the same time It also includes the combination of different motor abilities at the same time in different movements. This fact is based on different research that can be found in the literature. The focus on

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mobility, or actively moving through a range of motions, requires a combination of motor control, stability and flexibility, and more closely relates to the movement requirements an athlete will face [3, 4]. Thus, explaining the involvement of flexibility, especially active flexibility, to the movements that require mobility such as a trunk bent forward, leg raises forward, leg raises sideward, etc., which may increase the gymnast's performance. For this reason, the movements mentioned above and used by us in this study were determined as a test to measure the gymnasts' performance [1, 2].

However, what in reality is the problem that caused the need for this study? One of the authors of the NSCA argues that improving the range of motion (ROM) will not be fully reflected in functional movements. Moreover, he mentioned that, "this seems to be one of the first studies suggesting that increasing the ROM of a joint may not translate into function or change of a default movement pattern" [8].

Therefore, as it is challenging for the gymnast to improve their general motor abilities such as coordination, force and speed, it is also difficult to improve active and passive flexibility. Nevertheless, the biggest challenge for gymnasts is to combine these abilities. The question arises as to whether these improvements in flexibility or strength will transfer to function. Specifically, if a gymnast presents with limited hip mobility, is there any evidence that improvements in hip range of motion (ROM) or core endurance will alter functional movement patterns? [8].

Even gymnasts improve their flexibility enough according to the norm values given by the World Gymnastic Federation (FIG), which can be tested by side split, forward-backward split, and arm- angle in a passive way, in the execution of the elements with the similar biomechanical and anatomical requirements but, where force is involved such as a leg raise sideward, leg raises forward, arm-trunk angle in bridge techniques is a usual image to see that not 100% of the flexibility is functional. For instance, even the gymnasts can open legs in forward-backward split more than 180^0 during the execution of the element with similar biomechanical and anatomical requirements, such as a split leap or tour jete, it can be seen that not more than 60-70% of the flexibility showed in the forward-backward split are expressed. Aims of all gymnastics coaches and gymnasts are to make the flexibility during dynamic movements 100% functional, which requires both force and flexibility. Unfortunately, the literature does not clarify the ratio of the functional flexibility during movements required, in both flexibility and other motor abilities, such as force, power, etc.

Based on these facts, this study's aim is to conduct a biomechanical examination of the inclusion of active flexibility in artistic gymnastic movements requiring mobility (actively moving through a range of motion), flexibility and other motor abilities such as force, power, etc. Besides this, the study aims to determine the ratio of the functional flexibility in the movements required for mobility in certain movements in artistic gymnastics.

Material and Methods

Participants

To determine the correlations and effects of the active flexibility to mobility in functional movement patterns a causal relational research model was used. The study included 17 girl gymnasts aged 7-9 years old, with a body height of 140.7±10.2, weighing 34.1±6.4, and body mass index of 17.6±3.0. As some gymnasts did not participate in all performance tests, the study sample may vary for each test. For that reason, we have given the sample size in each group in the tables of the results.

The gymnasts and their parents were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study. The study was approved by the Ethics Board of the Istanbul Gelisim University.

Research design

In line with the purpose of the present study, the Correlational Survey Method, which aims to determine the presence and/or level of a covariance among variables identified in the relevant part of the method, and the causal-comparative method, which aims to determine the reasons of an existing / naturally occurring situation or event, its effects on these causes, and the contributing variables or the results of an effect, were used.

Testing Procedures

Forward-Backward Split (FBS^0): The test's main aim is to measure the active flexibility of the lower limbs and hips *(iliopsoas: psoas major, iliacus, quadriceps femoris group: rectus femoris, vastus lateralis, vastus medialis, sartorius, hamstrings: biceps femoris, semitendinosus, semimembranosus etc.)* [10]. The angle reference point was the hips (greater trochanter) and the angle line was put across the legs to the ankle (lateral malleolus). In exceptional situations (if the athlete's knee was not straight), the angle tool's reference point was the thigh plane to the knee. The test was applied on two sides; right leg forward position, and left leg forward position. The results were recorded us a different variable for the left and right leg and the results were given in degrees [1, 2].

Side Spit (SS^0): The test's main aim is to measure the active flexibility of the lower limbs adductors *(pectineus, gracilis, adductor brevis, adductor longus, adductor magnus, etc.)* [10]. The angle reference point was the coccyx bone and the angle line was put across the legs to the ankle (lateral malleolus). The results were given in degrees [1, 2].

Arm-Trunk Angle Backward ($AT\_^0B$): The test's main aim is to measure the active flexibility and mobility of the shoulders and upper limbs (*triceps brachii, posterior deltoid, teres minor, teres major, latissimus dorsi pectorals abdominal and sternocostal part, etc.)* [10]. The angle reference point was the upper limit of middle axillary line (biacromial elevation level) and the angle line was put across the hand joint (styloid process of ulna) and hips (greater trochanter). The results were recorded us an angle given between the trunk and raised arms [1, 2].

Trunk Bent Forward (TBF): The test's main aim is to measure the active flexibility and mobility of the low back *(hips muscles: gluteus maximus, multifidus, quadratus lumborum, intertransversarii, longissimus, erector spinae group, iliocostalis muscle)* and hamstrings *muscles (biceps femoris, semitendinosus, semimembranosus, etc.)* [10]. During the measurement, the gymnast stands on the bank, leaning ahead-down reaching the longest point as is possible with their fingers. The results were registered based on the toes and in centimeters. During the test, the knees should be straight and the maximal position reached must be held for at least 2 seconds.

Leg Raise forward (LRF⁰): The test's main aim is to measure the lower limbs flexor muscles *(iliopsoas, pectineus, rectus femoris, sartorius, adductor longus, tensor fasciae latae, etc.)* mobility *(the ability of the athlete to apply movements from a wide-angle and in different directions as far as the joints allow)* [10]. The reference of the measurement, where the angle was based on, was the hips (greater trochanter). The angle line was put across the raised leg to the ankles (lateral malleolus) and the angle's other line was put across the upper body exactly on the vertical line on the coronal plane (frontal plane). The results of the test were determined by the angle degree between raised leg and upper body [1, 2].

Leg Raise Sideward (LRS⁰): The test's main aim is to measure the lower limbs abductor muscles *(gluteus medius, gluteus minimus, tensor fascia lata, gluteus maximus, etc.)* mobility *(the ability of the athlete to apply movements from a wide-angle and in different directions as far as the joints allow)* [10]. The reference of the measurement was the angle based on was the coccyx (tailbone). The angle line was put across the raised leg to the ankles (lateral malleolus) and the angle's other line was put across the upper body exactly on the vertical line on the sagittal plane. The results of the test were determined by the angle degrees between raised leg and upper body [1, 2].

Bridge (B⁰): The bridge technique was made according to the FIG rules and used to measure the mobility *(the ability of the athlete to apply movements from a wide-angle and in different directions as far as the joints allow)* of the gymnasts. The criteria of the evaluation for the bridge technique based on the angle degrees between two imaginary lines that were across the leg *(the line was across the malleolus and greater trochanter)* and arm *(the line was across the styloid process of the ulna and acromial elevation level)* [10]. The application of the test was; no break on the knee, and elbow ankle [1, 2].

Standing long Jump (SBJ): The test's aim is to measure the power (*low extremities explosive force*) of the gymnasts [11] by jumping forward from the starting position (on both feet) in order to cover a distance. The explosive force of the lower extremities is measured [12]. The result is registered in centimeters. However, according to FIG this test's evaluation base is the body length of lying on the face, and hands reach forward [1, 2].

Lift Trunk Forward-60secs (Crunches) (LTF_60s): The test's aim is to measure the strength continuity of the abdominal muscle *(rectus abdominis, external oblique, internal oblique, transversus abdominis, etc.)* of the gymnasts [10]. The gymnast lies on his back, joins his hands at the nape, pulls his knees gently towards his abdomen (*knees at 90 degrees*), and the soles completely touch the mat. When getting up, the elbows should come forward and touch the knees at the end of the movement. Hands must be tied together at the nape throughout the entire movement. The ankles of the subject are held by an assistant. While starting the second movement, enough time should be given in order to let the shoulders touch the mat. The subject tries to repeat this movement as many times as possible within 60 seconds. The assistant keeps the subject's feet on the mat during the entire test. The right and image 13 measurement of 60-Lift Trunk Forward Test completed crunches are counted and recorded as a result within 60 seconds. A "QQ Japanese HS45 10 Lap Memory" stopwatch was used to measure the time [1, 2, 13, 14,].

Angle Degree of the Leg Split Position in Cartwheel (A⁰LSPCT): The test's aim is to measure the ratio of active flexibility during performance (*inaction*) that requires mobility. Recorded videos of the cartwheel technique were used in the test. The video was stopped in the frame the gymnast is in at a handstand position and the legs are split in the sagittal plane. The criteria of the evaluation for the angle degree of the leg split position in the cartwheel technique based on the angle degree based on the coccyx of two imaginary lines, which were across the leg (heel). The application of the test was; no break on the knee [1, 2].

Arm-Upper Body Angle Backward in Bridge Technique (AUB°BB): The bridge technique was made according to the FIG rules and used to measure the mobility *(the ability of the gymnast to apply movements from a wide-angle and in different directions as far as the joints allow)* of the gymnasts [10]. The criteria of the evaluation for the bridge technique were based on the angle degree between two imaginary lines which were across the leg *(the line was across malleolus and greater trochanter)* and arm *(the line was across the styloid process of the ulna and acromial elevation level)*. The application of the test was; no break on the knee, and elbow ankle [1, 2].

Statistical Analysis

For the data analysis of the variables the Kinovea 0.8.15 program, which is a video player for sports analysis and provides a set of tools to capture, slow down, study, compare, annotate and measure technical performances [15], was used. To mark location, measure distance and determine the angle degree of the videos, tools of the program such as a line, circle, cross marker, angle, etc. were used. The videos are made by a Galaxy S10 which has three cameras on the back: a main 12-megapixel with an aperture that shifts between f/1.5 and f/2.4 depending on light, an ultra-wide 16-megapixel unit, and a telephoto 12-megapixel for zooming.

In the SPSS 24 program was used for data analysis. General descriptive analysis was made by using descriptive analysis; correlations between variables were made by the Pearson correlation; and relationships between variables and success scores were revealed by the Pearson correlation analysis. The percentage of the functional active flexibility were calculated by using the formula "%= (angle^0 of the mobility in functional movement / angle^0 of the active flexibility) *100".

Results

Table 1 shows active flexibility (SS°) and mobility (LRS°) in degrees. The results have shown that active flexibility expressed in the SS° technique was used 90.7% in movements including mobility (LRS°). Furthermore, the p-values (LL_RS°: .358 and RL_RS°: .839) were not statistically significant, and 100% of the active flexibility requiring mobility was found to be not functional in gymnastics movements.

Table 2 shows active flexibility (SS°) and mobility (A°LSPCT) in degrees. According to the results, only 78.5% of the active flexibility exhibited in the SS° technique was functional in mobility-requiring techniques such as A°LSPCT. In addition, p-values (.190) not found to be statistically significant and 100% of the active flexibility requiring mobility was not functional in gymnastics movements requiring mobility.

The results shown in the previous table 3 have made clear that active flexibility (AT_°B) is not completely used in techniques that require active flexibility, force and mobility. Active flexibility expressed in the AT_°B technique was used just 17.5% in the movements with a similar biomechanical and anatomical structure including mobility (AUB°BB). Moreover, the p-values (.785) were not statistically significant, indicating that 100% of active flexibility was not functional in mobility-requiring gymnastics movements such as a bridge, cartwheel, forward Salto and backward Salto techniques.

The previous table shows the results of active flexibility (FBS°) and mobility (LRF°) in degrees. According to Table 4, the active flexibility expressed in the FBS° technique was used 99.7% in the movements including mobility (LRF°). When the correlation between LLA_FBS° and LL_RF° was not significant (p-value: .548), the correlation between RLA_FBS° and RL_RF° was significant (p-value: .011). It seems that unlike other variables given in the above tables, gymnasts used 99.4% of their active flexibility during the execution of the techniques requiring force and flexibility, i.e. mobility. The cause of this can be seen in the analysis of the results in the discussion part.

Table 5 gives the results that show the differences by bridge techniques scores between active flexibility expression, mobility expression, and force expression variables. The results show that compared to the active flexibility expression variables (AT_°B and TBF) and

Table 1. Functional acti e fl xibility "Side Split (SS°)" during the execution of the techniques requires mobility "Leg Raise Sideward (LRS°)"

Variables	N	X̄±SD		%		r	p
		SS°	LRS°				
LL_RS°	15	168.3±14.53	106.8±11.46	90.5	90.7	.266	.358
RL_RS°			105.5±11.07	90.9		.060	.839

X̄±SD: mean and std. Deviation, LL_RS°: Left Leg Raise Sideward (°),RL_RS°: Right Leg Raise Sideward (°), N: sample, SS° : Side Split (°), LRS°: Leg Raise Sideward (°), %: Percentage of functional SS° in the LRS°, r: correlation, p: p: sig. (p< 0.05)*

Table 2. Functional active flexibility "Side Split (SS°)" during the execution of the techniques requiring mobility "Leg Split in Handstand Position in Cartwheel Technique (A°LSPCT)"

Variables	N	X̄±SD	%	r	p
SS°	9	173.6±13.17	78.5	.481	.190
A°LSPCT		136.0±12.23			

SS° : Side Split (°), A°LSPCT: Angle Degree of the Leg Split Position in Cartwheel Technique (°), N: sample, X̄±SD: mean and std. Deviation, %: Percentage of functional SS° in the A°LSPCT, r: correlation, p: sig. (p< 0.05*)

Table 3. Functional active flexibility "Arm-Trunk Angle Backward (AT_°B)" during the execution of techniques requiring mobility "Arm-Upper Body Angle Backward in Bridge Technique (AUB°BB)"

Variables	N	X̄±SD	%	r	p
AT_°B	7	139.9±11.83	17.5	.088	.785
AUB°BB		174.6±13.21			

AT_°B: Arm-Trunk Angle Backward (°), AUB°BB: Arm-Upper Body Angle Backward in Bridge Technique (°), N: sample, X̄±SD: mean and std. Deviation, %: Percentage of functional AT_°AB in the AUB°BT, r: correlation, p: sig. (p< 0.05)*

Table 4. Functional active flexibility "Forward-Backward Split Technique (FBS°)" during execution of techniques requiring mobility "Leg Raise Forward (LRF°)"

N	FBS° Variables	$\bar{X}$±SD	LRF° Variables	$\bar{X}$±SD	%		r	p
15	LLA_FBS°	146.7±12.11	LL_RF°	99.5±9.97	101.4	99.4	-.176	.548
	RLA_FBS°	153.3±12.38	RL_RF°	99.4±9.97	97.5		-.657	.011*

N: sample, FBS°: Forward-Backward Split (°), LLA_FBS°: Left Leg Ahead Forward-Backward Split Degree (°), RLA_FBS°: Right Leg Ahead Forward Backward Split Degree (°), LRF°: Leg Raise Forward (°), LL_RF°: Left Leg Raise Forward Degree (°), RL_RF°: Right Leg Raise Forward Degree (°), $\bar{X}$±SD: mean and std. Deviation, %: Percentage of functional FBS° in the LRF°, r: correlation, p: sig. (p< 0.05)*

Table 5. Differences between flexibility, mobility and force tests to the bridge technique in artistic gymnastics

Ability	Variables	Bridge score	$\bar{X}$ ±Ss	F	P	Tukey
Active flexibility	AT_°B	1 (poor)^{1}	152,0±15.6	.68	.584	-
		2 Statisfactory^{2}	128.5±38.5			
		3 (good)^{3}	146.5±13.6			
		4 (excelent)^{4}	151.0±4.2			
	TBF	1 (poor)^{1}	4.4±9.1	1.62	.296	-
		2 Statisfactory^{2}	9.0±1.4			
		3 (good)^{3}	13.1±3.6			
		4 (excelent)^{4}	15.5±6.2			
Mobility	AUBA°BB	1 (poor)^{1}	183±4.0	5.39	.025*	1>4
		2 Statisfactory^{2}	185.2±5.1			2>4
		3 (good)^{3}	176.3±3.0			
		4 (excellent)^{4}	167.5±10.6			
	B°	1 (poor)^{1}	97.3±13.6	7.09	.012*	1<4
		2 Statisfactory^{2}	87.5±10.5			2<4
		3 (good)^{3}	71.0±11.2			
		4 (excellent)^{4}	55.5±.7			
Force	SBJ	1 (poor)^{1}	124.1±11.1	2.47	.176	-
		2 Statisfactory^{2}	124.5±2.1			
		3 (good)^{3}	127.0±13.2			
		4 (excellent)^{4}	146.8±1.6			
	LTF_60s	1 (poor)^{1}	25.6±18.1	.589	.637	-
		2 Statisfactory^{2}	31.0±18.7			
		3 (good)^{3}	24.2±20.3			
		4 (excellent)^{4}	44.0±4.2			

AT_°B: Arm-Trunk Angle Backward (°), TBF: Trunk Bent Forward (cm), AUBA°BB: Arm-Upper Body Angle Backward in Bridge Technique (°), B°: Bridge (°), SBJ: Standing Broad Jump (cm), LTF_60s: Lift Trunk Forward in 60 secs (crunches), p: sig. (p< 0.05)*

force expression variables (SBJ and LTF_60s and B°), mobility expression variables (AUBA°BB and B°) had a significant difference of gymnast's whose bridge techniques scores were high and low. Respectively, the gymnasts who have more positive results in the mobility variables (AUBA°BB: 1>4, 2>4, B°:1<4, 2<4) also had more positive scores in the bridge technique.

Discussion

Results of the study have shown that active flexibility performed in the movements such as side split, forward-backward split, and arm-trunk angle has not been highly functional in mobility-requiring movements (actively moving through a range of motion). Convenient levels of flexibility are a precondition for proper performance of many basic body elements such as a jumps, balance and rotation [16]. Subsequently, one of the crucial reasons for failure in artistic gymnastics is the fact that active flexibility and force are not combined and functional during active movements.

To be more specific in this topic we have made an analyze of the results of the study where it can be seen that active flexibility expressed in the side split technique was functional around 90.7% in movements requires mobility, such as the leg raise forward. This result is reinforced by the correlation analysis between flexibility and mobility based on the techniques mentioned above. Thus, it is statistically verified that one of the biggest challenges of gymnasts is making functional all ranges of motions during active movements that require force, power, etc. Baptista's research concluded that many gymnasts with high spine flexibility failed to achieve the higher level in the maximum trunk lift due to the gymnasts showing high flexibility in spine joints, but not yet presenting sufficient strength to maintain the determined position [17].

Similarly, active flexibility showed in the side-split technique (173.6°) resulted to be functional at just around 78.5% in the movements requiring mobility, such as the angle degree of the leg split in the cartwheel technique (136.0°) in the floor routine. The result was reinforced by the correlation analysis of these two variables, which also did not result in any statistical significance. In this way, even the side-split technique and the side split position in the cartwheel technique which have similar biomechanical and anatomical structures, gymnasts failed to use 100% of active flexibility as a source of mobility. The literature also showed that despite the large increases in passive hip ROM, there was no evidence of increased hip ROM used during functional movement testing [8]. Similarly, the only significant change in lumbar motion was a reduction in lumbar rotation during the active hip extension maneuver (p, 0.05). These results indicate that changes in passive ROM, or core endurance, do not automatically transfer to changes in functional movement patterns. This implies that training and rehabilitation programs may benefit from an additional focus on "grooving" new motor patterns if a newfound movement range is to be functional.

Another example of functional flexibility during movements that require mobility is given. When it the angle degree between arm-upper and trunk in the bridge position (174.6°), which requires both force and flexibility was measured, i.e. mobility, and in the same test according to the biomechanical and anatomical perspective, the arm-trunk angle backward in the stand position (139.9°) again resulted to be different. Only 17.5% of the active flexibility had been functional in the movement where both force and flexibility are required, i.e. mobility. The arm-trunk angle is key to gymnasts' performance, such as it is in the bridge technique, for that reason this test is used worldwide to determine gymnasts' performance [18, 19, 20]. The literature indicates that hip extension measurements obtained passively do not reflect those used during dynamic activity [21, 22].

Unlike other variables mentioned above, it seems that 99.7% active flexibility, which is expressed in the forward backward split technique (LLA_FBS°: 146.7°, RLA_FBS°:153.3°) was also functional in the leg raise forward technique (LL_RF°99.5°, RL_RF°:99.4°). However, the main reason for the high rate of functionality of active flexibility in these variables, is the fact that the test which measures flexibility and the test measuring mobility were not identical in a biomechanical and anatomic perspective. In the measurement of the right or left leg flexibility, the other leg was extended back also, the extension of the quadriceps muscle group of the leg which is back, reduced the extension of the leg which is ahead. Whereas, during the leg raise ahead test, the other leg was straight in the standing position, which does not stretch the quadriceps muscle. If we eliminate the effect of this anatomical difference, it can be seen that the ratio of flexibility-mobility will be similar to the above variables. Furthermore, there is little objective evidence that combined improvements in hip mobility and core endurance will be reflected in volitional functional activity [8].

To clarify the effect of the development of mobility (actively moving through a range of motions) per contra force and flexibility as an independent motor skills, the study has applied correlation analysis between mobility, flexibility and force to bridge technique execution success, which was evaluated in stages (1: poor, 2: satisfactory, 3: good, 4: excellent) (1, 2).

Statistically significant results have shown that gymnasts who have better scores in the bridge execution technique, also had better arm-upper body angle degrees in the bridge technique, an ability which requires mobility.

The results have shown that flexibility did not directly reflect movement where force is required. This may be because flexibility still was not functional in the active movements. According to the literature, many gymnasts with high spine flexibility failed to achieve the higher level in the maximum trunk lift. This result is probably due to the gymnasts showing high flexibility in spine joints, but not yet presenting sufficient strength to maintain the determined position [17]. Besides, the bridge angle degree which were measured between two imaginary lines across the leg (the line across malleolus and greater trochanter) and the arm (the line across the styloid process of the ulna and acromial elevation level), and which requires both flexibility and force (mobility) to execute, it had a positive impact to the bridge technique score. Flexibility ability plays a major role in the power-intensive and high-difficulty techniques of the Artistic Gymnastics [18, 19, 23].

In conclusion, the results of the study have shown gymnasts and coaches must concentrate on mobility (actively moving through a range of motions) as much (or more) as they concentrate on force and flexibility improvement, rather than concentrating on flexibility and force as an independent motor skills. Based on the results on the study of Moreside, and Mcgill (2013), despite large increases in passive hip mobility in groups 1 and 2, there were no significant increases in hip extension or rotation used during dynamic activities

In summary, the functionality ratios of active flexibility in techniques requiring mobility are limited to the techniques in this study, which gives an idea for other techniques. Much of the literature discussing changes to movement patterns subsequent to an exercise routine is sport specific [24, 25, 26].

A limitation for interpretation of the data is that the subject numbers are low. Therefore, we suggest increasing the study sample and including also males, as there can be significant differences in the technique angle degrees between males and females. In artistic gymnastics, it is more important to analyze the movements, motor skills, and training reliability from the biomechanical perspective instead of classic methods such as a heart rate, repetition number, sets, or volume per session, etc.

To achieve better results we should conduct more similar studies and include more elements that measure the flexibility, mobility, and success scores of gymnasts. By including a larger number of elements in the study, the rate of functionality of the given active flexibility will be more valid and reliable.

Conclusions

As a result, it was determined that the functionality rate of the techniques requiring active flexibility and requiring mobility of the same biomechanical and anatomical structure was around 65-75%. Therefore, to execute 100% of the flexibility in action (during active elements) as it is in a passively or actively, it may significantly increase force in the large range of motion. In the light of this information, we put forward some practical suggestions below that may be useful for coaches and gymnasts.

Training applied in different body planes and positions may result in more functional flexibility during the execution of high difficulty degree elements in artistic gymnastics.

Based on the fact that gymnasts and coaches aim to use or expose 100% of the flexibility during the execution of the active or dynamic elements, we can conclude that artistic gymnastics training should be prepared according to these aims. Thus, increasing mobility means also increasing coordination and other motor abilities. Furthermore, increasing a mobility also means force is combined with other motor abilities and used better; and especially flexibility is more functional in different elements of artistic gymnastics such as a cartwheel, bridge, walkover forward, walkover backward, handspring forward, Salto variations, etc.

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Conflict of interests

No potential conflict of interest was reported by the authors.

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Participation tactics of elite freestyle wrestlers in competition system in 2013-2016 Olympic cycle

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Abstract

Background and Study Aim Tactics is one of the basic terms underlying the management of competitive activities of athletes. In freestyle wrestling, the participation tactics of athletes in the competition system is covered fragmentally and needs proper justification. The purpose of the study was to determine the features of the participation tactics of elite athletes in the competition system in freestyle wrestling during 2013-2016 Olympic cycle.

Material and Methods This study analyzes the dynamics of performances and results of 24 elite freestyle wrestlers who won gold, silver and bronze medals at the Games of XXXI Olympiad 2016 in Rio de Janeiro in different weight categories (four athletes in each of six weight categories). To do this, we used athletes' individual profiles on the United World Wrestling. Used an expert assessment devoted to the issues of tactics and tactical training. The experts (n = 8) were well educated (3 among them held Ph.D. diplomas) and experienced – 2 coaches of Ukrainian national team, and 1 athlete–national team's member. On average, experts had almost 10 years of experience in training wrestlers of different ages. The results were processed using Microsoft Excel software.

Results The volume of competition practice of elite athletes during 2013-2016 changed in each season. In the 2013 season, the average group number of competitions in which athletes participated was 3.84 ± 2.06, in 2014 – 3.50 ± 1.79. In the 2015 season, those indicators were the highest – 4.17 ± 1.87, but in 2016 they decreased to 3.71 ± 1.52. The participation tactics in the competition system in freestyle wrestling during the season and the four-year cycle differed depending on the dynamics of sports results. Four types of tactics used by the elite athletes in freestyle wrestling in 2013-2016 were identified: leadership holding, gradual improving of results, combined, leadership returning. It was found that during 2013-2016, most athletes (58.33-79.17%) used a variety of tactics that involved performances in one Olympic weight category. In 2014 and 2015, some athletes (20.83 and 25.00%, respectively) used different options in other weight categories, choosing one of them as a priority and one or two – as additional.

Conclusions: There are four types of participation tactics in the competition system in freestyle wrestling. In 2013-2016 Olympic cycle they included leadership holding, gradual increase of results, combined, leadership return. The main differences between types of tactics are the volume of competition practice, the dynamics of results, the choice of weight category. The most relevant was the type of tactics with performances exclusively in the Olympic weight category during four seasons.

Keywords: competitions, Olympic Games, calendar, season, results.

Introduction

Tactics is one of the basic terms in combat sports [1, 2]. In scientific papers there is a lot of definitions of this term. However, the main explanations were given by Keller [3] and Platonov [1]. According to Keller, it means a way of combination and implement of motor actions to solve competition problems, taking into account the rules and different conditions [3]. Platonov considers tactics as a theory and practice of organizing and conducting specialized activities to achieve goals in specific conflict situations on the basis of principles, schemes and norms of behavior [1]. According to Malkov and Gozhin [4], different interpretations of tactics are connected with the subjective perception of its defining link (classifier).

During the last ten years, in most papers in wrestling, tactics reflects athlete's ability to use proper technical action in the most adequate situation in the bout [5, 6]. In our opinion, this interpretation does not allow to create a holistic view of all the features of tactics. Moreover, it enables to make conclusions about its transformation due to the current trends: complication of Olympic qualification system, changes of international and national calendars, competition rules, selection systems in national teams [7].

From this point of view, the most reasonable interpretation of tactics was given by Tumanyan [8]. He insists that tactics in wrestling is a kind of activity implemented on four levels: 1 – in special situation, 2

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– during the whole bout, 3 – during the tournament and its stages, 4 – in the competition system. The principle position of the author is that at each level tactics is inseparable from the strategy. Both categories are types of activities of the coach and the athlete [8].

During the last five years, the main subjects of research in wrestling are the analysis of competition performance and changes caused by new competition rules [9-11], development of innovative means for technical and tactical training [12-15]; movement parameters of the elite athletes [16-19]. Other works are devoted to injury prevention during competition season [20-22], psychophysiological indicators of elite athletes during different events [23-25].

Based on the Tumanyan's ideas about four levels of tactics [8], we may conclude that the most studied are the first and second levels (performance in special situation and during the bout). Instead, the participation tactics in a specific event or competition system are covered fragmentally [5]. According to Kamayev et al., the participation tactics in the event aims at the appropriate distribution of effort at each stage by achieving the planned result [5]. The components of tactics at this level are the choice of weight category, determining the tactics for the bout against a particular opponent [5]. At the same time, the participation tactics in the competition system requires the implementation of the planned dynamics of competitive achievements and determines the strategy of four-year and annual cycle [8]. In our opinion, these issues are not represented in scientific literature properly. Some researches described competitive achievements of elite wrestlers within few Olympic cycles [17, 26]. However, the obtained data allowed them to predict the effectiveness of wrestlers' competitive activities in the Olympic arena and to create the models of their training [16]. We believe that the dynamics of athletes' performances during the season or Olympic cycle might be used for identifying the types of participation tactics in the competition system. Our previous papers confirmed this possibility in fencing [27].

Despite the great attention to elite wrestlers' tactics in modern papers, none of the studies revealed tactical schemes of their participation in different events. There are still no data on the types of tactics of weight category choice during the season and the whole Olympic cycle.

Hypothesis. We assumed that the participation tactics of elite freestyle wrestlers may differ depending on the dynamics of sports results in official international tournaments not only during the seasons, but in general during the Olympic cycle. According to our assumption, the differences between the types of participation tactics in the competition system may also consist in various types of the weight category choice during one season and the whole Olympic cycle.

The purpose of the study was to determine the features of the participation tactics of elite athletes in the competition system in freestyle wrestling during 2013-2016 Olympic cycle.

Materials and methods

Participants

This study analyzes the dynamics of performances and results of 24 elite freestyle wrestlers who won gold, silver and bronze medals at the Games of XXXI Olympiad 2016 in Rio de Janeiro in different weight categories (four athletes in each of six weight categories). To do this, we used athletes' individual profiles on the United World Wrestling (UWW) website [28].

Study design

The next step included an expert assessment devoted to the issues of tactics and tactical training (February – August 2019). The experts (n = 8) were well educated (3 among them held Ph.D. diplomas) and experienced – 2 coaches of Ukrainian national team, and 1 athlete– national team's member. On average, experts had almost 10 years of experience in training wrestlers of different ages.

The questionnaires were administered to the experts in two different ways. 5 questionnaires were administered in a paper form and filled under the supervision of the researcher. The other 3 questionnaires were distributed by e-mail. Each expert was asked to rank the components of tactical training in each section. The number of components in sections ranged from 5 to 10. Rank 1 was always considered the most significant. The highest rank indicated the least important component (eg. in section with 9 components, rank 9 was the least important).

In order to confirm the accuracy of the answers, the concordance coefficient was determined in each group of experts (W). The statistical validity of the concordance coefficient was verified using the $\chi 2$ criterion (Pearson's chi-squared test). According to Shiian et al. [29], the critical value of the concordance coefficient was defined as W=0.5. Therefore, at $0.69>W\geq0.5$, the agreement of experts' opinions was evaluated as average, at $W\geq0.7$ as high (strong), and at $W<0.5$ as low (weak).

The next step of the research (September 2020 – January 2021) was analyzes of 24 elite wrestlers' individual profiles on UWW [28]. In total, we analyzed the participation and results of 24 freestyle wrestlers, representatives of all weight categories, during the Olympic cycle 2013-2016. To make conclusions on their participation tactics our attention was focused on such indicators:

- the number of competitions in which each athlete participated during the season (absolute value and percentage of the maximum number of competitions for his or her weapon);
- the results at the main competitions of the season: during the 1st-3rd seasons – at the World Championships (WCh), in the 4th – at the Games of XXXI Olympiad);
- the number of competitions in which the athlete won medals during the season (percentage of the total number of competitions in which he participated during the season, hereinafter – "indicator of medal achievements");
- "average place" – the average mean of all places that

athletes took in competitions during the season;
- the ratio of competitions of different age categories in which the athlete took part during the season (Cadets, Juniors, Seniors);
- the highest and lowest result during the season (place in competitions);
- the number of competitions that the athlete finished at different stages – 1/4, 1/8, etc. (percentage of the total number of competitions in which the athlete participated during the season);
- peculiarities of the Olympic qualification – whether the athlete or another representative of the NOC of the country succeeded personally; in which of the four stages of the Olympic qualification system it was done.

Additionally, we took into account the range of weight categories in which each wrestler performed during the four seasons 2013-2016, and the number of competitions held in the particular weight category (if the athlete competed in few categories).

Statistical Analysis

All obtained data were statistically processed using the STATISTIKA 10.0 software and Microsoft Excel 2016. The data are represented as the average mean ± standard deviation (SD), Max – maximum in the season; Min – the minimum in the season. Shapiro-Wilk's test was used to check normality of distribution of the indicators of competition practice and results of 24 elite freestyle wrestlers during four seasons within 2013-2016 Olympic cycle. This test was also used to check normality of distribution of the same indicators in three groups of athletes who used different types of participation tactics in 2013-2016 Olympic cycle. In order to determine the significance of differences of the results in each group during the whole Olympic cycle 2013-2016 we used parametric and non-parametric tests. In case of normal distribution of indicators, we used the single-factor analysis of variance ANOVA. In case of absence of normal distribution, we used non-parametric Kruskal-Wallis H-test. If the indicators in one season were normally distributed, but in other seasons there was absence of normal distribution, we used both tests ANOVA and Kruskal-Wallis H-test. Method Bonferroni was used for correction in both tests. The level of statistical significance of differences was set at $p \leq 0.05$.

Results

We took into account expert's opinion on three questions. We discovered that control of elite wrestlers' tactics and tactical preparedness should be based on the analysis of competitive performance and results in particular competitions (average ranks 1.33 and 1.75 respectively, W=0.26, $p<0.05$). The main component of tactical training for elite wrestlers is the improvement of tactical thinking: how to trick an opponent and make him make a mistake during the fragment of the bout, the whole match or at different stages of competitions, how to choose proper tactics for competitions of different levels such as World Cups, World and Continental Championships, The Games of Olympiad (average rank 1.50, W=0.74, $p<0.05$). We also discovered that 100.0 % of experts insist on the differentiation of tactical training for individual and team events. The results of this part of research were discussed in our previous papers [30].

Features of the competition system are regulated by the "International Wrestling Rules" [28]. Analysis of the UWW competition calendars for "Seniors" age category indicated that during the 2013-2016 Olympic cycle, freestyle wrestlers could participate in 44-45 tournaments in each season. It was established that the dynamics of elite wrestlers' performances during 2013-2016 changed in waves. The average group results at the main competitions and the indicators of medal achievements grew gradually every season. The "average place" (arithmetic mean of all places), the highest and lowest results increased during the 1st-3rd seasons, but in the 4th they decreased slightly compared to the 3rd (Table 1). Table 1 represents Kruskal-Wallis and ANOVA p-values for each of six indicators, with statistical significance $\alpha = 0.05$.

The analysis of the obtained results allowed to assert the absence of a normal distribution in majority of indicators. The Kruskal-Wallis H-test showed that the results during four seasons are significantly equal at $p \leq 0.05$. Instead, the ANOVA test indicated that the highest results in each season and the results at the main competitions (WCh) were significantly different at $p \leq 0.05$. According to our hypothesis, it is connected with the specifics of competition practice and results dynamics of elite athletes who used different types of participation tactics in each of four seasons and the whole Olympic cycle.

That is why the next step of our research aimed to compare those data in each group of wrestlers. The first group (n = 7) included representatives of all weight categories, which showed high results in each season. Their participation tactics in the competition system in 2013-2016 was defined as leadership holding (Table 2).

During the 1st and 2nd seasons, athletes in this group increased the amount of competitive practice. In 3rd season, this indicator remained stable, in the 4th – decreased again. The results at the main competitions of the season, the indicators of medal achievements, the arithmetic mean of all places were consistently high in each season. An exception in this group of athletes was the representative of the Russian Federation A. G., who for reasons unknown to us did not participate in the WCh 2013 and 2014, but showed high results at other tournaments, including the European Championships (ECh). The Kruskal-Wallis p-values showed that there are no significant differences between the means of any indicator at statistical significance $p \leq 0.05$. It confirmed that athletes' results during four seasons were almost equal and high (as they were leaders).

The second group (n = 10) included representatives of all weight categories, whose results gradually increased in each season (they were the highest in 2016). The number of competitions in which athletes participated gradually increased, except for the 2nd season, in which the number

Table 1. The dynamics of competition practice and results of elite freestyle wrestlers in 2013-2016 Olympic cycle (n = 24)

Indicators		Seasons 2013	2014	2015	2016	ANOVA p-value	KW p-value
The number of events	Mean ± SD	3.84 ± 2.06	3.50 ± 1.79	4.17 ± 1.87	3.71 ± 1.52	0.660	0.706
	Range (Min – Max)	1 – 8	1 – 6	1 – 7	1 – 7		
	Shapiro-Wilk p-value	0.231	0.013	0.097	0.326		
AP	Mean ± SD	4.40 ± 3.15	4.16 ± 3.46	2.91 ± 1.91	3.25 ± 2.67	0.262	0.436
	Range (Min – Max)	1.00 – 11.50	1.00 – 12.00	1.00 – 7.67	1.00 – 13.00		
	Shapiro-Wilk p-value	0.013	0.004	0.0009	0.00004		
The highest result	Mean ± SD	1,68 ± 1.25	2.60 ± 3.03	1.30 ± 0.70	1.33 ± 0.64	0.044*	0.373
	Range (Min – Max)	1 – 5	1 – 12	1 – 3	1 – 3		
	Shapiro-Wilk p-value	0.0003	0.0003	0.0004	0.0003		
The lowest result	Mean ± SD	10.16 ± 10.20	7.00 ± 6.46	5.83 ± 5.25	5.96 ± 5.54	0.175	0.345
	Range (Min – Max)	1 – 37	1 – 20	1 – 21	1 – 20		
	Shapiro-Wilk p-value	0.0005	0.002	0.0006	0.0001		
IMA, %	Mean ± SD	67.21 ± 31.40	70.08 ± 39.86	83.70 ± 23.18	83.56 ± 21.06	0.137	0.199
	Range (Min – Max)	0 – 100	0 – 100	28.57 – 100	33.33 – 100		
	Shapiro-Wilk p-value	0.022	0.001	0.001	0.001		
Results at the main competitions	Mean ± SD	8.70 ± 9.38	4.64 ± 6.50	3.94 ± 5.51	2.25 ± 0.85	0.025*	0.260
	Range (Min – Max)	1 – 30	1 – 20	1 – 21	1 – 3		
	Shapiro-Wilk p-value	0.023	0.0002	0.001	0.0005		

Note. Mean – arithmetic mean; SD – standard deviation; Max – the maximum in the season; Min – the minimum in the season; AP – "average place", the average mean of all places that athletes achieved in competitions during the season; IMA, "indicator of medal achievements" – the ratio of events in which athletes won medals to the total number of tournaments held by them during the season (%); the highest/ the lowest results – the highest/ the lowest places which athletes achieved during the season; results at the main competitions – the places taken by athletes at the World Championships in 1st-3rd seasons (2013-2015), and the Games of XXXI Olympiads the 4th season (2016); * – significantly different indicators ($p \le 0.05$).

of competitions was lower than in the 1st one. Indicators of medal achievements, results at WCh, the arithmetic mean of all places also gradually increased in each season, but the largest increase was found in 2016 (Table 3). Interestingly, most athletes (n = 7) missed a different number of seasons (from one to three). Three athletes did not take part in the 2013-2015 WCh, but performed in other official international events.

The Kruskal-Wallis and ANOVA p-values showed that there was no significant difference between majority of indicators in the second group. Exception was found in results at the main competitions where significant difference was present at level $p \le 0.05$.

The third group (n = 6) included wrestlers who improved their results during the 1st and 2nd seasons, and kept them at a high level in the following ones. Their tactics was described as combined. As in other groups, two athletes missed the 2013 and 2014 WCh (Table 4).

Kruskal-Wallis and ANOVA p-values showed that in the third group there was no significant difference between

Table 2. The dynamics of competition practice and results of elite freestyle wrestlers who used tactics of leadership holding in 2013-2016 Olympic cycle (n = 7)

Indicators		Seasons				ANOVA	KW
		2013	2014	2015	2016	p-value	p-value
The number of events	Mean ± SD	3.71 ± 2.29	4.00 ± 1.47	4.00 ± 1.72	2.86 ± 1.68	0.653	0.528
	Range (Min – Max)	1 –7	2 – 6	2 – 7	1 – 6		
	Shapiro-Wilk p-value	0.519	0.925	0.658	0.277		
AP	Mean ± SD	1.90 ± 0.71	1.82 ± 1.17	1.84 ± 1.09	2.17 ± 1.43	0.885	0.808
	Range (Min – Max)	1.00 – 3.00	1.00 – 4.00	1.00 – 3.43	1.00 – 5.00		
	Shapiro-Wilk p-value	0.932	0.009	0.031	0.086		
The highest result	Mean ± SD	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.29 ± 0.76	0.434	0.414
	Range (Min – Max)	1 – 1	1 – 1	1 – 1	1 – 3		
	Shapiro-Wilk p-value	0.998	0.998	0.998	0.001		
The lowest result	Mean ± SD	4.00 ± 2.94	3.00 ± 2.73	3.29 ± 3.08	3.29 ± 3.15	0.881	0.682
	Range (Min – Max)	1 – 9	1 – 8	1 – 8	1 – 10		
	Shapiro-Wilk p-value	0.274	0.016	0.036	0.019		
IMA, %	Mean ± SD	92.72 ± 9.23	93.33 ± 13.61	92.35 ± 13.88	90.48 ± 18.90	0.967	0.938
	Range (Min – Max)	80.00 – 100	66.67 – 100	71.43 – 100	50.00 – 100		
	Shapiro-Wilk p-value	0.019	0.0008	0.002	0.002		
Results at the main competitions	Mean ± SD	1.75 ± 0.96	1.75 ± 0.89	2.00 ± 0.98	1.57 ± 0.79	0.817	0.830
	Range (Min – Max)	1 – 3	1 – 3	1 – 3	1 – 3		
	Shapiro-Wilk p-value	0.382	0.068	0.023	0.028		

Note. Mean – arithmetic mean; SD – standard deviation; Max – the maximum in the season; Min – the minimum in the season; AP – "average place", the average mean of all places that athletes achieved in competition during the season; IMA, "indicator of medal achievements" – the ratio of events in which athletes won medals to the total number of tournaments held by them during the season (%); the highest/ the lowest results – the highest/ the lowest places which athletes achieved during the season; results at the main competition – the places taken by athletes at the World Championships in 1st-3rd seasons (2013-2015), and the Games of XXXI Olympiads the 4th season (2016).

the number of events, indicator of medal achievements, results at the main competitions. Instead, the average place and the lowest result were significantly different at level $p \leq 0.05$. It confirmed that athletes of the third group combined tactics of gradual increase of results (in the 1st and 2nd seasons) and leadership holding (in the 3rd and 4th).

Additionally, we should describe the participation tactics of the representative of Georgia G. P. We didn't include him in previous groups, because his tactics was defined as leadership return. In all seasons (excepting the 2nd), he showed consistently high results in major competitions, winning bronze medals. Medal achievements were also high – 75.00-100% (except in 2014, where he did not win any awards). The wrestler finished the 1st season as the leader, winning a bronze medal at the WCh. In the 2nd season, he lost the lead, but in 2015-2016 managed not only to regain it, but also to keep it.

A separate component of wrestlers' participation in the competition system is the choice of weight category (WC) [16]. Thus, the next step of the study was to identify its features during each season and the overall Olympic cycle of 2013-2016 (Table 5).

Table 3. The dynamics of competition practice and results of elite freestyle wrestlers who used tactics of who used tactics of gradual increase of results in 2013-2016 Olympic cycle (n = 10)

Indicators		Seasons 2013	2014	2015	2016	ANOVA p-value	KW p-value
The number of events	Mean ± SD	3.67 ± 2.16	3.13 ± 1.89	3.78 ± 2.44	4.20 ± 1.69	0.745	0.693
	Range (Min – Max)	1 – 7	1 – 5	1 – 7	2 – 7		
	Shapiro-Wilk p-value	0.998	0.031	0.065	0.556		
AP	Mean ± SD	5.04 ± 2.42	5.10 ± 3.53	4.29 ± 2.31	4.34 ± 3.64	0.921	0.775
	Range (Min – Max)	2.25 – 8.20	1.5 0– 12.00	1.50 – 7.67	1.25 – 13.00		
	Shapiro-Wilk p-value	0.537	0.279	0.189	0.027		
The highest result	Mean ± SD	2.00 ± 1.55	3.50 ± 3.85	1.78 ± 0.97	1.40 ± 0.70	0.204	0.610
	Range (Min – Max)	1 – 5	1 – 12	1 – 3	1 – 3		
	Shapiro-Wilk p-value	0.019	0.008	0.004	0.0008		
The lowest result	Mean ± SD	11.17 ± 8.91	8.75 ± 7.27	8.44 ± 7.14	8.90 ± 7.16	0.908	0.774
	Range (Min – Max)	3 – 25	3 – 20	2 – 21	2 – 20		
	Shapiro-Wilk p-value	0.231	0.021	0.035	0.062		
IMA, %	Mean ± SD	51.87 ± 34.74	55.83 ± 47.67	73.54 ± 32.11	78.05 ± 23.22	0.366	0.472
	Range (Min – Max)	0 – 100	0 – 100	28.57 – 100	33.33 – 100		
	Shapiro-Wilk p-value	1	0.017	0.008	0.116		
Results at the main competitions	Mean ± SD	12.33 ± 5.86	11.00 ± 12.73	13.67 ± 8.08	2.70 ± 0.48	0.001*	0.020*
	Range (Min – Max)	8 – 19	2 – 20	5 – 21	2 – 3		
	Shapiro-Wilk p-value	0.574	1	0.999	0.0003		

Note. Mean – arithmetic mean; SD – standard deviation; Max – the maximum in the season; Min – the minimum in the season; AP – "average place", the average mean of all places that athletes achieved in competitions during the season; IMA, "indicator of medal achievements" – the ratio of events in which athletes won medals to the total number of tournaments held by them during the season (%); the highest/ the lowest results – the highest/ the lowest places which athletes achieved during the season; results at the main competitions – the places taken by athletes at the World Championships in 1st-3rd seasons (2013-2015), and the Games of XXXI Olympiads the 4th season (2016); * – significantly different indicators (p ≤ 0.05).

It was established that in 2013 the majority of athletes performed in one Olympic WC. One athlete (M. I. I., Republic of Uzbekistan) held 50.00% of tournaments in two Olympic WCs, one of which was lighter than the one in which he competed in subsequent seasons. Instead, another representative of this country, I. N., took part in competitions in the priority Olympic (75.00% of tournaments) and additional non-Olympic WC (25.00%), which was heavier than the priority. Five wrestlers completely missed the 2013 season. One of them (R.H.) competed exclusively in the age category "Cadets".

In the 2014 season, most athletes preferred to perform in one Olympic WC. Four more chose the Olympic WC as a priority (66.67-75.00% of tournaments), and used the non-Olympic WC as an additional (25.00-33.33% of events). Three of them competed in the non-Olympic WC, which was heavier than the priority Olympic. At the same time Sh. Sh. (Republic of Azerbaijan) competed in the additional non-Olympic WC, which was much lighter than the priority ("96 kg" and "70 kg", respectively). H. A. (Republic of Azerbaijan) performed in the priority non-Olympic WC. In addition, he used the Olympic WC,

Table 4. The dynamics of competition practice and results of elite freestyle wrestlers who used combined tactics in 2013-2016 Olympic cycle (n = 6)

Indicators		Seasons				ANOVA	KW
		2013	2014	2015	2016	p-value	p-value
The number of events	Mean ± SD	4.20 ± 2.28	4.20 ± 1.92	4.83 ± 1.33	3.67 ± 0.52	0.663	0.439
	Range (Min – Max)	2 – 8	1 – 6	3 – 6	3 – 4		
	Shapiro-Wilk p-value	0.277	0.271	0.079	0.006		
AP	Mean ± SD	7.27 ± 3.81	4.64 ± 4.03	2.29 ± 0.64	2.92 ± 1.36	0.035*	0.041*
	Range (Min – Max)	3.33 – 11.50	1.00 – 11.50	1.25 – 3.17	1.50 – 5.00		
	Shapiro-Wilk p-value	0.346	0.167	0.979	0.539		
The highest result	Mean ± SD	2.20 ± 1.64	1.80 ± 1.10	1.00 ± 0.00	1.33 ± 0.52	0.224	0.198
	Range (Min – Max)	1 – 5	1 – 3	1 – 1	1 – 2		
	Shapiro-Wilk p-value	0.077	0.019	1	0.006		
The lowest result	Mean ± SD	18.20 ± 14.31	9.00 ± 7.52	5.33 ± 2.42	4.67 ± 2.42	0.042*	0.092
	Range (Min – Max)	5 – 37	1 – 19	2 – 8	2 – 8		
	Shapiro-Wilk p-value	0.226	0.872	0.484	0.484		
IMA, %	Mean ± SD	48.33 ± 29.11	77.67 ± 27.28	86.11 ± 12.55	81.95 ± 21.35	0.061	0.083
	Range (Min – Max)	0 – 75.00	33.33 – 100	66.67 – 100	50.00 – 100		
	Shapiro-Wilk p-value	0.262	0.244	0.242	0.144		
Results at the main competitions	Mean ± SD	20.00 ± 14.14	5.25 ± 6.55	1.50 ± 0.55	2.17 ± 0.98	0.003*	0.077
	Range (Min – Max)	10 – 30	1 – 15	1 – 2	1 – 3		
	Shapiro-Wilk p-value	1	0.074	0.010	0.047		

Note. Mean – arithmetic mean; SD – standard deviation; Max – the maximum in the season; Min – the minimum in the season; AP – "average place", the average mean of all places that athletes achieved in competitions during the season; IMA, "indicator of medal achievements" – the ratio of events in which athletes won medals to the total number of tournaments held by them during the season (%); the highest/ the lowest results – the highest/ the lowest places which athletes achieved during the season; results at the main competitions – the places taken by athletes at the World Championships in 1st-3rd seasons (2013-2015), and the Games of XXXI Olympiads the 4th season (2016); * – significantly different indicators (p ≤ 0.05).

which was heavier than the priority. Four more athletes missed the 2014 season for reasons unknown to us. Two of them performed exclusively in the age category "Juniors".

In 2015, majority of athletes (n = 14) performed exclusively in the Olympic WC. Four wrestlers combined performances in the Olympic and non-Olympic, giving preference to the first (50.00-71.43% of events). The additional non-Olympic WC was heavier than the Olympic one. H. A. (Republic of Azerbaijan) performed mainly in the non-Olympic WC (66.67%), using the heavier Olympic as an additional (33.33%). H. Ya. from the Islamic Republic of Iran was limited to performances only in the non-Olympic WC. Three more wrestlers competed in two Olympic WCs, one of which (heavier) was a priority (50.00-80.00%).

In 2016, the majority of athletes (79.17%, n = 19) performed only in the Olympic WC. Sh. Sh. (Republic of Azerbaijan) competed in two Olympic WCs (additional was heavier than priority). Interestingly, this WC was chosen as an athlete exclusively for performances at the Games of XXXI Olympiad 2016 (in previous seasons, he preferred to perform in the heavier Olympic WC). Three more athletes used the Olympic WC (50.00-75.00% of

Table 5. Tactics of weight category choice in elite freestyle wrestlers during the Olympic cycle of 2013-2016 (n = 24)

Type of Tactics	Seasons							
	2013		2014		2015		2016	
	Number of athletes							
	Abs.	%	Abs.	%	Abs.	%	Abs.	%
O	17	70.83	15	62.50	14	58.33	19	79.17
O + O	1	4.17			3	12.50	1	4.17
O + N	1	4.17	4	16.67	4	16.67	3	12.50
N					1	4.17		
N + O			1	4.17	1	4.17		
N + O + O							1	4.17
Missed the season*	5	20.83	4	16.67	1	4.17		

Note. Types of tactics: O – performances exclusively in one Olympic weight category (WC); O + O – a combination of performances in two Olympic WCs, one of which is a priority; O + N - a combination of performances in two WC (Olympic and non-Olympic) with preference for the first; N – performances exclusively in one non-Olympic WC; N + O – a combination of performances in two WC (non-Olympic and Olympic) with the preference of the first; N + O + O – a combination of performances in three WC (non-Olympic and two Olympic) with the preference of the first; N + N + O – a combination of performances in three WC (two non-Olympic and one Olympic) with preference for one non-Olympic; Abs. – the number of wrestlers who used a certain type of tactics (absolute value); % – the number of wrestlers who used a certain type of tactics (percentage of the total number, n = 24); * – the number of wrestlers who did not take part in any official international event during the season.

events) as a priority, and the heavier non-Olympic – as an additional (33.33-50.00%). The tactics of WC choice used by H. A. (Azerbaijan) deserve special attention. In the 4th season, he preferred to perform in the non-Olympic WC, occasionally performing in the heavier Olympic. However, in the Olympic arena, he performed in a lighter WC than the one that was chosen as a priority in previous seasons. Assume that, as in the case of Sh. Sh. the change of the priority WC exclusively for the performance at the Olympic Games was due to the deterioration of the results in the priority WC during the fourth season compared to the previous ones.

Discussion

Problems of tactics and tactical training are widely covered in the scientific literature [31-33]. Nevertheless, the interpretation of the term tactics is still the subject of scientific discussions [34-36]. Due to the lack of a unified approach to the interpretation of the term tactics, the study of its features in the system of competitions is the subject of a small number of research. Most of them are theoretical in nature [5, 8, 16, 37]. In turn, the available empirical studies on wrestling take into account tactics at the level of the bout and its episodes [7, 35]. Given the above, the participation tactics of athletes in competition system requires proper scientific justification and more detailed study.

Our previous papers highlight the participation tactics of elite fencers [27]. The specifics of participation tactics during the Olympic cycle largely depend on the Olympic qualification criteria. Fencers are interested in participating in at least seven events in each season to improve or maintain their position in the official Rankings. Instead, there is no need for this in wrestling. First of all, the prospect of Olympic qualification in wrestling does not depend on the position in the official Rankings. It is important mainly for the draw before WCh, World Cup, Continental Championships, Ranking Series [28].

The obtained data allowed to find that elite freestyle wrestlers increase their competition practice during the 1st-3rd seasons, but decrease it in the 4th. Similar results were described by Latyshev and Tropin about Greco-Roman wrestling from 1993 to 2016 [17]. However, the number of competitions in their work is the sum of performances of all Olympic champions. It does not reflect the performances' dynamics during each season of the Olympic cycles.

Instead, we found that in 2013-2016, some wrestlers (n = 9) missed a different number of seasons (from one to three). Three athletes did not take part in the WCh 2013-2015, but performed in official international events. According to our assumption, one of the reasons may be the change of sports citizenship in the current Olympic cycle, which did not allow to successfully pass the national selection and get into the national team. The reason for the omission of the 1st and 2nd seasons by R. H. from Japan could be a combination of performances in the age categories "Juniors" and "Seniors". The USA representative J. M. T. C., in 2013-2015 did not participate in any official international event, but in 2016 he became a leader and won awards in all competitions, including the Games of XXXI Olympiad.

Comparing the performance's dynamics and results of each athlete during the Olympic cycle allowed to identify different types of tactics for choosing the weight category (WC). Just like in women's wrestling, in freestyle wrestling in 2013 the boundaries of the WCs were changed, and new ones were added to the Olympic program [25]. In contrast to women's wrestling, the number of Olympic categories for men was reduced from seven to six. At the same time, at the 2013 WCh, men could compete in seven WCs, and in 2014-2015 – in eight (the non-Olympic WC "70 kg" was introduced in the competition program).

During 2013-2016 the most relevant tactics involved performances exclusively in the Olympic WC. In different seasons 58.33-79.17% used it. In the 2014 and 2015, some wrestlers used different types of performances in other WCs, choosing one of them as a priority and one or two as additional. Interestingly, most athletes performed in those additional WCs that were heavier than the priority. Only three athletes competed in the additional WC, which was easier than the priority. This type of WC choice was used by M. I. I. in 2013, and in 2014 by Sh. Sh., In 2015 – I. S. (Republic of Belarus). In the case of performances in several age categories, most athletes competed in similar WCs (WC limits for "Cadets" or "Juniors" coincided with WCs for "Seniors").

Comparison of the results with similar data in women's wrestling [38] indicated that during 2013-2016 both men and women used four types of participation tactics in the competition system: leadership holding, gradual increase of results, combined and leadership return.

The tactics of WC choice during the season provided for giving preference to performances in one prior WC. Most athletes chose the Olympic WC as a priority. Performances in additional WCs (Olympic or non-Olympic) were either absent or episodic (1-2 events per year). The same athletes used different tactics of WC choice depending on the place of the season in the four-year Olympic cycle and the dynamics of sports results. Based on this, the following types of WC choice were identified:

1. Performances in one Olympic WC and in its updated version (after changes in the rules of UWW 2013) for four seasons. It was used by ten athletes.
2. Performances in several WCs (Olympic and non-Olympic) with the preference of the Olympic for several seasons or the whole cycle, including for performances at major competitions (WCh and Olympic Games). Performances in the non-Olympic WC were episodic – 1-2 events per season. This type of tactic was common to six athletes.
3. Performances in the non-Olympic and Olympic WC during the 1st-3rd seasons, preferring the non-Olympic, a full transition to the Olympic WC in the 4th season. It was used by H. Ya. Ch. (Islamic Republic of Iran).
4. Performances in several Olympic WCs during a cycle or several seasons, preferring the one in which the highest results were demonstrated. It was used by three fighters.
5. Performances in non-Olympic and Olympic WCs during the 1st-3rd seasons, preferring non-Olympic, including. Performance in several Olympic WCs (heavier and lighter than non-Olympic) in the 3rd or 4th seasons and choosing the Olympic one with more prospects. Its elements were used by H. A. (Azerbaijan Republic).
6. Performances in one priority Olympic WC during all seasons, and occasional performances in another Olympic WCs (1-2 tournaments per season) with demonstration of equally successful results in both WCs. Typical for A. S. (Russian Federation).
7. Performances in one priority Olympic WC throughout the cycle and a sudden choice of another WC only for performances in the Olympics due to the decrease of results in the 4th season in the priority Olympic WC. In its "pure" form, this kind of tactic was typical for Sh. S., partly – for H. A. (both – representatives of the Republic of Azerbaijan).
8. Performances in one Olympic WC during the 1st or 2nd season, complete transition to another Olympic WC in the 3rd or 4th season with demonstration of equally successful performances in both WCs. It was used by A. S. (Romania).

Comparison of the obtained results with similar ones in women's wrestling [28] allowed to state that for men it was typical to use more types of tactics of WC choice during the Olympic cycle (six varieties were found among women). Most of the representatives of women's wrestling in 2013-2016 combined several types of tactics of choosing WC [28], and men preferred one of them.

In our opinion, the obtained results are relevant in the current Olympic cycle of 2016-2020. In 2017 in freestyle wrestling (men) there were introduced new WC. Their number in the program of competitions for the World Cup 2018 and 2019 was increased to ten. That's why WC choice still involves preferring the prior and, if necessary, one or two additional WC. Unfortunately, due to the global pandemic, the main part of the 2020 season was cancelled (including the World Olympic Qualifying Events). Therefore, it is impossible to make correct conclusions about the participation tactics during 2017-2020. However, given that the 2020 Olympic selection system has not changed much compared to the same in 2016 (except for the number of World Qualifying Events), we assume that the results can be extrapolated to the current Olympic cycle.

Conclusions

There are four types of participation tactics in the competition system in freestyle wrestling. In 2013-2016 Olympic cycle they included leadership holding, gradual increase of results, combined, leadership return. The main differences between types of tactics are the volume of competition practice, the dynamics of results, the choice of weight category. The most relevant was the type of tactics with performances exclusively in the Olympic weight category during four seasons.

Conflict of interest.

The authors declare no conflict of interest.

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ORIGINAL ARTICLE

Effect of different training models on motoric and swimming performance in prepubescent swimmers

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Abstract

Background and Study Aim The aim of this study was to examine the effects of different training programs on the improvement of motoric and swimming performance prepubescent swimmers.

Material and Methods Forty-five children between the ages of 9 -11 years with at least 2 years of training experiences, participated in the study. Three different [(1) dry-land with elastic resistance band group + swimming (ERB); (2) dry-land without elastic resistance band (DL) + swimming and (3) swimming group (SG) with swimming training alone] training group were formed. And a 12-week training program was implemented thought the study. Biceps, chest, waist, hip, thigh body circumference measurements were taken from all participants. Vertical jump (VJ), flexed-arm strength (FAS), speed, upper body strength (UBS), Standing horizontal jump (SHJ), flexibility, aerobic endurance (AE), balance, and 50 m freestyle swimming (FS) score were tested on the participants. As statistical analysis, normality and homogeneity of variance assumption were checked (Shapiro-Wilk and Levene tests, respectively). A non-normal distribution was found. The values of each variable were expressed as mean ± standard deviation, and median. The training effects within the groups were evaluated using analyses of Friedman for repeated measures and the level of significance was set at $p<0.05$ for all tests.

Results There was a significant difference in SHJ, UBS, FAS, speed, and FS score among the assessment times 1-3 and 1-4 in both of ERB and DL training groups ($p<0.05$). ERB and DL training were significantly effective compared to the SG on VJ, FAS, speed, UBS, and freestyle swimming performance ($p<0.05$).

Conclusions: The study findings showed that DL training more effected relatively on motoric performance.

Keywords: children, athletes, freestyle, dry-land training, elastic band.

Introduction

In most sports, strength and conditioning training regimes are required to enhance performance and prevent injuries. Swimming is a complex sport that requires multifactorial training involving endurance, strength, power, speed, agility, and anthropometrics. Many studies reported that the effectiveness of these components on swimming performance was clear [1-4].

Scientists and coaches report that swimming training should consist of both dry-land and in-water sessions. Therefore, the researchers focused on not only in-water training, but also on dry-land training, evincing its contribution to a better swimming performance [3, 5-7]. In order to enhance the physical condition, resistance training is an important component of the training program. Following resistance training increase arm strength lead to in higher maximum stroke force, and also improved sprint swim performance [8-10].

However, some resistance training models, including using free weights or resistance-training machines which may have certain risks such as injury, so they may not be suitable particularly for childhood. American Academy of Pediatrics has supported to avoid resistance training such as powerlifting, bodybuilding, and maximal lifts for preadolescents and adolescents until reach physical and skeletal maturity [11]. In addition to this, every kind of resistance training may not be similar effect on the conditioning components, including strength, power etc. A study from Cuenca-Fernández et al [12] reported that semi-tethered loaded swimming training showed to be sensitive on improving swimmer's technique rather than increasing physical conditioning. Some studies reported that resistance training would not be the main reason for in itself; either the load was not suitable or the lifting technique caused negative results [11, 13]. Therefore, the diversities in resistance training regimes may provide both the age requirements and multi-functional improvement for young athletes. Elastic resistance band training, a technique commonly used in rehabilitation, provides a safe and effective progressive overload technique, applicable for people of all ages [14].

Besides, elastic resistance band is types of equipment that are relatively inexpensive, easy to use, portable and safe, thus widely used. It provides advantages with respect to training with free weights or weight machine in rehabilitative medicine [15]. Several studies have investigated the effects of elastic band training on

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performance and healthy life on different groups including athlete, [16-18] patients [19], postmenopausal women, and the elderly [20]. The studies in the literature, there was a lack of research about the effects of ERB training on swimming performance in prepubescent swimmers.

Although there were many resistance training methods implemented, there is a limited knowledge as to whichever methods are better to enhance the multi-functional performance improvements that affected swimming performance. For this reason, it would be of a great worth for the coaches to have a resource of more beneficial resistance training protocols. It may be presented to the information on how it influences swimming performance on prepubescent swimmers. In this study, dry-land training consisted of two different practices including (a) resistance training with self-body weight and medicine ball and (b) only elastic resistance band. Therefore, the main purpose of the current study was (i) to compare the effects of twelve weeks of the dry-land training and in-water training, (ii) to assess the efficacy of resistance training with using self-body weight and medicine ball (DL training) and the elastic resistance band (ERB training) for improvement motoric and swimming performance in prepubescent swimmers.

Materials and Methods

Participants

Forty-five prepubescent swimmers (boys: n=23; girls: n=22, the range of age 9-11 year), who have at least 2-year sport experience and free from injuries or health problems, participated in this study. Before of the study, to determine the homogeneity for all groups, physical performances test and circumferences measurements were performed for all participants. Then according to statically analyzes the results there was no found significant differences in variables, including VJ, FAS, speed, UBS, FS score, SHJ, flexibility, endurance, balance, biceps, chest, waist, hip, thigh. Power analyzes test was applied to determine the sample size using for each of the variables. As based on the power analyzed results, it was determined the group size using highest sample size taken from the power analyzed. In addition, the participants did not engage to another sports, engaged to just swimming. The participants were randomly divided into the three groups: elastic resistance band group (boys: n=8; girls: n=7), dry-land resistance training group without elastic band (boys: n=6; girls: n=9), and swimming group (boys: n=9; girls n=6). Tanner stage test was performed by the physician to determine whether the participants entered adolescence or not. As a criterion for the tanner stage, it was taken breast development for female and, external genitalia for male [21]. As a result of the stage test, it was determined that there were no participants who entered the adolescent stage. The written informed consent form was signed by the parents, because the participants were under 18 years of age. The study was conducted by the ethics committee of Hitit University, with the Declaration of Helsinki for research involving human participants (Decision no: 2018-12).

Design and Procedures

In this study, ERB and DL groups were named as the experimental groups; the control group was named as the swimming group. All measurements were carried out for all variables in each of measurement time by the expert practitioner. The assessments were carried out four times during the study: at the beginning of the study (1), and after four (2), eight (3) and twelve-week of the training session (4). The start of the study, the implemented equipment and procedures were familiarized to the participants. The measurements consisted of the anthropometric and performance tests, including motoric components and swimming performance performed in each of the four evaluation times. During the study, the participants were not involved in any other training program. The participants were instructed not to exercise for at least 24 hours and not to eat for at least three hours before the performance analysis. The performance analysis followed systematic order without affecting results and started with a 10-min warm-up performed by all subjects. The measurements performance analyze were designed according to the criterias including used energy systems, muscle groups, and recovery duration.

Training protocol

As remarked in the section of the participants, the study groups were separated as the elastic resistance band group, the dry-land resistance training group without the elastic band, and the swimming group. Different venues were used to the training for each group. The ERB and DL training sessions (3 sessions per week of 30 minutes each), before in-water training took part in addition to regular swimming training sessions. The swimming training program with 60 minutes was performed as the common training program for experimental groups. Each training session lasted 90 minutes (DL and ERB training: 30 minutes, and the swimming training: 60 minutes; the swimming training lasted 90 minute for the SG). Different color bands, including yellow, red, green, blue, were used in ERB training based on the resistance intensity from mild to hard respectively. In the 3rd set, when 15 repetitions were reached, an upper colored band was used in the next training session. The components such as; the same body parts, set, repeat, and training volume in the selection of exercise- according to the training protocols to provide the equivalent between trainings- were taken into account [22]. The detailed information about the DL and ERB training protocols were presented in Table 1.

Assessment

Test procedures were explained and demonstrated to the participants before each of the tests. All the tests were performed at the same time of the day to avoid any effect of circadian rhythms. Experimental groups and the SG were evaluated at the same moment in the procedures schedule in preliminary, after 4, 8, 12 weeks. In measurements of VJ, SHJ, UBS, FAS, balance, it was given 2-min rest interval between each of the 3 trial and recorded the best score. In measurement of speed, 3-min rest interval was given between each of the 3 trial, and the best scores were recorded. In measurement of flexibility, 30 second rest interval was given between each of the 3 trial, the best score was recorded to analysis. The subject waited at least 2 seconds at maximum reached distance. In Swimming performance, all subjects completed three 50 m free style swimming trials with a 15 min rest period between the trials. The performance analyses were completed including: which included SHJ, and VJ tests to measure explosive power, the UBS test was measured with throwing medicine ball, the FAS test was used to measure static arm strength endurance, the sit and reach test (S&R) was used to measure hamstrings and lumbar spine flexibility; the cooper test (covered distance during 9 minute) was to measure AE, 30 m speed test was used to measure acceleration and speed, the flamingo test (count the number of falls in one minute of balancing) was used to measure the ability to balance successfully on a leg, were completed [23].

Anthropometric data included five body circumferences such as biceps flexion, chest, waist, hip, thigh. Besides, the weight was determined within 0.1 kg for each subject using an electronic scale calibrated before each measurement session (Seca 664, Hamburg, Germany). The height was determined using a fixed wall-scale measuring device to the nearest 0.1 cm. The measurements were obtained using a Holtain anthropometric set by the expert practitioner according to the techniques recommended by Miller [23]. Skinfold thickness (mm) was measured at three identified anatomical landmark sites, including the chest, the abdomen, and the thighs for boys and the triceps, the suprailium, and the thighs for girls, using a Holtain caliper. The Body fat (BF) percentage for boys and girls was calculated by using Jackson-Pollock equation [24].

Statistical Analyses

Normality and homogeneity of variance assumption were checked (Shapiro-Wilk and Levene tests, respectively), and a non-normal distribution was found. Non-parametric tests were conducted. The values of each variable were expressed as mean ± standard deviation, and median. The training effects within the groups were evaluated using analyses of Friedman for repeated measures. Following the Friedman test, Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied in order to find out which groups (time point) caused the differences. All the analyses were performed with SPSS (version 22.0; SPSS Inc, Chicago, IL), and the level of significance was set at $p<0.05$ for all tests.

Results

A total of 45 prepubescent swimmers (15 in ERB, 15 in DL, and 15 in C) were measured at the baseline. At the baseline, there were no significant differences between any of the physical characteristic variables (Table 2), thus, it was provided acceptable homogeneity among the groups.

Table 1. The training programs, according to the groups.

ERB training protocol			**Dry-land training protocol**		
Wednesday Sunday	**Friday**	**Sets x reps**	**Wednesday Sunday**	**Friday**	**Sets x reps**
Shoulder fl x	Lateral raise	Week 1 - 4	Ball Slams	Front raise MB	Week 1 - 4
Knee ext	Minisquat	3 x 10	Jumping	Squat	3 x 8
Elbow fl x	Elbow kick back	Week 5 - 8	Arm fl x MB	Dibs	Week 5 - 8
Back ext	Crunch	3 x 10	Sit-up	V ups	3 x 10
Elbow ext	Arm curl	Week 9 - 12	Arm ext MB	Push up	Week 9 - 12
Shoulder abd	Front raise	3 x 10	V push up	V push up	3 x 12

Abbreviations: Abd: Abduction; **Add:** Adduction; **Ext:** Extension; **Flex:** Flexion; **MB:** Medicine ball (1 kg).

Table 2. The subject characteristics according to the groups.

Variables	**ERB**		**Dry-land**		**Swimming**	
	Girls	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**
Age (year)	10.7±0.4	9.8±0.6	9.6±0.5	9.6±0.8	10.1±0.9	10.2±0.9
Height (cm) (1)	146.86±7.8	144.75±5.65	140.22±9.39	142.33±7.52 /	142.67±11.86	146.22±8.88
Height (cm) (4)	151.7±2.93	147.68±5.59	143.84±7.53*	145.13 ±8.35*	145.23±10.47*	148.05±7.68*
Body mass (kg) (1)	45.5±10.06	40±8.28	38.3±9.51	35.8±5.63	38±10.48	36.1±5.57
Body mass (kg) (4)	47.08±8.37*	41.21±6.40*	39.26±8.43*	38.38±5.05*	38.40±9.25*	37.98±3.87*
Fat (%) (1)	12.15±5.28	11.10±6.86	12.58±5.23	11.28±5.9	13.15±6.08	8.57±5.08
Fat (%) (4)	11.99±5.19	10.99±6.4	12.6±5.03	11.11±5.23	13.05±5.95	8.55±5.08
FFM (kg) (1)	36.3±5.78	38.13±6.6	34.14±7.18	30.41±4.70	29.48±6.31	34.47±5.90
FFM (kg) (4)	38.22±5.06	38.91±5.27	35.97±5.88	31.90±3.00	30.55±4.67*	36.78±4.29*

***p<0.05;** FFM: Free fat mass; *Pre-study measurement (1)**;** *Post-study measurement (2).

Figure 1 presents the changes of biceps, chest, waist, hip and thigh circumference values for all groups that were obtained through the study. The results showed that there was a statistically significant difference in biceps and chest circumference between the assessment times 1-3 and 1-4 for the ERB training group. Besides, a statistically significant difference was found in biceps circumference between 1-3 and 1-4 for DL training group. No differences were found for the other parameters.

Figure 2 presents the change of results in-group throughout the study in VJ, FAS, UBS, speed, SHJ, flexibility, balance, AE, and FS score performance components for all groups. For the ERB and DL training groups, there was a statistically significant difference in SHJ, UBS, FAS, speed, and FS score among the assessment times 1-3 and 1-4. For the SG, a statistically significant difference was found in UBS, FAS, speed, FS score, SHJ between the assessment times 1 and 4. No statistically significant difference was found in balance, endurance and flexibility parameters of any assessment times during the study for all groups.

Table 3 presents both the improvement of performance variables depending on each of the assessment time from the beginning of the training period (1) to the twelve-weeks of the training session (4) and the total change difference (TCD) as % among all groups. There was a significant difference in VJ performance in both the second and third measurement times between the DL and SG ($p<0.001$). In the fourth measurement, there was a significant difference in VJ performance in both ERB and DL versus SG ($p<0.001$). In TCD, there was no significant change between the ERB and DL training group, but the change difference was significant in ERB and DL training group comparing to the SG ($p<0.05$). In FAS performance change, there were significant differences in the second, third and fourth measurements, in both ERB and DL versus SG ($p<0.001$). In TCD, there was no significant change between the ERB and DL training group, but the change difference was significantly in ERB and DL training group comparing to the SG ($p<0.05$). In speed performance change, there was a significant difference in both the third and fourth measurement times between the

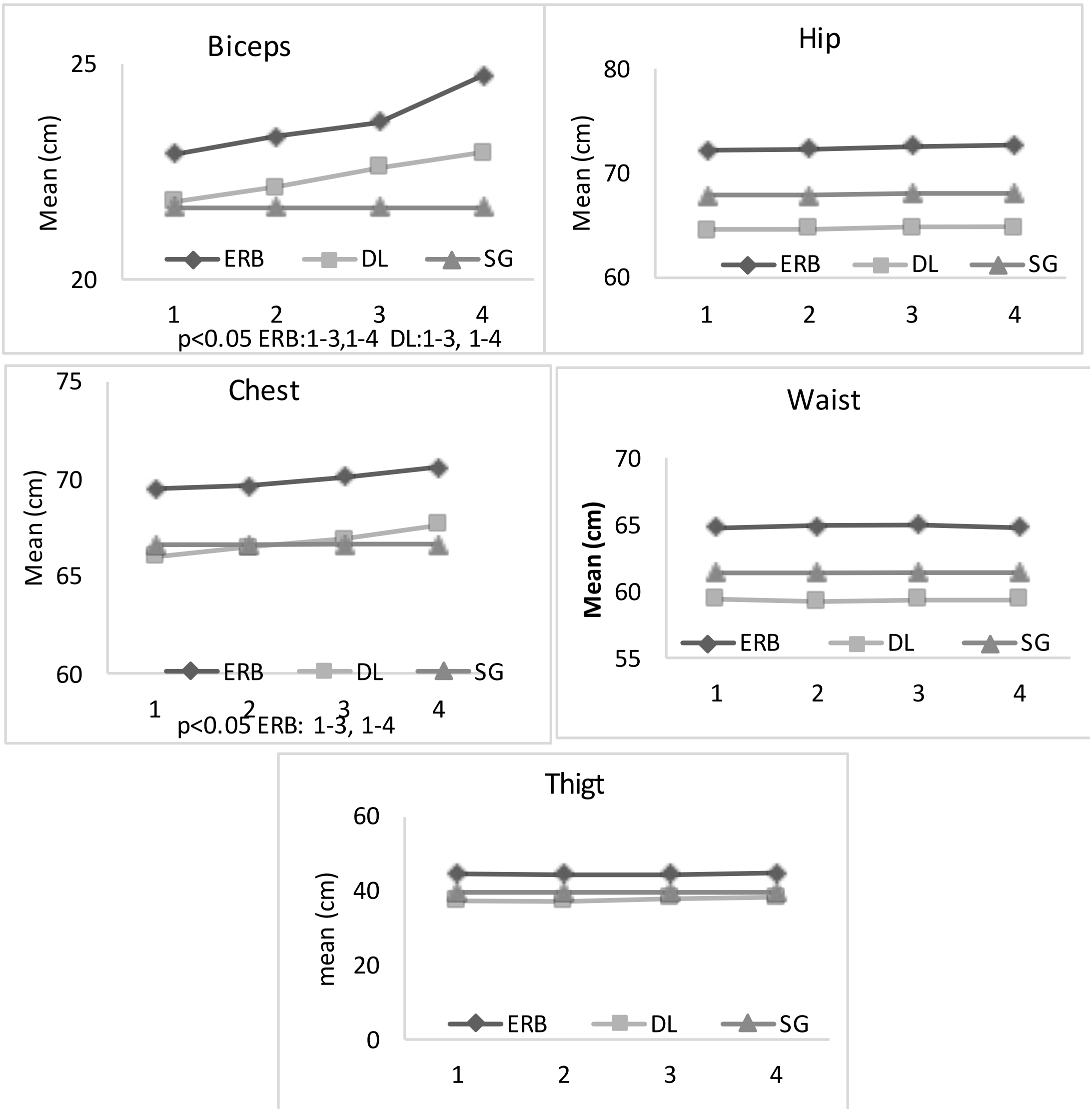
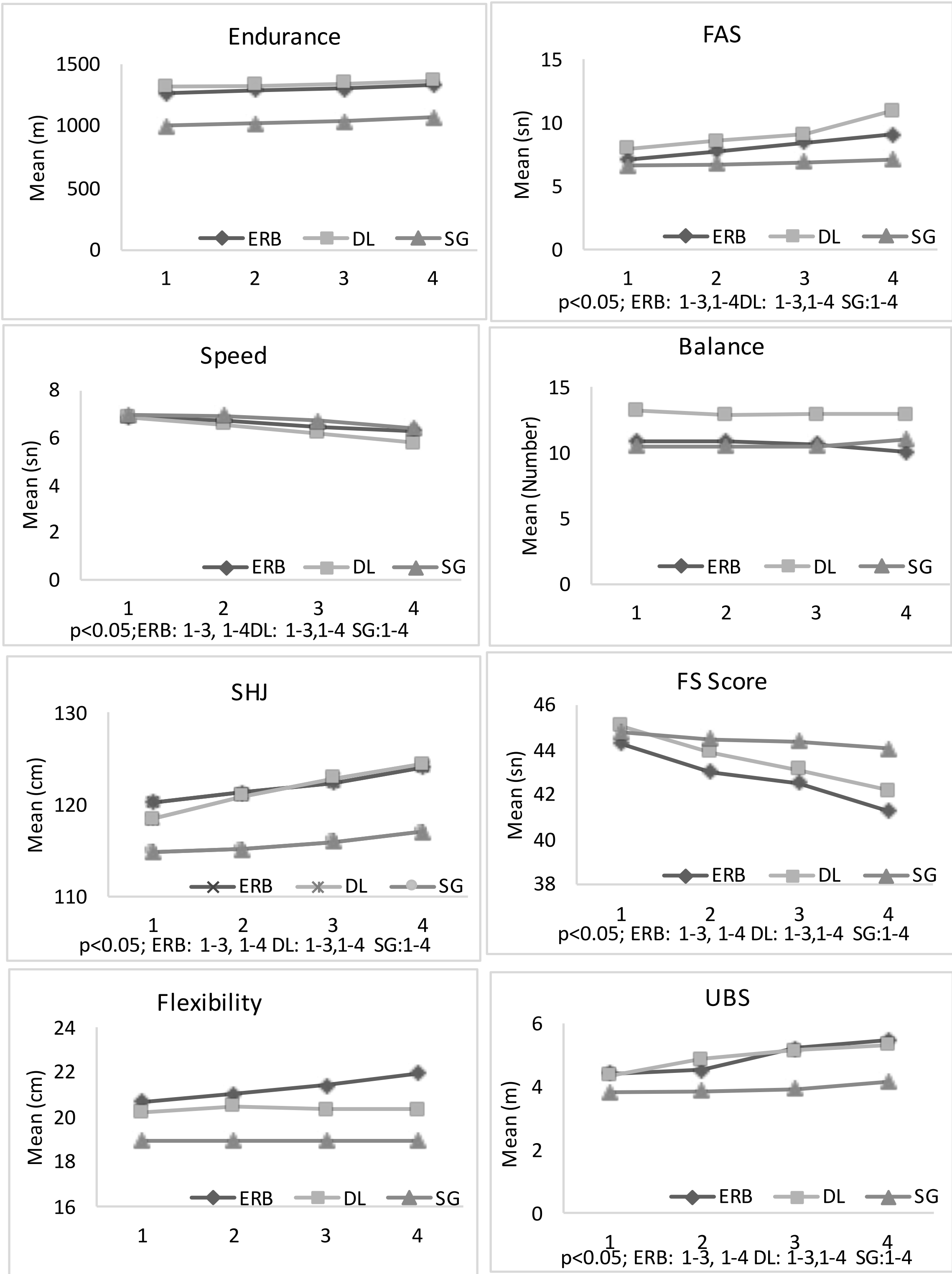
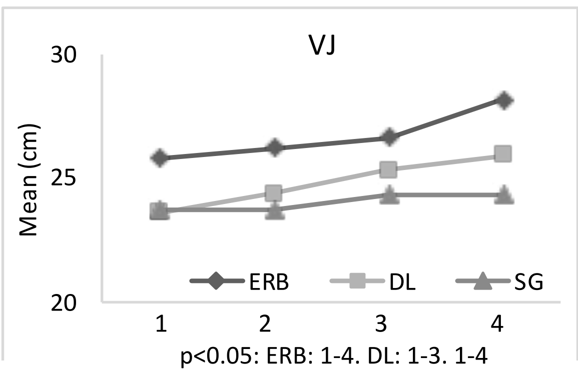


Figure 1. The circumference variables according to the groups.





*p<0.05; FAS: flexed-arm strength; FS: Freestyle; UBS: upper body strength; SHJ: Standing horizontal jump; VJ: Vertical jump

Figure 2. The motoric and freestyle score variables according to the groups.

Table 3. The performance variables as based on the assessment times and total change difference.

Variables	TM	ERB[a]	Dry-land[b]	Swimming[c]	p	Post-Hoc p
		M ± SD (median)	M ± SD (median)	M ± SD (median)		
VJ (cm)	1	25.80±4.0 (27)	23.60±2.9 (23)	23.73±4.6 (24)	-	-
	2	26.20±4.3 (27)	24.39±2.7 (23.7)	23.73±4.6 (24)	0.001	0.001 (b-c)
	3	26.66±4.5 (27)	25.34±2.5 (25)	24.33±3.9 (24)	0.010	0.007 (b-c)
	4	28.2±4.4 (29)	25.90±2.5 (25.8)	24.33±3.9 (24)	0.001	0.005 (a-c) 0.004 (b-c)
TCD		9.3%	9.4%	2.5%	0.001	a-c;b-c
FAS (s)	1	7.08±3.6 (6.4)	7.92±2.6 (7.8)	6.62±2.0 (6.4)	-	-
	2	7.75±3.5 (7.1)	8.51±2.5 (8.1)	6.68±2.0 (6.5)	0.001	0.006 (a-c) 0.003 (b-c)
	3	8.46±2.9 (8.1)	9.02±2.4 (8.5)	6.91±2.1 (6.7)	0.002	0.015 (a-c) 0.004 (b-c)
	4	9.08±2.9 (9.1)	10.95±2.7 (10.7)	7.08±2.1 (7.2)	<0.001	0.003 (a-c) 0.001 (b-c)
TCD		28.2 %	38.3%	6.9 %	0.001	a-c; b-c
Speed (s)	1	6.88±0.5 (6.1)	6.87±05 (6.7)	6.98±05 (6.9)	-	-
	2	6.75±0.4 (6.1)	6.58±04 (6.4)	6.94±05 (6.9)	0.083	-
	3	6.49±0.5 (5.8)	6.21±03 (5.9)	6.72±05 (6.6)	0.017	0.014 (b-c)
	4	6.29±0.5 (5.6)	5.81±03 (5.7)	6.41±04 (6.2)	0.008	0.027 (a-b) 0.016 (b-c)
TCD		8.6%	15.4%	8.1%	0.008	a-b; b-c
UBS (m)	1	4.40±1.0 (4.5)	4.34±0.6 (4.5)	3.82±1.1 (4.1)	-	-
	2	4.52±0.9 (4.5)	4.88±0.5 (4.9)	3.87±1.0 (4.1)	0.001	0.020 (a-c) 0.001 (b-c)
	3	5.22±0.9 (5.2)	5.14±0.5 (5.2)	3.93±0.9 (4.2)	<0.00	0.002 (a-c) 0.001 (b-c)
	4	5.47±0.8 (5.7)	5.31±6.6 (5.2)	4.15±0.7 (4.2)	0.001	0.002 (a-c) 0.009 (b-c)
TCD		24.3%	22.4%	8.6%	0.001	a-c; b-c
SHJ (cm)	1	120.20±9.5 (121)	118.46±8.5 (120)	114.83±8.6 (118)	-	-
	2	121.26±9.3 (124)	120.98±7.5 (123.7)	115.06±8.8 (119)	0.075	-
	3	122.38±7.9 (125)	122.82±7.6 (124.5)	115.93±7.6 (120)	0.075	-
	4	124.00±7.7 (125)	124.40±7.3 (125)	117.06±6.4 (120)	0.088	-
TCD		3.2%	5.0%	1.9%		NS
Flexibility (cm)	1	20.66±6.1 (21)	20.20±4.4 (21)	18.93±4.3 (20)	-	-
	2	21.00±6.0 (21)	20.46±3.8 (21)	18.93±4.3 (20)	0.173	-
	3	21.40±5.4 (21)	20.33±3.8 (20)	18.93±4.3 (20)	0.079	-
	4	21.93±5.3 (21)	20.33±3.8 (20)	18.93±4.3 (20)	0.068	-
TCD		6.1%	0.6%	0%		NS
Endurance (min)	1	1266±271 (1300)	1320±221 (1300)	1006±116 (1000)	-	-
	2	1293±234 (1300)	1326±212 (1300)	1020±108 (1000)	0.541	-
	3	1306±221 (1300)	1346±195 (1300)	1040±91 (1100)	0.718	-
	4	1333±191 (1300)	1366±183 (1300)	1073±103 (1100)	0.670	-
TCD		5.3%	3.5%	6.6%		
Balance	1	10.86±5.9 (10)	13.20±4.7 (14)	10.46±4.7 (10)	-	-
	2	10.86±4.7 (10)	12.86±4.1 (14)	10.46±4.7 (10)	0.563	-
	3	10.66±3.8 (10)	12.93±3.7 (14)	10.46±4.7 (10)	0.589	-
	4	10.06±3.5 (10)	12.93±3.7 (14)	11.00±4.7 (10)	0.159	-
TCD		7.4%	2.0%	5.0%		NS

$p<0.05$; Abbrevations: cm: centimetre; **m:** meter; **min:** minute; **NS:** non-significant; **s:** second; **TCD:** Between 1^{st} and 4^{th} measurement the total change difference. **TM:** times of measurement [(the beginning of the study (1), and after four (2), eight (3) and twelve- week of the training session (4)].

Table 4. The FS performance as based on the assessment times and total change difference.

Variable		ERB[a] M ± SD (median)	Dry-land[b] M ± SD (median)	Swimming[c] M ± SD (median)	p	Post-Hoc p	
	1	44.27±1.8 (44.1)	45.06±2.2 (45.4)	44.79±1.9 (45.2)	-	-	
	2	43.02±1.8 (42.8)	43.89±1.8 (44.2)	44.50±1.7 (45.2)	0.002	0.021 0.002	
	CD (1-2)	2.82 %	2.59 %	0.64 %	0.002	0.21 0.002	
FS Score (s)	**3**	42.55±1.7 (41.2)	43.12±1.7 (43.5)	44.39±1.8 (45.1)	<0.001	0.012 0.001	(a-c) (b-c)
	CD (1-3)	3.88 %	4.30 %	0.89 %	0.000	0.012 0.001	
	4	41.27±1.4 (40.2)	42.21±1.6 (42.8)	44.07±1.7 (44.8)	<0.001	0.001 0.001	
	TCD (1-4)	6.77 %	6.32 %	1.6 %	0.000	0.000 0.000	

p<0.05; CD: Between measurement change differences; **s:** second; **FS:** Freestyle; **TCD:** Between 1st and 4th measurement the total change difference.

DL and SG (p<0.001). Besides, there was a significant difference in the fourth measurement time between the ERB and DL (p<0.001). In TCD, there was a significant change both between the ERB and DL training group, and besides, the change difference was significantly in DL training group comparing to the swimming group (p<0.05). In UBS performance change, there was a significant difference between ERB and DL, and also DL and swimming in second measurement. In the third and fourth measurements, there was a significant difference in both ERB and DL versus SG (p<0.001). In TCD, there was no significant change between the ERB and DL training group, but the change difference was significantly in ERB and DL training group comparing to the SG (p<0.05). In other variables, there was no significant difference among the groups in any measurement times.

In FS performance change, there was a significant difference in both of ERB and DL training groups versus SG in all measurements except the first (p<0.001). In TCD, there was no significant change between the ERB and DL training group, but the change difference was significantly in ERB and DL training group comparing to the swimming group (p<0.05).

Discussion

The first purpose of the study is to compare the effects of 12- weeks of the dry-land training (ERB and DL) that are named as experimental and in-water training, named as swimming (SG). The main findings of the study showed that experimental groups had statistically significant increase in both VJ and SHJ performance conditions compared to the SG (Figure 2). Besides, it showed that all groups had statistically significant increases in speed, UBS, FAS, but the experimental groups accessed the improvements at the end of week 8 of the study, while the SG had the improvements at week 12 of the study (Figure 2). However, no statistically significant improvements were observed in balance, endurance, and flexibility for all groups. But it was observed that flexibility was improved more relatively in ERB group compare the other groups (Figure 2, Table 3). Paralleled to these finding, biceps circumference statistically increased in experimental groups, while just chest circumference increased in ERB group (Figure 1). Improvement in FS score occurred after 12 weeks of ERB and DL training groups with the rate of 6.77 % and 6.32 % respectively compared to SG 1.6 %. Besides, it was seen statistically significant improvement for both of experiment group, but in ERB group the improvement was relatively more compared to DL group (Figure 2; Table 4). Some of the studies that used different training protocols in-water, Girold et al. [25] reported that combining swimming and dry-land strength or swimming and resisted and assisted sprint were more efficient than only the swimming program in increasing sprint performance in 50-meter front crawl swimming. The researchers observed that there were no differences between dry-land strength training and in-water resisted- and assisted-sprint training methods. Colado et al. [26], found that the training using aquatic devices in-water was as effective as training using ERB or weight machines to improve the physical capacity and body composition of postmenopausal women. In other studies, Breed and Young [27] stated that resistance training modes with free weight or machine improved leg power and jumping ability. Besides, the findings showed that improved jumping ability increased the vertical force components of on the grab, track and swing starts in swimming. According to the other study, Morais et al. [28] stated that the swimmers with higher body dimensions achieved better performances in the squat jump, countermovement jump, throwing velocity tests. Amaro et al. [5], reported that 6 weeks of complementary dry-land training led to improvements on strength and explosive, after a 4-week adaptation period for the swimmers. The explosive actions such as starts and turns are highly important on swimming performance that related relative contribution of anaerobic pathways to power production. Therefore, the improving muscle strength seems to be crucial for enhancing competitive swimming performance, and will lead to an increased ability to produce propulsive force in the water. In particular, the upper-body strength, that leads to producing most of the propulsive forces and swimming velocity, is produced as a necessity [29]. The studies supporting this hypothesis, Muniz-Pardos et al. [30] reported that the strength of the upper limbs provides approximately 75% of the energy required for an efficient propulsive force during front crawl, while the lower body strength contributed to the propulsive forces in low to moderate ways, but it had a huge effect during the start and turn phases. Pérez-Olea et al. [31] reported that upper-limb explosive strength was significantly correlated with the swimming performance, but there was no significant relationship between measures of lower-limb strength values and swimming performance. Sammoud et al. [32], reported that plyometric jump training together with the swimming training was more effective than just regular swimming training in improving jump and swimming performances. In another study, Andersen et al. [33], implemented full-body elastic resistance band program, before the regular handball training sessions. The researches [33], reported that the training improved explosive lower-limb performance, jump height, power output, and average velocity in the squat more than compared to the handball training alone. The literature and our findings confirm that engaged in the ERB or DL training program with a focus on gaining strength and power in particular upper body strength, has seemed like an important training part that should be added to the common swimming training schedule.

The second aim of the study was to assess the effectiveness of ERB and DL resistance trainings used and which one was (more) effective in enhancing the performance. The main findings of both training models showed similar level of improvements in performance components. But, DL training led to more improvements relatively in both FAS (38.3%) and speed (15.4%) performance in comparison with the ERB training regimen (FAS: 28.2 %; speed: 8.6%) at the end of the study. Besides, a statistically significant difference was found in speed performance between the ERB and DL training. However, no statistically significant improvements were seen in flexibility, balance and aerobic endurance during the study among both of training models (Table 3), but it was observed that flexibility was improved more relatively in ERB group (6.1%) compare the DL group (0.6%) (Figure 2, Table 3). A study finding that focused on what type of training was executed by swimmers according to their age groups reported that the age groups of ≤10 and 11-14 (years) spent 28%-40% on DL training, whereas the collegiate and master's groups spent 21% and 15%, respectively [34]. They stated that the ≤10 (years) age group spent less than 2 hours per week on dry-land training. Besides, Krabak et al. [34], stated that modes of training in younger swimmers (≤10 and 11-14 years) consisted of percent values with EBR: 7 %, body weight: 40%, medicine ball: 4%; ERB: 11%, body weight: 10 %, medicine ball: 10 % respectively. The literature focusing on the effects of the different training methods, Özsu [35], found that ERB exercises increased hand-grip strength, but did not improve flexibility and agility performance. Therefore, Özsu [35], reported that 6-week elastic resistance band exercises could be helpful to increase the muscular fitness level of children in 8-9 age groups. Similarly, Şahin et al. [7] stated that elastic band training led to more improvements in static squat and vertical jump performance. They reported that ERB compared to the body weight was only developed better in pre-adolescents. Janusevicius et al. [17] found that resistance training with elastic band at high movement velocity improved sprint performance. Janusevicius et al. [17] suggest that also suggested that elastic band training at high movement velocity would increase the overall hamstring muscle power output more, compared to the heavy resistance training. In our study, DL training showed a significant improvement in speed performance compared to the ERB training (rate of 15.4% and 8.6% respectively) (Table 3). In other studies, Joy et al. found that variable resistance training with the use of elastic bands resulted in greater changes in the rate of power development than the SG. Moreover, the training led to greater increases in squat, bench press, and all jumping measurements. Batalha et al. [36] reported that the strength training with the elastic band may lead to help swimmers reduce the risk of injury by increasing shoulder rotator strength and preventing any shoulder muscle imbalances. Similarly, Mascarin et al. [37] showed that strength training using elastic bands before regular handball training was effective to improve muscle power in shoulder internal and external-rotator muscle performance. They reported that the training with elastic bands presented higher values in ball speed with standing and jumping throws.

Based on the literature and our results, the findings support the use of the ERB / DL according to the training goals. Besides, a variety of training regimens versus only one way should be employed to augment strength and power. In fact, all the findings in studies in the literature and also ours support that any type of resistance training, not only just swimming, could be effective. It helps developing performance components to changeable rates based on the training aims. The findings suggest that each of the performance components should be included within the private training regimens that effected it directly.

Conclusions

According to the findings, each of the training modalities may lead to focus on different performance components. DL training provided more improvements the variables, including VJ, UBS, speed, FAS, SHJ compared to both of ERB and SG. ERB training also occurred more improvement in flexibility and balance according to the other groups, but swimming training was only effective on endurance performance. Besides, the findings showed also that ERB training provided relatively more improvement on swimming performance than the other groups. Based on the finding, it may be said that as the reason for the improvement of swimming performance, it caused elastic band movements that used in ERB training stem from the similar to the techniques used in swimming.

Conflicts of interest

The authors declare no conflict of interest.

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ORIGINAL ARTICLE

Functional preparedness of women of the first period of mature age of different somatotypes

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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 It is believed that the somatotype is a predictor of indicators of functional readiness. There are signifi ant di erences in the aerobic performance of the body for people of di erent somatotypes among students girls and men. Features of manifestation of anaerobic possibilities of an organism at persons of various somatotypes from 7 to 30 years old are described. We can assume that women of the fi st adulthood period of di erent somatotypes, indicators of functional readiness are manifested in di erent ways. The aim of the study was to identi y the features of aerobic, anaerobic lactate and anaerobic alactate productivity of women of the fi st period of mature age of di erent somatotypes.

Material and Methods The study involved 210 females 25-35 years old. Somatotype was determined in all subjects. Functional readiness was determined by indicators of anaerobic lactatic productivity, anaerobic alactatic productivity and aerobic productivity of the organism. The power of aerobic energy supply processes was investigated by VO_{2max}. To determine the VO_{2max} used cycling ergometric version of the PWC 170 test. The subjects was performed a stepwise increasing load on the ergometer to determine the TAM. At the end of each stage, heart rate was recorded. The TAM level corresponded to the inflection point on the heart rate growth chart. The capacity of anaerobic lactate processes of energy supply was investigated by indicator of the maximum quantity of mechanical work for 1 minute (MQMK). The subjects performed a bicycle ergometric load duration 1 min with a power of 225 W with a maximum pedaling frequency. The power of anaerobic lactate processes of energy supply was determined by the Wingate anaerobic test WAnT 30. The power of anaerobic alactate processes of energy supply was determined by the test WAnT 10. Statistical processing was performed using the program STATISTICA 13.

Results According to absolute indicators (WAnT10. WAnT30. MQMK, TAM, VO_{2max}) the advantage of representatives of endomorphic-mesomorphic somatotype was established. According to relative indicators of aerobic productivity (TAM, VO_{2max}) representatives of the ectomorphic and balanced somatotype predominate.

Conclusions: High values of absolute indicators of functional readiness are associated with high values of body mass in combination with a high percentage of muscle for women of different somatotypes. Accordingly, for representatives of somatotypes with lower body mass are characterized by lower absolute values of all indicators of functional fitness. The relative indicators of aerobic productivity are dominated by representatives of somatotypes, which are characterized by lower body mass.

Keywords: aerobic, anaerobic productivity, somatotype, females.

Introduction

In the field of sp orts, the possibilities of using the somatotype have been thoroughly studied. Somatotype is taken into account in sports selection, sports orientation and training. Based on the somatotype, morpho-functional models are developed as a reference point for achieving a certain level of preparedness. Over the past few years, significant progress has been made in the development of technologies for diagnosing functional readiness. Thus, modern cycling computers and running heart rate monitors allow you to determine the threshold of anaerobic metabolism and maximum oxygen consumption without special laboratory testing. To determine the anaerobic component of functional fitness, tests have been developed that can be performed in a regular fitness center. The availability of diagnostics has caused the need for physically active people to monitor their own level of functional fitness. This created a request to study the features of functional fitness of people of different somatotypes not related to sports.

Goran Spori et al. [1] found statistically significant difference in the values of maximum oxygen consumption (VO_{2max}) in military sailors of different somatotypes. Sukanta Saha [2] found that somatotype components (endomorphy, ectomorphy, mesomorphy) are well correlated with $VO_{2\ max}$. Dulo et al. [3] found significantly higher absolute indicators of physical performance (PWC 170) and $VO_{2\ max}$ women of endomorphic-mesomorphic somatotype, compared with other somatotypes. Neha Parve et al. [4] proved the relationship between somatotype, height, body weight and VO_{2max}. In our previous studies, we found a significant advantage of

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ectomorphic and balanced somatotype in the relative indicator of maximum oxygen consumption (VO_{2max}) in girls 17-19 years [5].

Zimnitskaya et al. [6] studied the threshold of anaerobic metabolism and the threshold of aerobic metabolism 25-35 years women of different somatotypes. The authors found higher performance of asthenics at the level of thresholds of aerobic and anaerobic metabolism in relative terms and higher performance of normosthenics in absolute terms.

In the modern scientific literature, less attention has been paid to the study of anaerobic productivity in non-athletes. Investigating the anaerobic lactate productivity of girls 17-19 years old in absolute terms of the maximum quantity of mechanical work for 1 minute (MQMK), we found a predominance of endomorphic and endomorphic-mesomorphic somatotype. According to the relative indicator of the maximum quantity of mechanical work for 1 minute, no statistically significant differences were found in the representatives of different somatotypes [5]. The determining role of somatotype in relation to the level of anaerobic lactatic productivity in men 26 ± 8.9 years old is indicated by Ryan-Stewart et al. [7]. In addition, the authors note that a third of strength indicators are predicted by somatotype. But such conclusions were made by the authors on the basis of the analysis of strength exercises, instead of functional tests. Furman et al. [8] established the standards of functional fitness of girls 17-19 years for the whole spectrum of energy supply of muscular activity, but this work does not take into account the somatotype of the subjects. Dulo [9] studied anaerobic alactic and anaerobic lactatic productivity in girls from 16 to 20 years old. The author found significantly higher values of the absolute indicators of the Wingate anaerobic test WAnT10 and WAnT30 in the endomorphic-mesomorphic somatotype. According to the relative indicators of WAnT10 and WAnT30 found significantly lower values in ectomorphic and endomorphic somatotype. Çinarli et al. [10] studied the anaerobic capacity of men of different somatotypes 22.1 ± 2.46 years old according to the WAnT test 30. The authors found that the relative values of peak power and average anaerobic power in different somatotypes do not have statistically significant differences ($p > 0.05$).

Studies of the features of the manifestation of indicators of functional fitness of women of the first period of adulthood of different somatotypes for the whole spectrum of energy supply of muscular activity (aerobic, anaerobic alactic and anaerobic lactatic) were not found. Similar studies were conducted by Kornienko et al. [11], but with a different age group. The authors investigated all modes of energy supply of muscular activity in boys and girls 7-17 years of age of different somatotypes. The difference in representatives of different somatotypes for indicators of power and capacity of aerobic and anaerobic productivity of organism is established. Features of these differences are strongly expressed at teenagers. The authors state that sometimes differences in the somatotype by more values than gender differences. Kaur et al. [12], Nikolic et al. [13], indicate to age-related changes in the relationship of components of the somatotype. Therefore, information about the functional preparedness of representatives of different somatotypes from one age group to another can not be correctly transmitted.

There is a need to test the hypothesis that women of the first period of adulthood of different somatotypes the indicators of functional readiness are differently manifested.

The aim of the study was to identify the features of aerobic, anaerobic lactate and anaerobic alactate productivity of women of the first period of mature age of different somatotypes.

Material and Methods

Participants. The study involved females 25-35 years old (the first period of mature age) n = 210. All subjects in the past had no experience in sports. Each subject gave written consent to participate in the experiment.

Procedure. Initially, somatotype was determined for all subjects by the Carter et al. [14] method.

Functional readiness is determined for indicators of aerobic alactic, anaerobic lactatic and aerobic productivity. The power of aerobic energy supply processes of muscular activity was investigated by the indicator of maximum oxygen consumption ($VO_{2\ max}$). $VO_{2\ max}$ was determined by the Karpman et al. [15] method. For this purpose was used a bicycle ergometric test of the PWC 170 version. The subjects performed two loads of different power. The power of the first load (N_1) was 1 W per 1 kg of body weight, the other (N_2) - 2 W per 1 kg of body weight. Pedaling frequency - 60 revolutions per 1 minute. The duration of each load was 5 minutes with 3 minutes interval. At the end of each load, the heart rate (f_1 and f_2) was determined. PWC 170 was calculated according to the algorithm [16]. To determine the values of $Vo_{2\ max}$, the value of $PWC_{170\ abs}$ was substituted into equation 1:

$$VO_{2max\ abs.} = 1{,}7 \cdot PWC_{170\ abs.} + 1240, \qquad (1)$$

where $VO_{2\ max\ abs.}$ displayed in $ml \cdot min^{-1}$; $PWC_{170\ abs.}$ displayed in $kg \cdot min^{-1}$.

The threshold of anaerobic metabolism (TAM) was determined by the test of Conconi et al. [17] in a modification of Furman [18, Art. 37-38]. The subjects performed a stepwise increasing load on the ergometer starting from a power of 60 watts, adding 10 watts at each stage. The duration of work and the frequency of pedaling at each stage are constant - the duration is 40s, and the frequency is 60 rpm^{-1}. At the end of each stage, heart rate was recorded. The level of TAM corresponded to the inflection point on the graph of heart rate growth. Results were presented in W.

To determine the capacity of anaerobic lactatic energy supply processes of muscular activity was used a method developed by Shogy et al. [19]. This method involves determining the maximum quantity of mechanical work for 1 minute (MQMK). The subject performed a bicycle ergometric load with 1 min duration, power of 225 W and maximum pedaling frequency. Results were presented in kg·min^{-1}.

The power of anaerobic alactatic energy supply processes of muscular activity was determined using the Wingate anaerobic test WAnT10 [20]. This test consists in performing a bicycle ergometric load 10sec duration with a power of 225 W and maximum possible pedaling frequency. The number of full pedal revolutions was counted. By mathematical calculations, the result was expressed in kg·min^{-1}.

The power of anaerobic lactatic energy supply processes of muscular activity was determined using the Wingate anaerobic test (WAnT30) [20]. The conditions of this test are similar to the WAnT10 test. The difference is duration of the load that lasted 30 seconds. Result was expressed in kg·min^{-1}.

To increase the informativeness of all indicators, absolute and relative values were studied. All tests were performed on a Christopeit Sport AX-1 bicycle ergometer (Christopeit, Germany).

Statistical analysis. Independent samples were compared, where the series reflected the trait in representatives of different somatotypes. Initially, the data series were checked using STATISTICA 13 for compliance with the normal distribution law. Data that corresponded to the normal distribution law were compared according to Student's t- criterion. Determined: $\bar{X}$ - arithmetic mean, S – standard deviation, t – value of Student's t-criterion, p – level of significance. The difference was considered significant at a significance level of $p<0.05$.

Results

The study of the power of anaerobic alactatic processes of energy supply in women of different somatotypes revealed were defined the predominance of representatives endomorphic-mesomorphic somatotype. Value of indicator WAnT $10_{abs.}$ in women with the endomorphic-mesomorphic somatotype is statistically significantly greater than the value of representatives all other somatotypes ($p<0.05$). In turn, the representatives of the endomorphic somatotype are dominated by women of ectomorphic and balanced somatotypes ($p<0.05$). Value of indicator WAnT $10_{abs.}$ in representatives ectomorphic and balanced somatotypes do not have statistically significant differences ($p>0.05$) (table 1).

The calculation of the indicator WAnT $10_{abs.}$ per kg of body mass of the subjects slightly changes the picture. According to the indicator of WAnT $10_{rel.}$ the value of the representatives of the endomorphic-mesomorphic somatotype exceeds the value of the representatives of all other somatotypes ($p<0.05$). Representatives of the endomorphic somatotype have an advantage only over women of the ectomorphic somatotype ($p<0.05$). The lowest values of the indicator of WAnT $10_{rel.}$ have representatives of ectomorphic and balanced somatotypes, which do not have a statistically significant difference ($p>0.05$) (table 1).

During an investigation of the power of anaerobic lactatic processes of energy supply according to the indicator WAnT 30abs. were found an advantage of representatives of endomorphic-mesomorphic somatotype over representatives of all other somatotypes ($p<0.05$). The value of representatives of endomorphic somatotype prevails over representatives of ectomorphic and balanced somatotypes ($p<0.05$). The values of ectomorphic and balanced somatotypes are the lowest and do not have statistically significant differences ($p>0.05$) (table 2).

Table 1. Power of anaerobic alactic processes of energy supply of women 25-35 years with different somatotypes

Somatotype groups	WAnT 10 (kg·min^{-1}) $\bar{X}$ ± S	The level of significance of the t-criterion t; p	WAnT 10 (kg·min^{-1}·kg^{-1}) $\bar{X}$ ± S	The level of significance of the t-criterion t; p
Endomorphic	2517.9±302.40	t=8.73; p=0.000*	37.8±3.41	t=2.65; p=0.009*
n = 49		t=-4.73; p=0.000●		t=-7.01; p=0.000●
		t=6.40; p=0.000■		*t=1.74; p=0.086*■
Ectomorphic	1981.8±305.39	t=-8.73; p=0.000○	35.8±3.89	t=-2.65; p=0.009○
n = 49		t=-12.30; p=0.000●		t=-9.23; p=0.000●
		t=-0.84; p=0.402■		*t=-0.59; p=0.554*■
Endomorphic-mesomorphic	2850.8±407.18	t=12.30; p=0.000*	42.7±3.82	t=9.23; p=0.000*
		t=4.73; p=0.000○		t=7.01; p=0.000○
n = 58		t=10.19; p=0.000■		t=7.79; p=0.000■
Balanced	2044.3±430.50	t=-6.40; p=0.000○	36.3±4.83	*t=-1.74; p=0.086*○
n = 54		*t=0.84; p=0.402**		*t=0.59; p=0.554**
		t=-10.19; p=0.000●		t=-7.79; p=0.000●

Notes: 1. WAnT10 – Wingate anaerobic test for 10 seconds. 2. ○ – relative to the endomorphic somatotype; * – relative to the ectomorphic somatotype; ● – relative to the endomorphic-mesomorphic somatotype; ■ – relatively balanced somatotype. 3. *t=-0.84; p=0.402* – italicized data where p>0.05.

Table 2. Power of anaerobic lactatic processes of energy supply of women 25-35 years with different somatotypes

Somatotype groups	WAnT30 (kg·min $^{-1}$)	The level of significance of the t-criterion	WAnT30 (kg·min $^{-1}$·kg $^{-1}$)	The level of significance of the t-criterion
	X̄ ± S	t; p	X̄ ± S	t; p
Endomorphic n = 49	2303.3±287.95	t=7.68; p=0.000*	34.6±3.42	t=2.69; p=0.008*
		t=-3.90; p=0.000●		t=-5.10; p=0.000●
		t=6.33; p=0.000■		t=2.75; p=0.007■
Ectomorphic n = 49	1780.2±380.03	t=-7.68; p=0.000○	32.1±5.45	t=-2.69; p=0.008○
		t=-10.45; p=0.000●		t=-6.73; p=0.000●
		t=-0.37; p=0.716■		*t=0.06; p=0.952*■
Endomorphic-mesomorphic n = 58	2569.1±396.55	t=10.45; p=0.000*	38.5±4.43	t=6.73; p=0.000*
		t=3.90; p=0.000○		t=5.10; p=0.000○
		t=9.25; p=0.000■		t=6.85; p=0.000■
Balanced n = 54	1811.2±469.52	t=-6.33; p=0.000○	32.0±5.57	t=-2.75; p=0.007○
		*t=0.37; p=0.716**		*t=-0.06; p=0.952**
		t=-9.25; p=0.000●		t=-6.85; p=0.000●

Notes: 1. WAnT30 - Wingate anaerobic test for 30 seconds. 2. ○ – relative to the endomorphic somatotype; * – relative to the ectomorphic somatotype; ● – relative to the endomorphic-mesomorphic somatotype; ■ – relatively balanced somatotype. 3. t=-0.37; p=0.716 – italicized data where p>0.05.

According to the relative indicator of WAnT 30. representatives of endomorphic-mesomorphic somatotype have a statistically significant advantage over representatives of all other somatotypes ($p<0.05$). WAnT $30_{rel.}$ value of representatives of endomorphic somatotype is statistically significantly greater than the value of ectomorphic and balanced somatotypes ($p<0.05$). The values of ectomorphic and balanced somatotypes do not have a statistically significant difference ($p>0.05$) (table 2).

The study of the capacity of anaerobic lactatic processes of energy supply on the absolute indicator of MQMK revealed the advantage of representatives of endomorphic-mesomorphic somatotype over the values of all other somatotypes ($p<0.05$). The value of $MQMK_{abs.}$ representatives of endomorphic somatotype exceed the value of ectomorphic and balanced somatotypes ($p<0.05$). And the value of the representatives of the ectomorphic somatotype exceeds the value of the representatives of the balanced somatotype, which is the lowest ($p<0.05$) (table 3).

The calculation of absolute indicator MQMK values per kg of body mass of the subjects revealed some differences. So the value of $MQMK_{rel.}$ representatives of endomorphic-mesomorphic somatotype statistically significantly exceeds only the value of representatives of endomorphic and balanced somatotypes ($p<0.05$). The values of representatives of ectomorphic somatotype exceed the values of endomorphic and balanced somatotypes ($p<0.05$). The values of representatives of endomorphic and balanced somatotypes have no statistically significant difference ($p>0.05$).

The study of the threshold of anaerobic metabolism of women of different somatotypes in absolute terms revealed the predominance of endomorphic-mesomorphic somatotype over all other somatotypes ($p<0.05$). Between the values of $TAM_{abs.}$ representatives of endomorphic, ectomorphic and balanced somatotypes, no statistically significant difference was found ($p>0.05$) (table 4).

The calculation of the TAM indicator per kg of body mass of the subjects revealed the highest value in the representatives of the ectomorphic somatotype, which exceeds the value of the representatives of the endomorphic and endomorphic-mesomorphic somatotypes ($p<0.05$). The value of $TAM_{rel.}$ representatives of the balanced somatotype do not have a significant difference from the values of the ectomorphic somatotype ($p>0.05$), but exceeds the value of the endomorphic and endomorphic-mesomorphic somatotypes ($p<0.05$). Representatives of endomorphic-mesomorphic somatotype according to $TAM_{rel.}$ dominated by representatives of the endomorphic somatotype ($p<0.05$) (table 4).

The study of aerobic productivity of women of different somatotypes in absolute terms of VO_{2max} revealed the predominance of representatives of endomorphic-mesomorphic somatotype over representatives of all other somatotypes ($p<0.05$). The value of $VO_{2max\ abs.}$ representatives of ectomorphic, endomorphic and balanced somatotypes do not have statistically significant differences ($p>0.05$) (table 5).

According to the relative indicator VO_{2max}, a statistically significant advantage of representatives of ectomorphic and balanced somatotypes over representatives of endomorphic and endomorphic-

Table 3. Capacity of anaerobic lactatic processes of energy supply of women 25-35 years of different somatotypes

Somatotype groups	MQMK (kg·min^{-1})	The level of significance of the t-criterion	MQMK (kg·min^{-1}·kg^{-1})	The level of significance of the t-criterion
	X̄ ± S	t; p	X̄ ± S	t; p
Endomorphic n = 49	1527.2±163.37	t=2.79; p=0.006* t=-5.17; p=0.000● t=6.39; p=0.000■	23.0±2.05	t=-4.22; p=0.000* t=-5.72; p=0.000● _t=-0.20; p=0.841■_
Ectomorphic n = 49	1405.9±255.95	t=-2.79; p=0.006○ t=-6.89; p=0.000● t=2.55; p=0.012■	25.4±3.52	t=4.22; p=0.000○ _t=-1.08; p=0.282●_ t=3.91; p=0.000■
Endomorphic-mesomorphic n = 58	1734.9±237.84	t=6.89; p=0.000* t=5.17; p=0.000○ t=10.50; p=0.000■	26.1±3.40	_t=1.08; p=0.282*_ t=5.72; p=0.000○ t=5.38; p=0.000■
Balanced n = 54	1288.5±209.94	t=-6.39; p=0.000○ t=-2.55; p=0.012* t=-10.50; p=0.000●	23.0±2.58	_t=0.20; p=0.841○_ t=-3.91; p=0.000* t=-5.38; p=0.000●

Notes: 1. MQMK - maximum quantity of mechanical work for 1 minute. 2. ○ – relative to the endomorphic somatotype; * – relative to the ectomorphic somatotype; ● – relative to the endomorphic-mesomorphic somatotype; ■ – relatively balanced somatotype. 3. t=-0.20; p=0.841 – italicized data where p>0.05.

Table 4. The threshold of anaerobic metabolism of women 25-35 years of different somatotypes

Somatotype groups	TAM (W)	The level of significance of the t-criterion	TAM (W·kg^{-1})	The level of significance of the t-criterion
	X̄ ± S	t; p	X̄ ± S	t; p
Endomorphic n = 49	138.6±12.91	_t=0.87; p=0.384*_ t=-4.15; p=0.000● _t=1.94; p=0.055■_	2.1±0.26	t=-7.79; p=0.000* t=-3.05; p=0.003● t=-6.56; p=0.000■
Ectomorphic n = 49	136.3±12.53	_t=-0.87; p=0.384○_ t=-5.04; p=0.000● _t=1.09; p=0.278■_	2.5±0.21	t=7.79; p=0.000○ t=4.56; p=0.000● _t=1.91; p=0.059■_
Endomorphic-mesomorphic n = 58	149.8±14.80	t=5.04; p=0.000* t=4.15; p=0.000○ t=6.08; p=0.000■	2.3±0.27	t=-4.56; p=0.000* t=3.05; p=0.003○ t=-3.12; p=0.002■
Balanced n = 54	133.5±13.48	_t=-1.94; p=0.055○_ _t=-1.09; p=0.278*_ t=-6.08; p=0.000●	2.4±0.19	t=6.56; p=0.000○ _t=-1.91; p=0.059*_ t=3.12; p=0.002●

Notes: 1. TAM – threshold of anaerobic metabolism. 2. ○ – relative to the endomorphic somatotype; * – relative to the ectomorphic somatotype; ● – relative to the endomorphic-mesomorphic somatotype; ■ – relatively balanced somatotype. 3. t=0.87; p=0.384 – italicized data where p>0.05.

Table 5. Power of aerobic processes of energy supply of women 25-35 years of different somatotypes

Somatotype groups	VO_{2max} (ml·min^{-1})	The level of significance of the t-criterion	VO_{2max} (ml·min·kg^{-1})	The level of significance of the t-criterion
	X̄ ± S	t; p	X̄ ± S	t; p
Endomorphic n = 49	2509.9±116.43	*t=0.72; p=0.475**	37.8±2.97	t=-11.11; p=0.000*
		t=-6.13; p=0.000●		t=-3.99; p=0.000●
		t=1.91; p=0.059■		t=-7.99; p=0.000■
Ectomorphic n = 49	2487.0±190.65	*t=-0.72; p=0.475○*	45.2±3.59	t=11.11; p=0.000○
		t=-5.67; p=0.000●		t=6.51; p=0.000●
		t=1.06; p=0.293■		*t=1.38; p=0.172■*
Endomorphic-mesomorphic n = 58	2681.1±163.61	t=5.67; p=0.000*	40.5±3.85	t=-6.51; p=0.000*
		t=6.13; p=0.000○		t=3.99; p=0.000○
		t=6.67; p=0.000■		t=-4.42; p=0.000⍰
Balanced n = 54	2445.2±209.38	*t=-1.91; p=0.059○*	44.1±4.70	t=7.99; p=0.000○
		*t=-1.06; p=0.293**		*t=-1.38; p=0.172**
		t=-6.67; p=0.000●		t=4.42; p=0.000●

Notes: 1. VO2max – maximum oxygen consumption. 2. ○ – relative to the endomorphic somatotype; * – relative to the ectomorphic somatotype; ● – relative to the endomorphic-mesomorphic somatotype; ■ – relatively balanced somatotype. 3. t=0.72; p=0.475– italicized data where p>0.05.

mesomorphic somatotypes was revealed ($p<0.05$). The value of $VO_{2max\ rel.}$ representatives of endomorphic-mesomorphic somatotype exceeds the value of representatives of endomorphic somatotype ($p<0.05$).

Discussion

Investigating the anaerobic alactic productivity of girls aged 16-20 years, Dulo [9] found significantly higher absolute and relative values of WAnT10 indicator for women of endomorphic-mesomorphic somatotype. In addition, the author found that women of endomorphic and balanced somatotypes are characterized by lower values of absolute and relative values of WAnT10. Our results also indicate that among women 25-35 years in absolute and relative WAnT10 indicator have a predominance of representatives of endomorphic-mesomorphic somatotype. But the lowest results we found in representatives of ectomorphic and balanced somatotypes. Therefore, with age, anaerobic lactatic women productivity of different somatotypes may change. In our previous studies, we found that endomorphic and endomorphic-mesomorphic somatotypes representatives is differ by more body mass, and ectomorphic and balanced representatives - less. In addition, representatives of endomorphic-mesomorphic and ectomorphic somatotypes have higher percentages of muscle component [21]. Thus, we found that anaerobic lactatic productivity of women 25-35 years is at the highest level in representatives of somatotypes with greater body mass. The predominance of representatives of endomorphic-mesomorphic somatotype is due to high body mass values combined with a high percentage of muscle in the body. Such data indicate a probable high correlation anaerobic alactic productivity with the body's mass and the percentage of muscle in the body. Additional research is needed to confirm this hypothesis.

The peculiarities of anaerobic lactate productivity of the organism women aged 25-35 of different somatotypes according to WAnT 30 indicators have the same tendencies as according to WAnT10 indicator. Only according to the relative WAnT 30 indicator representatives of endomorphic somatotype have lost their advantage over women of balanced and ectomorphic somatotypes. According to Çinarli et al. [10] there is no statistically significant difference for men 22 years old among representatives of different somatotypes by the test WAnT30. In the literature, we did not find data on the peculiarities of the manifestation of WAnT 10 and WAnT 30 for women aged 25-35 of different somatotypes.

According to the absolute and relative indicators of the capacity of anaerobic lactatic productivity of the organism, the advantage of the representatives of the endomorphic-mesomorphic somatotype was revealed. According to the absolute indicator of MQMK, a statistically significant difference was found between the representatives of all somatotypes in descending order: endomorphic-mesomorphic, endomorphic, ectomorphic, balanced. According to the relative indicator of MQMK, the highest values are in the representatives of endomorphic-mesomorphic and ectomorphic somatotypes. The lower values are in the women of endomorphic and balanced somatotypes. The data obtained by us are somewhat different from studies conducted with girls 17-19 years [5]. These differences relate to the relative rate of MQMK, as no statistically significant difference was found in girls aged 17-19 in representatives of different somatotypes. Thus, it can be argued that with age, for women the somatotype has a greater impact on anaerobic lactatic productivity.

According to the absolute indicator of the threshold of anaerobic metabolism, we found the advantage of the representatives of the endomorphic-mesomorphic somatotype over the representatives of all other somatotypes. According to the relative indicator of TAM, the advantage of representatives somatotypes who have less body mass - ectomorphic and balanced - was revealed. Zimnitskaya et al. [6] also investigated the threshold of anaerobic metabolism of women 25-35 years old. The authors found the predominance of normosthenic type in absolute terms and the predominance of asthenic type in relative terms. It should be noted that the authors used a different method of somatotyping. Therefore, these results can be taken into account, but to compare with our data is incorrect.

The obtained data on aerobic productivity of women in the first period of adulthood agreed with the data of previous studies on aerobic productivity of girls aged 17-19 [5]. For both age groups the advantage is endomorphic-mesomorphic somatotype for the absolute value of $VO_{2\ max}$, and the advantage is ectomorphic and endomorphic somatotypes for the relative value of $VO_{2\ max}$. Larry Kenny et al. [22], J. Furman [18] consider the relative indicator of $VO_{2\ max}$ more informative for the analysis of aerobic performance. Then it is possible to say that among 25-35 years old women the representatives of those somatotypes who have smaller body weight have the best aerobic opportunities. Rupasinghe et al. [23] claim that by the relative Vo2 max indicator among medical students is dominated by representatives with a predominance of ectomorphy. Since ectomorphy assumes low values of body mass relative to height, we can assume that these data are consistent with our results. Alkandari, et al. [24] found that for men and women aged 9 to 55 years, endomorphy has a strong negative impact on the ability to demonstrate aerobic capacity. Marangoz Irfan et al. [25] found in handball players aged 18-30 a high degree of negative correlation between $VO_{2\ max}$ and endomorphy. Kanae Oda et al. [26] found negative correlations between $VO_{2\ max}$ and body fat percentage in Japanese men and women aged 30-52. Similar data were obtained by Anjali Nilkanthappa Shete [27], who investigated girls aged 17-22 old. Such data are consistent with our studies, because according to our data, representatives of somatotypes where endomorphy dominates (endomorphic-mesomorphic and endomorphic) have lower values of $VO_{2\ max\ rel.}$.

Conclusions

High values of absolute indicators of functional fitness in women of different somatotypes are associated with high values of body weight combined with a high percentage of muscle. Accordingly, for representatives of somatotypes with lower body weight are characterized by lower absolute values of all indicators of functional fitness. The calculation of absolute values per kilogram of body weight significantly changes the distribution only in terms of aerobic productivity (VO2 max and TAM). According to the relative indicators of aerobic productivity, representatives of somatotypes, which are characterized by lower body mass, predominate.

The data obtained by us must be taken into account when analyzing the indicators of functional fitness of women who do not play sports. Also, these data must be taken into account when developing standards of functional readiness. The result of a woman of a certain somatotype can be significantly inferior (or superior) to the average level set for women without taking into account the somatotype, while corresponding to the average level for this somatotype.

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Conflict of interest

The authors state that there is no conflict of interest.

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ORIGINAL ARTICLE

The level of physical activity of university students in Slovakia during COVID - 19 pandemic

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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 COVID-19 coronavirus pandemic has affected several areas of human and public life. The implementation of the restrictions affects free movement, leading to limited physical activity (PA) level. The main aim of the study was to determine the level of PA of university students in Slovakia during COVID–19 pandemics.

Material and Methods The sample consisted of 3128 university students. Data was obtained from students from three universities with different specializations. A questionnaire about lifestyle with questions about physical activity was used. The questionnaire was distributed using online communication systems of universities. The online questionnaire was answered by 3128 students.

Results Analyzed data were obtained from 3128 students. The results indicate that 38% of all students exercise 3-4 times per week, while 41% exercise 1-2 times per week, and 21% do not exercise at all, or exercise 1-2 times per month. Found weak positive correlation (r=0,337) was between the exercise frequency and perception of well-being, and a very weak positive correlation (r=0,187) between the exercise frequency and stress intensity. A moderate positive correlation was found between the perception of health and life energy (r=0,579). A moderate positive correlation was observed between the perception of health and physical strength (r=0,579).

Conclusions COVID-19 restrictions have been associated with the reduction of physical activity of the students. To avoid the negative effects of a sedentary lifestyle, it is necessary to promote activity among university students.

Keywords: coronavirus, lifestyle, online communication, exercise, well-being

Introduction

The first cases of COVID-19 originally appeared in December 2019 in Wuhan, China, in Hubei Province, and the situation has quickly turned into a global pandemic [1]. The emergence of the global crisis COVID-19 has caused an immediate and significant burden on public health [2]. The COVID-19 pandemic has brought various challenges and changes to human life around the world, affecting the quality of life, lifestyles, and social life, and affected the local and international economy. In the early stages of the crisis, national governments took measures to reduce the spread of COVID-19, and many countries were constrained by various restrictions. Restrictions are likely to affect reducing physical activity [3]. Physical activity can be defined as any physical movement performed by skeletal muscle that requires energy expenditure. A subcategory of physical activity is exercising. It is a planned, repetitive activity aimed to improve or maintain any of the components of physical fitness. The beneficial effects of physical activity on human health are clear [4]. Lack of physical activity is associated with a higher risk of developing diseases. Sufficient physical activity is associated with lower mortality [5]. Physical activity is important in the prevention of cardiovascular diseases [6]. The benefit of physical activity is also applied in the prevention and treatment of oncological diseases [7]. Lack of physical activity is associated with weight gain [8]. Lack of physical activity at a younger age often may not cause any acute manifestations, the health consequences may manifest with higher age. Some studies have shown a decrease in physical activity during the corona crisis [9-11]. The restrictions imposed were a major barrier for physical activity, the closure of sports facilities and parks has reduced, in particular, the possibility of engaging in physical activity. It can be assumed that eLearning and teleworking contribute additionally to a sedentary lifestyle. A sedentary lifestyle is associated with a higher risk of developing diseases [12]. It can be seen that the COVID-19 crisis has led to the limitation of physical activity not only for healthy people but also for patients [13].

For this reason, our study aimed to measure the level of physical activity of university students in Slovakia. We hypothesized that the establishment of eLearning and government restrictions will contribute to decreasing the overall level of physical activity.

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Material and Methods

To assess the impact of the COVID-19 pandemic and the effect of restrictions we decided to investigate the level of physical activity of Slovak university students. The study was cross-sectional at 3 Slovak universities: Matej Bel University, Technical University of Košice, Slovak Medical University in Bratislava Faculty of Healthcare based in Banská Bystrica. The data were collected through the online questionnaire for 2 months, from October to November 2020.

Participants

We have focused on university students aged 18 and over. Students were from three universities with different specifications. A lifestyle questionnaire was used, from which we used questions about physical activity. The questionnaire was distributed using online communication systems of universities. All participants agreed to participate in the study and informed consent was obtained from all of the subjects. All data were collected anonymously without providing any personal data and participants were not rewarded. We received 3128 students who answered the online questionnaire. Of these, 2238 (71,5%) were students from Technical University of Košice., 620 (19,8%) were students from Matej Bel University and 270 (8,6%) were students from Slovak Medical University in Bratislava Faculty of Healthcare based in Banská Bystrica. 1689 men (54%) and 1439 women (46%) answered a questionnaire. The average age of the sample was 21,6 (SD±4,4). The average age in the group of men was 21,3 (SD±4) and in the group of women 22 (SD±4,8).

Questionnaire

Questions were selected from the lifestyle questionnaire. We have focused on the questions about physical activity during the coronavirus crisis. The questionnaire included questions: "How often do you exercise during the coronavirus crisis?", What kind of exercise do you prefer?", "What kind of sport have you practiced in the past?", "Where do you go to exercise?", "What kind of movement activity do you dislike?" In the following questions, students could note their perceptions on a scale of 1 to 10. "What level of stress have you been feeling recently?", "How healthy do you feel?", "In terms of your energy, how do you feel during the normal day?", "How strong you are physical?", "What are your coordination abilities?".

Statistical analysis

The frequencies of responses on categorical variables and ordinal variables were presented as numeric values and percentages). A non-parametric Mann-Whitney U test was conducted to test the hypothesis that the distributions of two populations (man vs. female) are equal. The strength of the dependence between ordinal variables was evaluated using Spearman's rank-order correlation coefficient. Statistical analysis was performed using Statistical Package for the Social Sciences - SPSS ver. 19.0 (IBM, Chicago, IL, USA). The threshold probability of $p < 0.05$ was taken as the level of statistical significance.

Results

The majority of students prefer aerobic exercises (n=1330) and strength exercises (n=1328). 328 students prefer interval type of exercises. 142 students prefer none of the exercises (Table 1).

The least favorite type of movement activity was running (38,4%). The second was football with (7,1%) and the third weight training (6,9%). The fourth least favorite type of movement activity was swimming (4,9%). Except noted movement activities, students mentioned also other types of not favorite movement activity: zumba (1,5%), hiking (1,3%), exercises as push-ups, sit ups, plank, squat (1,2%), skiing (1%), interval training (1%), cardio (0,8%), walking (0,76%), yoga (0,71%), hockey (0,55%), dancing (0,50%), boxing, aikido, karate (0,46%), inline skating (0,42%), tennis (0,34%), floorball (0,29%), golf (0,25%), climbing (0,25%).

38% of students exercise 3-4 times per week, 41% of students exercise 1-2 times per week. 21% of students do not exercise at all or exercise just 1-2 times per month.

We have received the following answers to the question "What kind of sport have you practiced in the past?":

- Men: Most male students in the past played football (n=340), cycling was performed by 243 students, fitness 222, running 147, home training 119, hiking 97, swimming 74, volleyball 77, and inline skating was performed by 12 students. 305 students have mentioned other sport. No sport was mentioned by 43 students.
- Women: Most female students in the past have practiced home training (n=279), fitness training performed 185 students, running 184, hiking 124, swimming 120, volleyball 104, cycling 100, inline skating 67, and football 36 students. 218 students have mentioned other sport. No sport was mentioned by 22 students.

The question "Where do you go to exercise?" was mostly answered that students do both: inside and outside training (45%). Only inside training is performed by 25% of students, only outside training is performed by 25% of students. 5% of students do not exercise anywhere. Only outside training is performed by men 27% vs. 19% of women. Only inside training is performed by women 29% vs. 22% of men. 6% of men and 7% of women do not exercise anywhere.

In Table 1 we have noted perception of stress during the coronavirus crisis. Scale 1-10 was available for students to respond, thereby 1 was used for feeling without stress and 10 was used for maximum stress. Overall, the average level of stress perception was at level 5.11. Regarding the perception of stress, we were curious if there is a statistically significant difference between men and women. Using the Mann-Whitney test, we tested the hypothesis that the distributions of both populations are equal. The result of the test ($p<0.05$) declares that the difference between men and women is statistically significant – women perceive stress worse (average value 5.51) than men (average value 4.78).

In Table 2 we recorded students ‘ perception of wellbeing during the coronavirus crisis. 17% of students selected maximum wellbeing (value 10). 53 % of students selected signs of wellbeing (7, 8, resp. 9). The average value of wellbeing perception was 7.77 in total. It represents a value on the scale of 1 to 10 in the range of the third and fourth quartiles, and can therefore be described as positive. Regarding the perception of wellbeing, we were curious if there is a statistically significant difference between men and women. Using the Mann-Whitney test, we tested the hypothesis that the distributions of both populations are equal. The result of the test ($p<0.05$) declares that the difference between men and women is statistically significant – women perceive wellbeing worse (average value 7. 56) than men (average value 7. 94).

The assessment of students' perception of energy during the day was recorded. The average value was 7.13, which is a relatively high value located in the third quartile of the 10-point scale. When testing the differences between men and women in the distributions of their responses, we observed a statistically significant difference ($p <0.05$): women perceive their energy (average value 6.91) worse than men (average value 7.34).

In Table 3, students answered the question of How strong do they feel physical, with meaning 1 as weak and 10 as full of strength. The average value was 7 in total (men 7.29, women 6.68). It indicates a positive evaluation of physical strength within the sample. Regarding the perception of physical strength, we were curious if there is a statistically significant difference between men and women. Using the Mann-Whitney test, we tested the hypothesis that the distributions of both populations are equal.

The result of the test ($p <0.05$) declares that the difference between men and women is statistically significant - women perceive their physical strength (average value 6.68) worse than men (average value 7.29).

In the last question, we asked how students perceive

Table 1. Students' responses regarding level of stress during corona crisis

Level of Stress	Male	Female	Total
10 (maximum)	80 (5%)	66 (5%)	146 (5%)
9	58 (3%)	72 (5%)	130 (4%)
8	167 (10%)	175 (12%)	342 (11%)
7	192 (11%)	227 (16%)	419 (13%)
6	129 (8%)	168 (12%)	297 (9%)
5	239 (14%)	248 (17%)	487 (16%)
4	170 (10%)	151 (10%)	321 (10%)
3	273 (16%)	163 (11%)	436 (14%)
2	221 (13%)	116 (8%)	337 (11%)
1	160 (9%)	53 (4%)	213 (7%)

Note: The first column shows the perception of stress: 10-maximum possible stress, 1-no stress. In the second and third columns the frequencies are relative and absolute for men and women separately and in the fourth column is cumulative frequency.

Table 2. Students' responses regarding of wellbeing feelings

Wellbeing feelings	Male	Female	Total
1	3 (0.2%)	2 (0.1%)	5 (0.2%)
2	6 (0.3%)	6 (0.4%)	12 (0.4%)
3	23 (1.4%)	25 (1.8%)	48 (1.5%)
4	40 (2.3%)	53 (3.7%)	93 (3.0%)
5	103 (6.2%)	135 (9.4%)	238 (7.6%)
6	118 (6.9%)	119 (8.3%)	237 (7.5%)
7	249 (14.7%)	275 (19.1%)	524 (16.7%)
8	458 (27.1%)	351 (24.4%)	809 (25.9%)
9	353 (20.9%)	270 (18.8%)	623 (20.0)%
10	336 (19.9%)	203 (14.1%)	539 (17.3%)

Note: In the first column you can see the perception of wellbeing: 10 - I feel extremely good, 1- I feel bad. In the second and third columns, the frequencies are absolute and relative for men and women separately and in the fourth column is cumulative frequency.

their coordination skills. They expressed it on a scale of 1 (uncoordinated) to 10 (coordinated). The average value in the sample was 7.92. The perception of men's coordination skills (average value 7.95) was statistically significantly higher than in women (average value 7.66).

In further analyzes, we focused on identifying possible dependencies between selected variables. Correlation between frequency of exercise and variables was evaluated: intensity of stress, perception of wellbeing, perception of energy, perception of physical strength, perception of coordination skills. Since all variables were ordinal, we used Spearman's rank-order correlation coefficient to calculate the strength and direction of the dependence. The results are shown in Table 4.

As can be seen in Table 9, in all cases there is positive dependence between frequency of exercise and variable. Intensity dependence is different: of five examined correlations, dependence between frequency of exercise and perception of wellbeing is the strongest, but this dependence is not strong (r=0,339). Dependence between frequency of exercise and stress intensity is the weakest, almost none (r=0,185).

We test the dependence between the perception of wellbeing and the perception of energy. Spearman´s rank-order correlation coefficient (r=0,579) declares the moderate positive dependence (r=0,579) (figure 1). Similarly, we noted positive dependence (r=0,418) between the perception of wellbeing and physical strength (figure 2).

Discussion

The most important question for us was the question of the frequency of exercise during the week. The optimal number of exercises per week was stated by 38% of students. A smaller number of exercises per week was reported by 62% of students. This number of exercises per week can put students at risk due to low physical activity, especially in the future. In the study, we focused on the students' level of stress. In our study men tolerate the current situation better than women. Stress is another negative factor that can contribute to reducing the physical activity of students. Increasing physical activity could be a beneficial factor in relieving stress caused by the coronavirus crisis [14]. With a lower level of stress of men, a better perception of wellbeing was found. Concerning men, we also noticed a feeling of higher energy during the day. The most popular type of physical activity for students was aerobic and strength training. Interval exercise was less popular. A surprising response to the question about the unpopularity of physical activity among students was running, which was marked by 913 students. This may be related to inappropriate education about the impact of physical activity since childhood. The physical activity preference results may help with creating online exercises for people at home with restrictions. Almost half of the students exercise both inside and outside. It is also caused by warmer weather. During the winter, this ratio is likely to change in favor of indoor exercise options. Education about appropriate home exercises could help increase

Table 3. Students' responses regarding of strong feelings

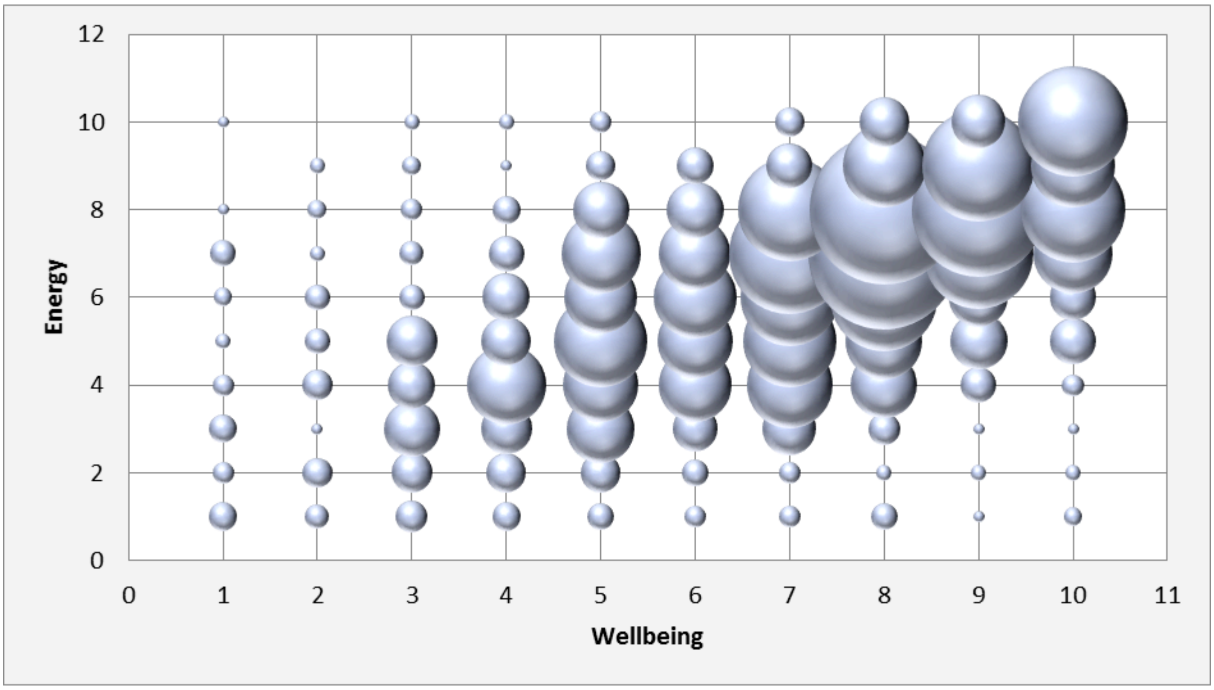
Feelings	Male	Female	Total
1	3 (0.2%)	3 (0.2%)	6 (0.2%)
2	6 (0.4%)	11 (0.8%)	17 (0.5%)
3	31 (1.8%)	52 (3.6%)	83 (2.6%)
4	56 (3.3%)	104 (7.2%)	160 (5.0%)
5	157 (9.3%)	205 (14.2%)	362 (11.5%)
6	228 (13.5%)	221 (15.4%)	449 (14.3%)
7	403 (23.9%)	363 (25.2%)	766 (24.5%)
8	422 (25.0%)	287 (19.9%)	709 (22.8%)
9	200 (11.9%)	104 (7.2%)	304 (9.9%)
10	183 (10.8%)	89 (6.2%)	272 (8.8%)

Note: Rating in the first column: 10–full of strength, 1–weak. In the second and third columns, the frequencies are absolute and relative for men and women separately and in the fourth column is cumulative frequency.

Table 4. Correlation between the frequency of exercise and selected variables (in order of dependence of strength)

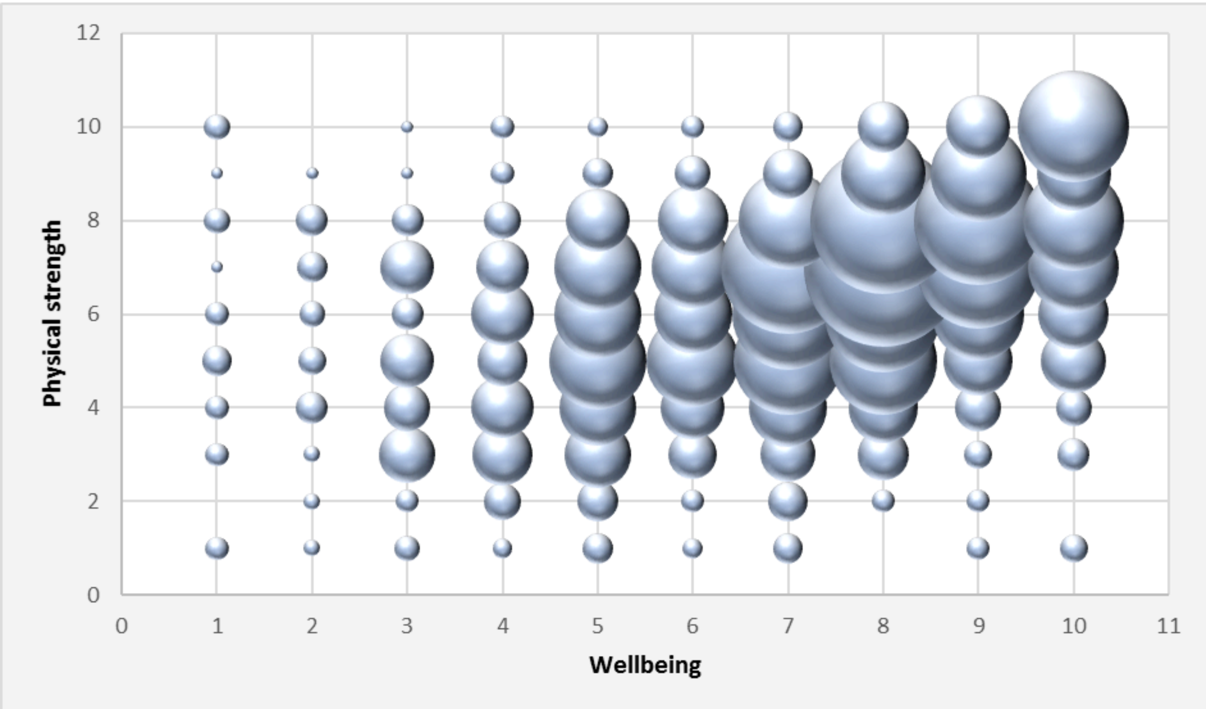
Correlation frequency of exercise	Male	Female	Total
Wellbeing	0.339	0.319	0.337
Perception of ene gy	0.313	0.325	0.287
Physical strength	0.310	0.294	0.319
Coordination abiliti	0.217	0.210	0.212
Stress intensity	0.185	0.167	0.183

Note: Numbers in the table declare values of Spearman´s rank-order correlation coefficient



Note: Wellbeing (1-bad, 10 - extremely good), energy (1 – very weak, 10 – full of energy). Size of the bubble shows numbers of response of the relevant ranking combination

Figure 1. Correlation b tween wellbeing and perception of ene gy



Note: Wellbeing (1 – bad, 10 – extremely good), physical strength (1-very weak, 10 – strong). Size of the bubble shows numbers of response of the relevant ranking combination

Figure 2. Correlation b tween wellbeing and physical strength

physical activity during a pandemic and thus reduce the risk of chronic diseases due to low physical activity.

In preventing most chronic diseases, exercising plays a vital role. Our body needs a relatively long period to benefit from the healthy adaptations that exercising generates, modulated by various molecular mechanisms such as epigenetics, metabolic modulation, or decreased inflammation [15]. This means that efforts to maintain an active lifestyle during home quarantine should be necessary to avoid the physical consequences associated with low physical activity. Low physical activity consequences on human health are wide-spectrum. We can observe human metabolic consequences such as increased insulin resistance, total body fat, abdominal fat, and increased inflammatory cytokines [16]. All these factors are closely related to the development of metabolic syndrome, which in turn increases the risk of several chronic diseases [17]. Excessive energy intake without expenditure may be a likely mechanism that contributes to given pathogenesis. Progress of COVID19 infection of obese patients is associated with worse prognostic factors [18-20].

Husain and Ashkanani [21] evaluated the change in lifestyle during the corona crisis. The sample consisted of 415 adults. There was noted a decrease in fast food consumption (p <0.001). There was also noted a decrease in physical activity and an increase in time spent in a sedentary lifestyle. The number of hours of sleep during the day increased and the number of hours of sleep at night decreased.

The effect of the corona crisis on physical activity and dietary habits in Italy was tested by Di Renzo et al. [22]. The sample consisted of 3533 Italians aged 12 to 86. Weight gain was noted in almost 48.6% of cases.

The level of physical activity increased slightly in 38.3% of people. A decrease in physical activity was also recorded among Italian students [23].

Lopez-Moreno et al. [24] tested the effect of the corona crisis on Spanish citizens. The sample consisted of 675 Spanish, of which 38.8 % experienced gain weight during the coronavirus crisis. 31.1% experienced weight loss. Weight gain correlated with age (Rs = 0.14, $p < 0.05$). Less quality sleep was connected to higher BMI and age (Rs = -0.18, $p < 0.05$) resp. (Rs = -0.21, $p < 0.05$). 44,7% did not exercise during the crisis.

Robinson et al. [1] tested the impact of the coronavirus crisis on lifestyle factors in the United Kingdom (n=2002). 56% of British reported deteriorated eating and worse exercise habits and weight loss problems than before the crisis. Higher British BMI correlated with lower physical activity and nutritional quality.

Lifestyle changes were also verified in the United Arab Emirates in a study by Ismail et al. [10]. The group consisted of 1012 adults. Weight gain was noted in 31%. In addition, 38.5% did not engage in physical activity and 36.2% spent more than five hours a day on screens. A significantly higher percentage of participants reported physical exhaustion, emotional exhaustion, irritability, and tension during a pandemic compared to the pre-pandemic period (p <0.001). During a pandemic, sleep disorders predominated in 60.8% of participants. The impact of restrictions on physical activity was tested by Srivastav et al. [25]. The sample consisted of 143 students and physiotherapists. Overall physical activity before the lockdown was on average 7809.7 (3849.7–11769.8) MET-min/week and during the lockdown, it decreased to MET-min/week and 4135.7 (867.2–7404.1) MET-min/week; p < 0.0001. While energy expenditure before and during COVID–19 lockdown period was 8189.8 (4242.1–12137.6) kcal/wk and 4221.7 (1004.6–7438.8) kcal/wk; p < 0.0001). Rutkowska et al. [26] compare physical activity during restrictions and the "unfreezing" stage. The study group consisted of 89 healthy Polish students. The average total PA rate during the first measurement was 8640 MET-min/week and in the second 10560 MET-min/week. The analysis of total energy expenditure showed a statistically significant difference (p<0.029). The establishment of "unfreezing" laws for sport and recreation and the reduction of restrictions have significantly contributed to an increase in the overall level of physical activity. In Poland, weight gain has been reported in 30% of people and weight loss in 18% [27]. A decrease in physical activity was also recorded in Greece [28].

Our study has several limitations that are associated with the design of the study. When completing the questionnaire, there could be a selection bias and the questionnaire may have been filled in by students who tend to do physical activity. Another limitation was the verifiability of the factors. Based on an online questionnaire, we could not verify the students' statements. Another limitation was the lack of basic data about a physical activity before coronavirus crisis, to objectively compare the effect of coronavirus crisis on the reduction of physical activity. Bias towards several questions as a level of coordination abilities could have resulted. The issue of coordination abilities is challenging and requires more objective measurement.

Conclusions

Low physical activity of Slovak university students during the COVID–19 pandemics was recorded. To avoid negative effects of a sedentary lifestyle, it is necessary to promote activity among university students.

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Conflict of Interest

The authors declare that they have no conflicts of interest regarding the publication of this article.

Adherence to Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants involved in the study.

Key points

- COVID-19 pandemics is associated with a low level of physical activity in Slovak students.
- Emergency plan for treatment COVID-19 should contain guidelines for physical activity.
- To avoid the negative effects of a sedentary lifestyle, it is necessary to promote activity among university students.

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ORIGINAL ARTICLE

The acute effect of different specific warm-up intensity on one repeat maximum squat performance on basketball players

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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 Squat exercises have some advantages in terms of time, practice and energy costs. It is also an exercise method used in training plan in terms of development of jumping ability in basketball players. There are many factors that affect squat performance both positively and negatively. These factors can vary as warm up, psychological and physiological conditions. In addition, squat performance may vary depending on warm-up types and intensity. It was aimed to determine the effect of different specific warm-up intensities on 1-maximum repetition squat performance (1-RM) on basketball players.

Material and Methods The sample group of the study consisted of 10 men (age: 22.90 ± 1.44 years, height: 188.10 ± 8.06 cm, body weight: 77.92 ± 13.41 kg, BMI: 21.70 ± 2.83), who played basketball regularly for at least 3 years. This group performed 3 different specific warm up intensities on non-consecutive days. Warm up protocols were determined as follows: light jogging for only 5 minutes (NSW), light jogging and % 40 intensity specific warm up (LISW), light jogging and % 80 intensity specific warm up (HISW).

Results Participants' 1-RM squat performance was found to be statistically different between NSW (91.10 kg), LISW (95.00 kg), HISW (100,50 kg) respectively ($p<0.05$). Additionally, 1-RM squat performance values were observed highest after HISW. Rate perceived exertion (RPE) and body temperature (BT) were found highest after HISW.

Conclusions: As a result of this study, HISW are recommended to basketball coaches and basketball players in order to get more performance before the squat movement.

Keywords: basketball, intensity, squat, warm-up

Introduction

Coaches and trainers often use maximum strength test to assess muscle fitness, monitor progress, provide motivation and develop individualized programs. With the help of qualified supervision and appropriate test guidelines, maximum strength test can be safe, effective and reliable method for assessing muscle fitness in athletes and non-athletes [1]. Although isokinetic and isometric tests are frequently used in the clinical settings, the 1 maximum repetition (1-RM) test using free weights can also be used to evaluate the strength of athletes and to determine strength imbalances. 1-RM is the maximum weight that can be lifted only once for a given exercise using an appropriate exercise technique [2]. However, there are several factors that affect the precision of 1-RM assessments. One of these factors is warm-up protocol [3]. Warm-up can increase the efficiency of muscle glycolysis and high-energy phosphate degradation during exercise by increasing muscle temperature, increase in muscle metabolism and muscle fiber conduction velocity, resulting in a positive change in muscle contractility following previous contractile activity of VO2 kinetics. It can improve muscle function by influencing muscle cross-bridge cycle velocity and oxygen uptake kinetics [4].

There are many studies on type, duration and intensity of warm-up protocols in the literature [5, 6, 7]. In addition, it is observed that the specific warm-up, combine warm-up and dynamic warm-up are more preferred in the literature. It is seen that the literature on linear and lateral warm-up is in a vicious circle. Linear and lateral warm-up protocols; It includes warm-up protocols made in different planes. Specific warm-up includes movements specific to the sport branch. In the literature, it has been suggested that voluntary contractions from low intensity to high intensity, such as dynamic warm-up, before the implementation of sportive activity, can increase strength and performance by activating nerve-muscle activation [8-10].

The fact that knowing the acute effect of different warm-up intensities on 1-RM squat performance in basketball players guides trainers and athletes can be considered as an undeniable fact in terms of the importance of the study. In addition, the fact that a study in which the acute effect of warm-up protocols applied at different intensities in basketball players was measured on squat performance has not been found in the literature, further increases the importance of the study. The aim of the study is to determine the effect of specific warm-up at different intensities on 1-RM in basketball players. For this purpose, as the research hypotheses (1) it is thought that 1-MT squat value will be positively affected in favor of specific warm-up applied at 80% intensity.

Material and Methods

Participants

The sample group of the study consisted of 10 men (age: 22.90 ± 1.44 years, height: 188.10 ± 8.06 cm,

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body weight: 77.92 ± 13.41 kg, BMI: 21.70 ± 2.83), who played basketball regularly for at least 3 years. All participants were informed about possible risks and details before starting the study and a voluntary consent form was signed. In addition, the participants were asked to sleep for 7-8 hours before the tests. All test and measurement applied in this study were approved by the Institute's Clinical Research Ethics Committee (Approval Number: 2021-2228). All tests and training practices were performed at the same time of the day (09.00-11.00).

Experimental Design of the Study

In the study, the anthropometric measurements of the participants were determined. Measurements were made in the Sports Hall of the Faculty of Sports Sciences. All volunteers who agreed to participate in the study were informed in detail about the content of the study before the test. Before the application started, the participants were given necessary information about the content, place and time of the study. After the first warm-up (5 minutes of light-intensity aerobic jogging), specific warm-up protocols at different intensities were applied on non-consecutive days under the supervision of the trainer. In addition, the participants performed 10 maximum repetitions (10-RM) tests in the session without specific warm-up. 10-RM was converted to 1 max rep (1MT) using Brzycki [11] equations.

1 MT= (Weight li ed/ (1.0278 - [0.0278 ×Repeats])

After specific warm-ups of different intensities, 5 minutes of passive rest was performed before 1-RM. This rest period was determined by considering the results of Willardson and Burkett [12] and Rahimi's [13] studies in which the effect of resting at different times on squat performance increased more after 5 minutes of rest. 24 hours before the tests, the participants were informed that they should not use heavy exercise, alcohol, caffeine, and should not use the ingredients in ergogen supplements.

Warm-up Protocols

No Specific Warm-up Phase (NSW)

After the participants were given detailed information about the test before the test started, the participants' maximum heart rate was determined [14]. Then, warm-up rate of jogging each individual was calculated as 30-40% according to the heart rate [15]. Participants in the study were warmed up under the control of experts. In this way, both the warm-up intensity and the warm-up differences between the participants in the study were eliminated. When the heart rate was between 110-120 per minute after resting for 5 minutes, the maximum strength values of the participants were obtained by performing 1 repetition maximum (1-RM_{max}) squat (Table 1) [11].

Low Intensity Specific Warm-up (LISW) (40%)

Participants performed 10 repetitive squat exercises consisting of 1 set at 40% intensity after 5 minutes of jogging. After the specific warm-up, the participants

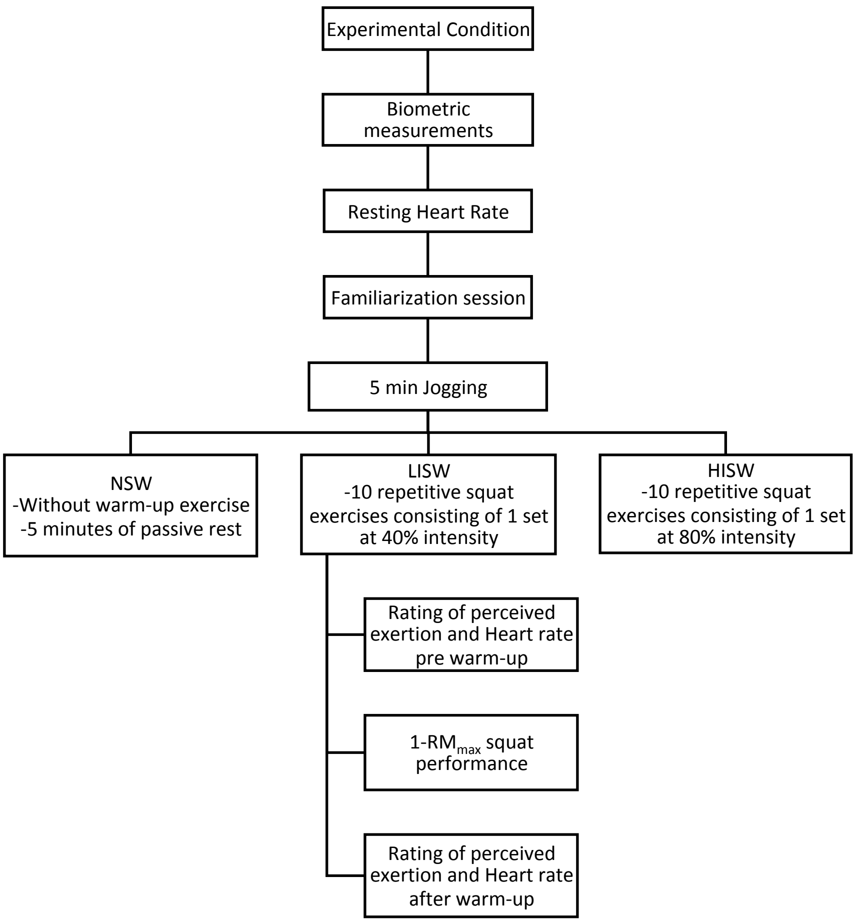

Figure 1. Experimental Design

were allowed to repeat the movement by adding 2.5-5 kg according to the weight they lifted and the level of difficulty they felt within the scope of 1 maximum squat repetitions obtained previously, and 1-RM$_{max}$ squat values were determined. The weight gain process was continued until the participants could no longer perform 1 repetition, and the participants' 1-RM$_{max}$ squat performance was observed (Table 1).

High Intensity Specific Warm-up (HISW) (80%)

Participants performed 10 repetitive squat exercises consisting of 1 set at 80% intensity after 5 minutes of jogging. After warm-up, the participants were allowed to repeat the movement by adding 2.5-5 kg according to the weight they lifted and the level of difficulty they felt within the scope of 1-RM squat previously obtained, and 1-RM maximum squat values were obtained. The weight gain process was continued until the participants could no longer perform 1 repetition, and the participants' 1-RM squat performance was observed (Table 1).

Statistical Analysis

The obtained data were analyzed in SPSS (25.0) package program. "Repeated Measures Anova" was used to determine the effect of specific warm-up protocols applied at different intensities on 1-RM squat performance. "Bonferroni" analysis, one of the multiple comparison tests, was used to determine which warm-up protocol favored the performance. Mauchly Test was used for homogeneity of variances and Greenhouse-Geisser correction factor was used to correct for variances. The significance level was chosen as $p<0.05$.

Results

In Table 2, the anthropometric and demographic values of the volunteers participating in the research are examined. As a result of this observation, it was determined that the mean age of the research group: 21±70 (years), height: 180.10±8.06 (cm), weight: 77.92±13.41 (kg), body mass index (BMI): 21.70±2,83 kg/m^2.

When rate perceived exertion level (RPE) after warm-up is examined in Table 3, there is a significant difference between different warm-up intensities ($p<0.05$). Considering the differences between the groups, there is a significant difference between the RPE values after each warm-up at different intensity and after 1-RM. In addition, when AZD after 1 MT is examined, there is a significant difference between different warm-up intensities ($p<0.05$).

In Table 4, 1-RM squat performances after specific warm-ups applied at different intensities were examined. The highest performance value is seen after warm-up at 80% intensity.

In Table 5, body temperature after specific warm-up applied at different intensities was examined. The highest temperature value was reported after warm-up at 80%

Table 1. Warm-up exercises

NSW	LISW	HISW
5 minutes jogging	5 minutes jogging + 40% specific warm-up intensity (10 reps)	5 minutes jogging + 80% specific warm-up intensity (10 reps)

Note: LISW - *Low Intensity Specific Warm-up*; HISW - *High Intensity Specific Warm-up*

Table 2. Demographic and anthropometric values of the participants

Parameter	Mean	Standard Deviation
Height (cm)	188.10	8.06
Body Weight (kg)	77.92	13.41
Age (years)	22.90	1.44
Body Mass Index (kg/m^2)	21.70	2.83
Resting Heart Rate (rpm)	64.20	4.87

Table 3. Rate perceived exertion (RPE) levels of the participants in terms of different warm-up intensities

Parameters	Warm-up Intensities	Mean	SD	F	p	Bonferroni
RPE A er Warm-up	5min jogging (1)	8.50	.79	8.88	0.00	1-2 (0.04)
	5min jogging + 40% Intensity (2)	10.90	.83			1-3 (0.00)
	5min jogging + 80% Intensity (3)	11.50	.61			2-3 (0.33)
RPE A er 1-RM	5min jogging (1)	18.50	.52	1.47	0.00	1-2 (0.02)
	5min jogging +40% Intensity (2)	17.50	.52			1-3 (0.00)
	5min jogging + 80% Intensity (3)	16.60	.51			2-3 (0.23)

Table 4. 1-RM values of participants in terms of different warm-up intensities

Parameters	Warm-up Intensities	Mean	SD	F	p	Bonferroni
1-RM After Warm Up	5min jogging (1)	91.10	11.29			1-2 (0.01)
	5min jogging +40% Intensity (2)	95.00	12.24	22.562	0.00	1-3 (0.00)
	5min jogging + 80% Intensity (3)	100.50	14.42			2-3 (0.01)

Table 5. Body temperature (BT) of participants after different warm-up intensities

Parameters	Warm-up Intensities	Mean	SD	F	p	Bonferroni
BT After Warm Up	5min jogging (1)	36.40	0.13			1-2 (0.00)
	5min jogging +40% Intensity (2)	36.83	0.13	500.39	0.00	1-3 (0.00)
	5min jogging + 80% Intensity (3)	37.23	0.14			2-3 (0.00)

Table 6. Heart rates (HR) of participants after different warm-up intensities

Parameters	Warm-up Intensities	Mean	SD	F	p	Bonferroni
HR After Warm-up	5min jogging (1)	133.30	4.37			1-2 (0.00)
	5min jogging +40% Intensity (2)	149.20	2.52	163.76	0.00	1-3 (0.00)
	5min jogging + 80% Intensity (3)	162.60	3.27			2-3 (0.00)

intensity.

In Table 6, HR after specific warm-up of different intensities is examined. The highest HR value is observed after warm-up at 80%.

Discussion

This study shows that the warm-up protocol of different intensities before 1-RM_{max} can have a significant effect on squat performance in male basketball players. In the study, the 1- RM_{max} performances of the participants were determined by 5 minutes jogging (91.10 ± 11.29), 5 minutes jogging + 40% intensity (95.00 ± 12.24) specific warm-ups and 5 minutes jogging + 80% intensity (100.50 ± 14.42) specific warm-ups. 1-RM squat performance after HISW increased by 5.5 kg (5.2%) compared to LISW. In addition, 1- RM_{max} squat performance after HISW showed an increase of 9.4 (8.5%) kg compared to NSW. To our knowledge, no other study has investigated the acute effects of specific warm-ups at different intensities on 1-RM_{max} squat performance.

There are very few studies in the literature in which the acute effect of warm-up protocols on maximum squat performance has been determined [5, 7, 10]. Kafkas et al., [10] determined the effect of different warm-up protocols on 1-maximum repetition squat performance (1-RM_{max}), and it was determined that 1-RM squat performance values increased the most after dynamic warm-up. Ribeiro et al., [5] found that the specific warm-up seems to enhance neuromuscular actions that enable a higher movement velocity during the first training repetitions and to allow greater peak velocities in less time. Çağlar et al. [7] reported that 1-RM squat strength after heel-assisted foam roller warm-up was higher than the strength measurement values after warm-up specific to heel-free strength. The results of the studies are that warm-up protocols and warm-up intensities can improve 1-RM performance. Santos et al. [16] compared the acute effect of different stretching protocols on the lower extremities using the sum of the maximum repetitions (RM) performed before the strength training session. Specific warm-up, static stretching, proprioceptive neuromuscular stretching and ballistic stretching were performed on 10 female jazz dancers. The results of the study showed that in the smith machine squat exercise, the ballistic stretching protocol had a significantly higher volume compared to all other protocols, while the PNF had a significantly higher volume compared to the specific warm-up. The results of the study showed that in the smith machine squat exercise, the ballistic stretching protocol had a significantly higher volume compared to all other protocols, while the PNF had a significantly higher volume compared to the specific warm-up. The positive effect of dynamic warm-up and ballistic stretching on performance can be supported by Bishop's [17] statement that active dynamic warm-up increases nerve conduction, improves speed-force relationship, improves agility performance, increases glycogenolysis and glycolysis. Aydın et al., [18] carried out the study to determine the effect of three consecutive sets of lower and upper body exercises at different repetitions on static stretching. In the study, 10 trained male athletes performed 3 sets of 10 repetitions of push down and leg extension exercises with 60% and 85% of 1 maximum repetition. Equal numbers of participants participated in the static stretching and non-stretching protocols. The results of this study showed that the number of repetitions decreased significantly after static stretching in two exercises of each intensity. Masamoto et al. [2] examined the acute effects of plyometric exercise on 1 maximum repetition (1-RM) squat performance in trained male athletes. Twelve male participants were evaluated in the 1-RM squat exercise during each of the 3 test sessions. Prior to all three trials, participants warmed up and performed static stretching on a fixed cycle for 5 minutes. Subjects then performed 5 sub-maximal sets of 1-8 reps before attempting a 1MT lift. In addition, the participants were waited for at least 4 minutes between 1MT trials. As a result of the study, it is shown that the drop jump performed before the 1MT test can increase the squat performance in trained male athletes.

In addition, there may be several mechanisms underlying warm-up intensity, warm-up protocols, and stretching protocols to alter 1-RM performance of plyometric training. Static stretching may influence neural mechanisms that could adversely affect muscular performance by reducing motor unit activation and muscle-tendon unit stiffness [19, 20]. Also, theoretically, greater muscle activation for a given velocity may increase energy expenditure and therefore, accelerate the onset of fatigue [21]. Therefore, it can negatively affect 1-RM performance. The reason for the performance improvement after specific warm-up may be the increase in nerve conduction, the development of the velocity-force relationship, the increase in glycogenolysis and glycolysis, and the increase in the use of high-energy phosphate [17].

Some limitations of the study can be mentioned. First, the current study may have a single-sex design and a small number of participants. Second, this research was conducted for a specific type of exercise activity (1-RM); different exercise types (bench press, etc.) or different warm-up protocols (functional, combined, etc.), different types of sports (such as football, judo), different ages and women may produce different results.

Conclusion

Warm-up protocols performed by basketball players were effective in the positive development of 1-RM squat performances. Positive responses to HISW revealed that the increase in warm-up intensity in basketball players improved 1-RM performance more than other protocols in parallel. Basketball players and coaches must perform tests in multiple situations to establish consistent responses to different warm-up protocols and thus create their own individual and optimal warm-ups. However, the results are clear in showing a positive effect, so future research is needed to better understand the ideal nature of warm-up procedures for basketball players.

Conflict of interest

The author declare that there is no conflict of interest.

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Women's 50km racewalking tactic using pace strategy analysis at World Championships

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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 We aim to design a walking tactic depending on pace strategy analysis for women's 50km racewalking at two IAAF championships: World Racewalking Team Championships Taicang2018 and World Athletics Championships Doha2019.

Material and Methods We collected data from the records of the women's 50km racewalking results from both mentioned championships in which the times of 10 stages of 5km each. The research sample included 30 racewalkers (top 15 from each championship) aged 21 to 41.

Results Results indicate that elite racewalkers followed a variable pace strategy. As they started a 50km racewalking with a slow and appropriate speed. Then there was a gradual increase in the next stages until reaching the speed plateau (25km). After that, the speed was changed between increasing and decreasing until the end of the race. The results also indicate that there is a strong positive correlation between the performance time of all the stages in both championships. In addition, it is indicated that there are statistically significant differences using the T-test between all stages between both championships, except for the stage (10th 5km). So last 5km have no major impact on changes for the final classification.

Conclusions: We divided the race into seven successive tactical phases depending on the speed and the effort rate during the race stages. These phases are slow start, primary acceleration and speed regulation, the maximum speed, transitional, final acceleration, deceleration, and finish. Our analysis can extend theoretical knowledge, so coaches and racewalkers can make use of it in designing the training programs.

Keywords: 50km, racewalkers, endurance, pace strategy, performance, tactic phases.

Introduction

Racewalking is one of the long-distance races within athletics [1]. It differs from running in that one foot must tend to be always in contact with the ground [2]. At the World Athletics Program and the Olympic Games, (men and women) compete in two racewalking distances (20km and 50km). 50km Racewalking is the longest athletics event held as part of the Olympic Games and World Athletics Championships [3]. It became part of the Olympic schedule in 1932 for men [4] and IAAF World Championships scheduled in 2017 for women [5]. This event lasts nearly 4 hours of competition with keeping a gait rhythm that follows IAAF rules 230,1 [3, 6]. And the racewalker attempts to complete a known distance in the shortest amount of time available [7]. Pacing in racewalking is a basic requirement of endurance performance success [8, 9]. Endurance performance in marathon races also has been associated with pacing among physiological and psychological factors [7, 10].

Pace strategy refers to the mechanism by which athletes manage their rate of energy consumption to complete a challenge in the shortest time [11]. This strategy is a basic prerequisite of competitive endurance, a critical factor for performance [7, 9]. Championship racing features much more variable pacing that reflects tactical decision-making. Where the primary aim of elite athletes is to win regardless of finishing time [12]. The majority of long-distance races are held at a pace lower than the critical speed, which is the speed above which finite, primarily non-oxidative exercise is conducted [13, 14]. The aim of an effective pacing strategy is to deplete all possible energy reserves (whether by anaerobic or aerobic metabolism) by the end of the race, but not so early so disastrous deceleration doesn't occur [13].

Even so, it is currently unclear if racewalkers use pre-programmed tactics or "unconsciously" perform assigned tactics while racewalking. And since the analysis of digital achievement levels of elite racewalkers is an indicator and auxiliary guide for both coaches and racewalkers. As it helps them to distribute effort during the race stages and know the tactic of performance for the race stages. So that, the coach during the training processes can take care of them and train them according to scientific results. To this day, sport literature has not been interested in tactical analysis in women's 50km racewalking. And therefore, we will study the women's 50km racewalking to find out the relationship between the race stages in two championships. These championships are IAAF World Racewalking Team Championships Taicang 2018 and IAAF World Athletics Championships Doha 2019. In this paper, we analyze the performance time during races stages that affect and contribute to the level of digital

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achievement of women world champions. We identify the relationship between stages using statistical parameters. Therefore, we could design a walking tactic depending on pace strategy analysis at mentioned championships to help coaches and racewalkers in designing training programs.

The purpose of our research can be summarized from the IAAF World Racewalking Team Championships Taicang 2018 (**WRTC2018**) and IAAF World Athletics Championships Doha 2019 (**WAC2019**), through:

1. Analysis of the performance times of the 50km walking stages for the elite racewalkers in terms of the pacing strategy.
2. Determine the correlations between the times of the women's 50km racewalking stages and the final time of 50km.
3. Identify the differences between the times of the women's 50km racewalking stages and the final time of 50km.
4. Designing a walking tactic by dividing the women's 50km racewalking into phases according to pace strategy and effort rate

The remainder of the paper is divided as follows: Section 2 introduces the material and methods. Experimental results are illustrated in Section 3. Section 4 summarizes the discussion of these results. Finally, Section 5 discusses the conclusions of the paper.

Material and Methods

Participants

The research sample in this paper includes 30 racewalkers, where the top 15 racewalkers were selected from each of two championships (WRTC2018 and WAC2019) [15, 16] aged 21 to 41, with a mean of 28.4.

The current study is a focused review with a practical application of the theoretical foundation in the race.

Independent variables: 30 high-level women athletes in the 50 km racewalking in both championships, they are divided into two groups: the first group was those top 15 in WRTC2018, and the second group is top 15 in WAC2019.

Dependent variables: The performance of top-level women athletes in the race of 50 km. The individual times of the athletes in the 10 stages of the race, as well as their pace strategy and the effort rate.

Research Design

Initially, we collected data from the records of the women's 50km racewalking results in WRTC2018 and WAC2019. These data were obtained from IAAF's competition archive [15, 16]. The certified distance of the racewalking (50km) divided into 10 stages of 5km each was recorded, as the overall race times and 5km split times were obtained for racewalkers in both championships from IAAF's archive. The same thing happened with the times (average, final) corresponding to the individual stages (5 km) of the race. Based on the data of the individual race distances and the respective times of the athletes, the pace strategies were found that describe the athletes' tactics in this race.

Statistical analysis

The statistical analysis in both championships in this paper included:

1. Descriptive statistics: mean (M), standard deviation (SD), coefficient of variation (V), Maximum value (MAX), and Minimum value (MIN).
2. Pace strategy analysis and effort rate
$$\frac{Average\ \ speed\ \ of\ each\ stage}{Average\ \ speed\ \ of\ 50km} * 100$$
3. Rate of Change (ROC) in speed
$$\frac{Average\ \ speed\ (WAC2019)-Average\ \ speed\ (WRTC2018)}{Average\ \ speed\ (WRTC2018)} * 100$$
4. Relations between performance times for stages and final stage:
   - Correlation coefficients (r),
   - Analysis of variance (Enova: Single Factor), and
   - T-Test.

Results

The following results expand the theoretical knowledge of women's pace strategy in 50km of racewalking. The time for the 15 racewalkers in the 50km racewalking at in **WRTC2018** ranged from (4:04:36) to (4:28:49) hours = (14676) to (16129) sec., and the time for the 15 racewalkers in the 50km racewalking at in **WAC2019** ranged from (4:23:26) to (4:58:44) hours = (15806) to (17924) sec. Nine racewalkers are the same in both Championships, which means that these athletes had a high level of training experience and endurance. The ranking positions, racewalkers' ages, and performance time for 15 racewalkers in both Championships are shown in Table 1 and Figure $1_{a,b}$.

Table 2 illustrates the mean, minimum, maximum, standard deviation, variation coefficient for 30 racewalkers in both championships (15 in each). It is indicated that the coefficient of variation (CV) ranged between (0.792: 8.127) %, which is less than 30%, which indicates the homogeneity of the research sample.

Figure 2 shows the average speed that ranged between (3.295: 2.95) m/s in both championships and the best average speed was in the stage (5th 5km) which was 3.295 m/s at **WRTC2018.** The lowest average speed was in the stage (9th 5km) which was 2.95 m/s at **WAC2019**.

Figure 3 shows the average effort rating at each stage of 50km racewalking concerning the average effort of the final 50km. This rate is increased during the (2nd to 8th) 5km and decreased during the (1st - 9th - 10th) 5km in **WRTC2018**. In **WAC2019**, the effort rate was increased with (3rd to 7th and 10th) 5km and decreased with (1st -2nd - 8th - 9th) 5km.

Table 3 shows the performance time average (sec), average speed (m/s), and effort rate (%) between the stages and final 50km in both championships. In **WRTC2018**, the racewalkers started (1st 5km) with an average speed of 3.234 m/s. Then the average speed gradually increased until it reached its highest value at (5th 5km), with an average of 3.295 m/s. Then the average speed gradually decreased until the end of the race. In **WAC2019**, the racewalkers started (1st 5km) with an average speed of 2.969 m/s. The average speed gradually increased until it reached its highest value at the (5th 5km) with an average of 3.025 m/s. After that, the average speed decreased

Table 1. Ranking positions, Ages of racewalkers (year), and Performance time (sec) of 50km. N=30

Ranking positions	**WRTC2018 (n=15)**			**WAC2019 (n=15)**		
	racewalkers	**Age (year)**	**The time of 50km (sec)**	**racewalkers**	**Age (year)**	**The time of 50km (sec)**
1	Rui Liang	23	14676	Rui Liang	25	15806
2	Hang Yin	21	14949	Maocuo Li	26	16000
3	Claire Tallent	36	14973	Eleonora Giorgi	30	16153
4	Paola Pérez	28	15176	Olena Sobchuk	23	16418
5	Faying Ma	24	15208	Faying Ma	26	16496
6	Johana Ordóñez	30	15268	Khrystyna Yudkina	34	16560
7	Maocuo Li	25	15287	Magaly Bonilla	27	16623
8	Júlia Takács	28	15397	Júlia Takács	30	16700
9	Nastassia Yatsevich	33	15480	Paola Pérez	29	16734
10	Nadzeya Darazhuk	28	15511	Maria Juárez	26	16768
11	Magaly BONILLA	26	15544	Masumi Fuchise	33	16862
12	Khrystina udkina	33	15735	Nastassia Yatsevich	34	17041
13	Vasylyna Vitovshchyk	28	15848	Nadzeya Darazhuk	29	17246
14	Mayra Herrera	29	16110	Angeliki Makri	41	17649
15	Alina Tsvilii	23	16129	Mara Ribeiro	24	17924
Mean (M)		**27.67**	**15419.40**	Mean	29.13	16732
Standard Deviation (SD)		**4.19**	**414.85**	Standard Deviation	**4.78**	**571.02**
coeffici t of variation (C V)		**15.13**	**2.69**	coeffici t of variation	**16.40**	**3.41**
Max		**36**	**16129**	Max	**41**	**17924**
Min		**21**	**14676**	Min	**23**	**15806**

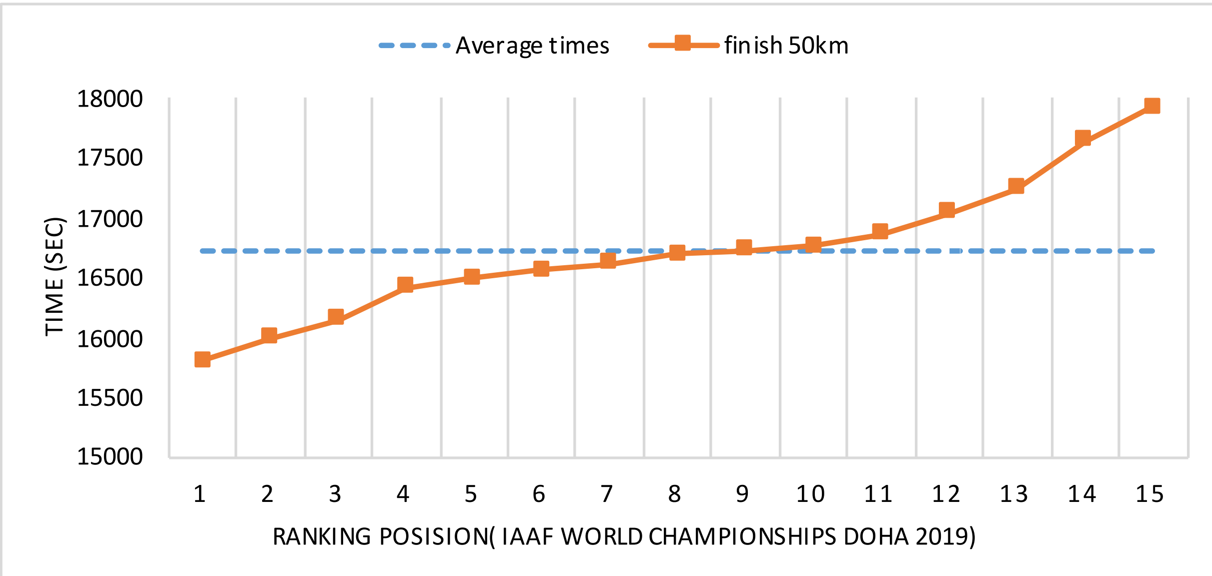

Figure 1$_a$. The performance tim of women's 50km racewalking in relation to their classifi ation position for WAC2019

gradually to (9th 5km) and increased significantly in the last stage of the race at the (10th 5km).

Table 4 and Figure 4 show the rate of change in speed between both championships for each stage. It is noticed that there are differences in rates of change in speeds at all stages in favor of **WRTC2018**. The largest value of change rate in speed is 30% in the (2nd 5km), and the lowest value is 8% in the (10th 5km). The change rate in the speed of the final 50km is 26%.

Table 5 and Figure 5 show correlation coefficients (r) between the performance times averages of the race stages and the final 50km in **WAC2019**. It is noticed that so there was a direct correlation between all the stages of the race and each other. There is a strong positive correlation between all the stages and the final 50km. The largest correlation coefficient for the performance

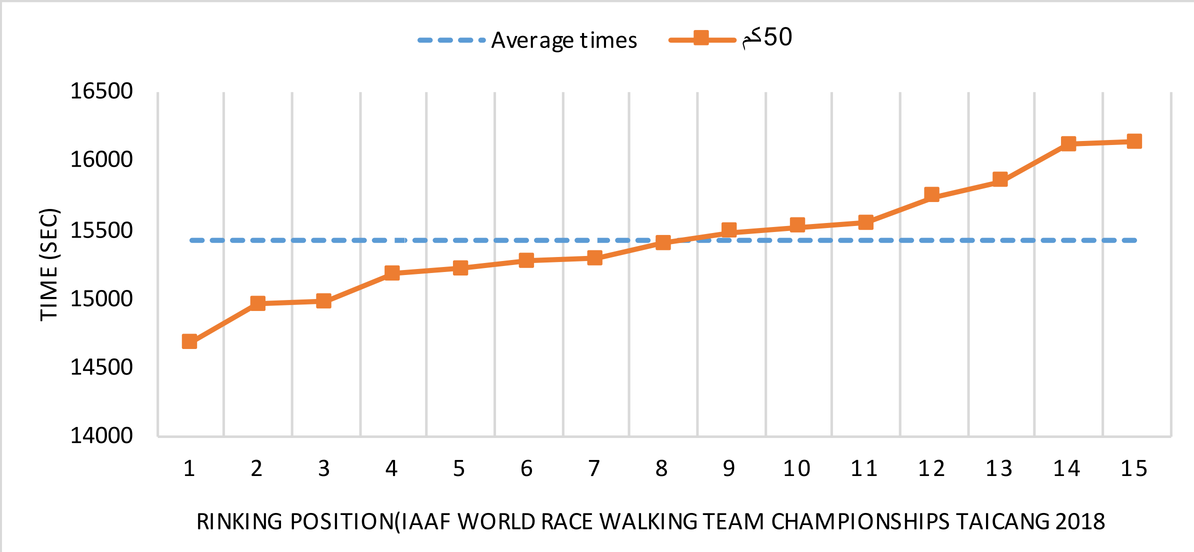

Figure 1$_b$. The performance tim of women's 50km racewalking in relatio to their classifi ation position for WRTC2018

Table 2. Mean (M), Standard Deviation (SD), Coefficient of Variation (C.V), Maximum (Max), and Minimum (Min) of performance time for race stages in both Championships.

Race stages	WAC2019 Mean(M) of performance time (sec)	Standard Deviation (SD)	coefficient of variation (C.V)	Max	Min	WRTC2018 Mean(M) of performance time (Sec)	Standard Deviation (SD)	coefficient of variation (C.V)	Max	Min
1st 5km	1546.1	58.982	3.815	1648	1478	1684.1	13.344	0.792	1705	1666
2nd 5km	1527.3	52.075	3.410	1621	1464	1680.6	22.878	1.361	1737	1651
3rd 5km	1523.7	45.600	2.993	1606	1471	1671.4	34.096	2.040	1713	1614
4th 5km	1519.5	35.510	2.337	1577	1475	1662.8	34.262	2.061	1707	1598
5th 5km	1517.3	34.159	2.251	1566	1479	1652.9	48.295	2.922	1714	1573
6th 5km	1532.1	31.827	2.077	1599	1480	1657.6	59.448	3.586	1753	1550
7th 5km	1526.5	46.223	3.028	1631	1475	1671.7	79.725	4.769	1854	1521
8th 5km	1540.1	54.872	3.563	1680	1461	1690.2	99.378	5.880	1907	1540
9th 5km	1562.8	63.789	4.082	1715	1416	1695.0	118.097	6.967	1974	1548
10th 5km	1624.0	131.979	8.127	1933	1426	1665.7	110.982	6.663	1885	1543
Final 50km	15419.4	**414.852**	**2.690**	**16129**	**14676**	**16732.0**	**571.024**	**3.413**	**17924**	**15806**

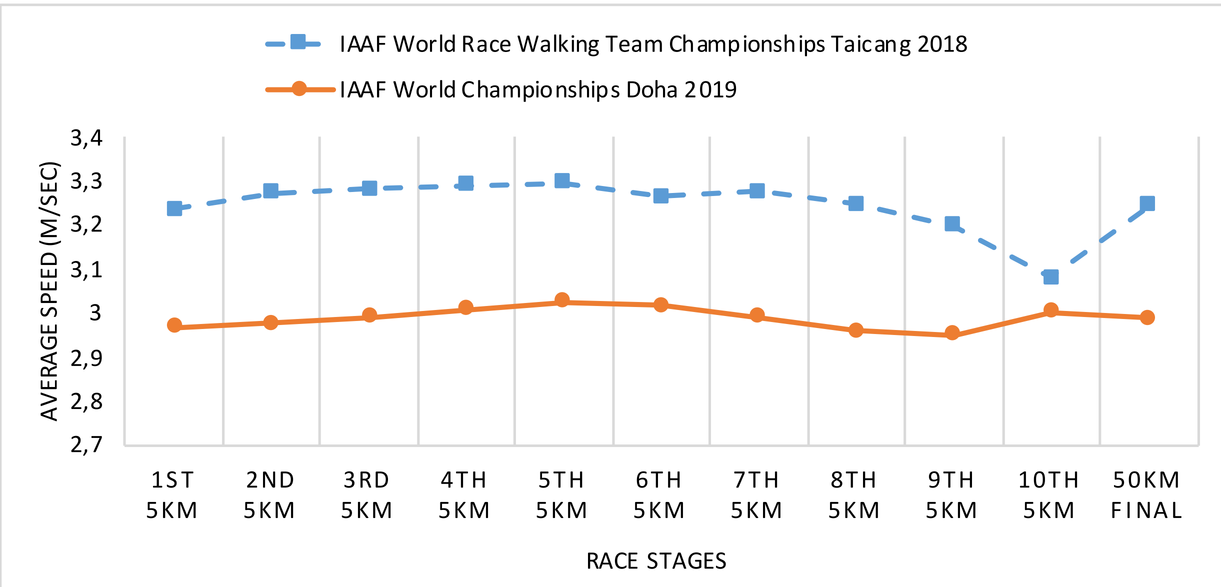

Figure 2. Average Speed (m/sec) of the stages of women's 50km racewalking

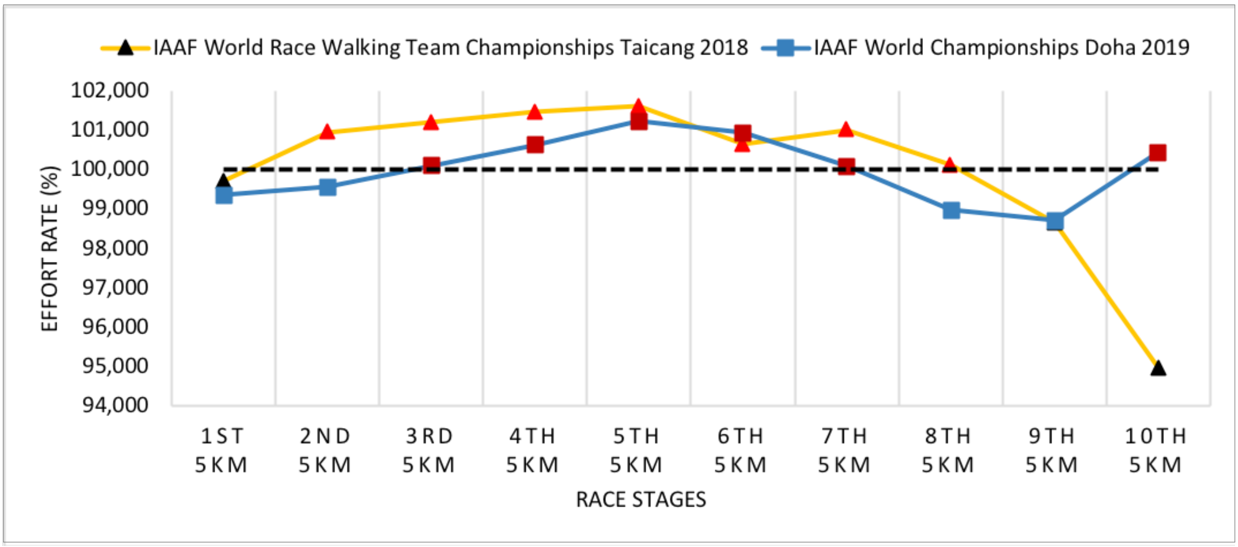

Figure 3. E ort rate (%) of the stages of women's 50km racewalking

Table 3. Average Performance Time (sec), Average Speed (m/sec), and Effort Rate between the stages and final 50km (%) in both Championships.

Race stages	WAC2019				WRTC2018			
	Mean(M) of performance time (sec)	**Average Speed (m/sec)**	**Change in velocity (m/s)**	**Effort rate (%)**	**Mean(M) of performance time (Sec)**	**Average Speed (M/Sec)**	**Change in velocity (m/s)**	**Effort rate (%)**
1st 5km	1546.1	3.234	0.009	99.729	1684.1	2.969	0.019	99.355
2nd 5km	1527.3	3.274	-0.031	100.961	1680.6	2.975	0.013	99.560
3rd 5km	1523.7	3.282	-0.039	101.199	1671.4	2.992	-0.003	100.108
4th 5km	1519.5	3.290	-0.048	101.475	1662.8	3.007	-0.019	100.625
5th 5km	1517.3	3.295	-0.053	101.622	1652.9	3.025	-0.037	101.230
6th 5km	1532.1	3.263	-0.021	100.640	1657.6	3.016	-0.028	100.941
7th 5km	1526.5	3.276	-0.033	101.014	1671.7	2.991	-0.003	100.088
8th 5km	1540.1	3.247	-0.004	100.122	1690.2	2.958	0.030	98.994
9th 5km	1562.8	3.199	0.043	98.665	1695.0	2.950	0.038	98.714
10th 5km	1624.0	3.079	0.164	94.947	1665.7	3.002	-0.013	100.448
Final 50km	15419.4	3.243			16732.0	2.988		

Table 4. Rate of change in speed (%) between both Championships for each stage.

Race stages	WRTC2018		WAC2019		rate of change in speed (%)
	Mean(M) of performance time (sec)	**Speed (m/sec)**	**Mean(M) of performance time (Sec)**	**Speed (M/Sec)**	
1st 5km	1546.1	3.234	1684.1	2.969	27%
2nd 5km	1527.3	3.274	1680.6	2.975	30%
3rd 5km	1523.7	3.282	1671.4	2.992	29%
4th 5km	1519.5	3.290	1662.8	3.007	28%
5th 5km	1517.3	3.295	1652.9	3.025	27%
6th 5km	1532.1	3.263	1657.6	3.016	25%
7th 5km	1526.5	3.276	1671.7	2.991	29%
8th 5km	1540.1	3.247	1690.2	2.958	29%
9th 5km	1562.8	3.199	1695.0	2.950	25%
10th 5km	1624.0	3.079	1665.7	3.002	8%
Final 50km	15419.4	3.243	16732.0	2.988	26%

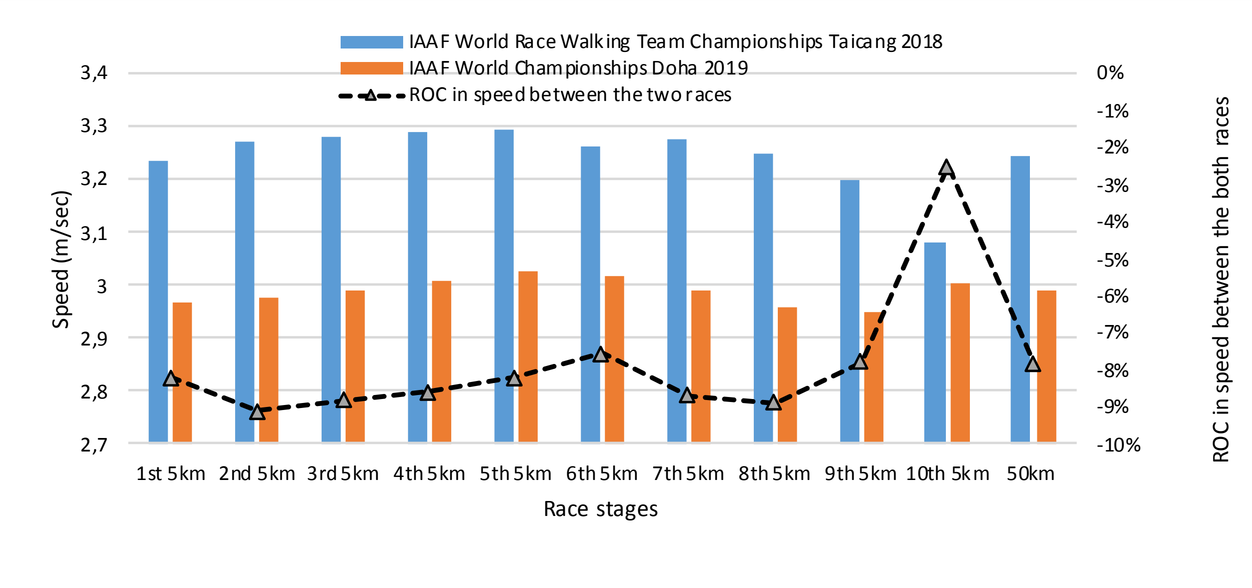

Figure 4. Rate of change in speed (%) between both Championships for each stage.

Table 5. Correlation coefficients (r) between the performance times averages of stages and with final 50km in **WAC2019.**

Race Stages	**Final 50km**	**1st 5km**	**2nd 5km**	**3rd 5km**	**4th 5km**	**5th 5km**	**6th 5km**	**7th 5km**	**8th 5km**	**9th 5km**	**10th 5km**
Final 50km	X										
1st 5km	.895**	X									
2nd 5km	.910**	.790**	X								
3rd 5km	.817**	.713**	.831**	X							
4th 5km	.860**	.829**	.800**	.958**	X						
5th 5km	.901**	.890**	.860**	.880**	.938**	X					
6th 5km	.909**	.769**	.881**	.859**	.881**	.860**	X				
7th 5km	.939**	.767**	.878**	.796**	.829**	.829**	.945**	X			
8th 5km	.979**	.829**	.902**	.779**	.793**	.849**	.868**	.918**	X		
9th 5km	.936**	.817**	.791**	.600*	.651**	.744**	.746**	.834**	.955**	X	
10th 5km	.907**	.884**	.752**	.594*	.681**	.747**	.706**	.764**	.863**	.927**	X

*Correlation is significant at the 0.01 level (2-tailed).*** *Correlation is significant at the 0.05 level (2-tailed).**

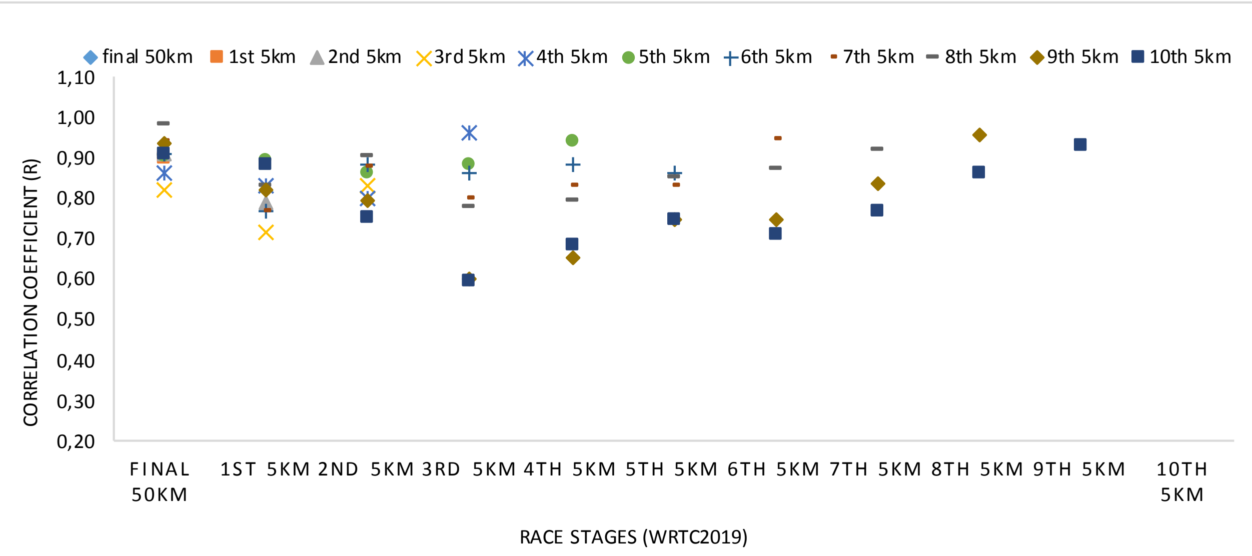

Figure 5. Correlation coeffici ts (r) between the performance times averages of the women's 50km racewalking stages in **WRTC2019.**

times of stages is (8th 5km with r= 0.979), and the lowest correlation coefficient is (3rd 5km with r= 0.817).

Table 6 and Figure 6 show correlation coefficients (r) between the performance times averages of the stages and the final 50km in **WRTC2018**. It is noticed that there was a direct correlation between all the stages of the race and each other. There is a strong positive correlation between all the stages and the final 50km. The largest correlation coefficient for the performance times of stages is (5th 5km with r= 0.918), and the lowest correlation coefficient is (10th 5km with r= 0.594).

Table 7 and Figure 7 show correlation coefficients (r) between the performance times averages of the stages and the final 50km in both championships. It is noticed that there is a strong positive correlation between the final 50 km in both championships, (r=0.988). Also, there is a strong positive correlation between the performance times of all stages in both championships. Where there is a high correlation coefficient between the successive stages, at the distances between 15 and 20 km (r=0.999 in **WTC2018**, r=0.994 in **WAC2019**) and between 20 and 25 km (r=0.994 in **WTC2018**, r=0.995 in **WAC2019**). While the correlation coefficient of performance times between 5km to 10km (r=0.978 in **WTC2018**, r=0.913 in **WAC2019**) is the lowest correlation coefficient between the successive stages.

Table 6. Correlation coefficients (r) between the performance times averages of stages and with final 50km in **WRTC2018.**

Race Stages	Final 50km	1st 5km	2nd 5km	3rd 5km	4th 5km	5th 5km	6th 5km	7th 5km	8th 5km	9th 5km	10th 5km
Final 50km	X										
1st 5km	.776**	X									
2nd 5km	.815**	.903**	X								
3rd 5km	.758**	.914**	.760**	X							
4th 5km	.860**	.934**	.916**	.937**	X						
5th 5km	.918**	.842**	.871**	.793**	.916**	X					
6th 5km	.715**	.435	.500	.444	.574*	.778**	X				
7th 5km	.872**	.594*	.740**	.587*	.757**	.882**	.829**	X			
8th 5km	.743**	.375	.507	.440	.568*	.720**	.610*	.858**	X		
9th 5km	.751**	.314	.441	.315	.443	.623*	.518*	.732**	.889**	X	
10th 5km	.594*	.231	.227	.225	.241	.288	.312	.290	.183	.423	X

*Correlation is significant at the 0.01 level (2-tailed).*** *Correlation is significant at the 0.05 level (2-tailed).**

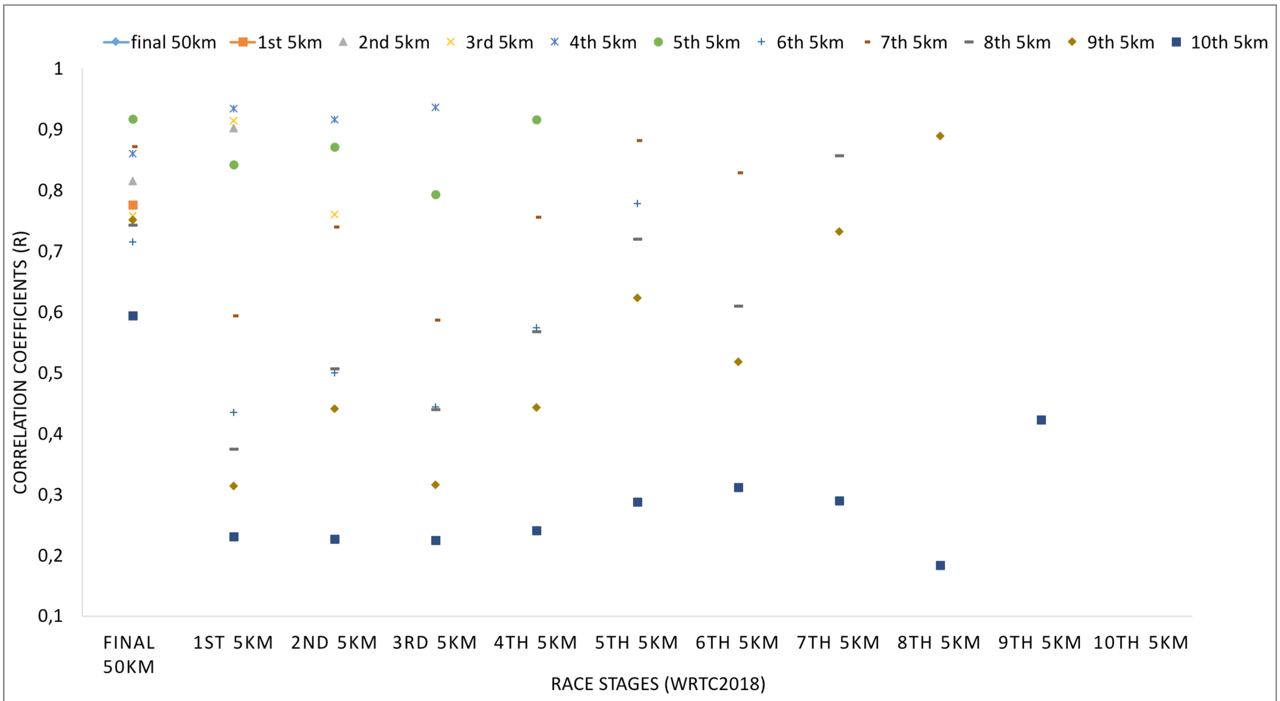

Figure 6. Correlation coeffici ts (r) between the performance times averages of the women's 50km racewalking stages in **WRTC2018.**

Table 7. Correlation coefficients (r) between the performance times averages of the race stages in both Championships.

Race Stages		Taicang										Doha								
		5km	10km	15km	20km	25km	30km	35km	40km	45km	50km	5km	10km	15km	20km	25km	30km	35km	40km	45km
Taicang	10km	.978**	X																	
	15km	.988**	.988**	X																
	20km	.982**	.985**	.999**	X															
	25km	.974**	.982**	.995**	.997**	X														
	30km	.954**	.967**	.979**	.984**	.994**	X													
	35km	.922**	.948**	.957**	.965**	.980**	.994**	X												
	40km	.876**	.912**	.922**	.933**	.954**	.974**	.991**	X											
	45km	.826**	.870**	.877**	.889**	.915**	.939**	.965**	.990**	X										
	50km	.776**	.814**	.822**	.832**	.858**	.886**	.911**	.932**	.954**	X									
Doha	5km	.804**	.852**	.833**	.839**	.860**	.871**	.877**	.885**	.892**	.913**	X								
	10km	.669**	.713**	.714**	.725**	.759**	.789**	.819**	.854**	.889**	.956**	.913**	X							
	15km	.670**	.693**	.714**	.724**	.746**	.762**	.779**	.800**	.825**	.927**	.851**	.957**	X						
	20km	.692**	.714**	.738**	.748**	.766**	.777**	.788**	.802**	.820**	.920**	.853**	.934**	.994**	X					
	25km	.693**	.721**	.742**	.754**	.772**	.784**	.798**	.816**	.837**	.927**	.875**	.938**	.987**	.995**	X				
	30km	.683**	.711**	.735**	.749**	.771**	.788**	.807**	.829**	.851**	.937**	.861**	.941**	.984**	.990**	.992**	X			
	35km	.671**	.700**	.726**	.740**	.764**	.784**	.809**	.833**	.859**	.947**	.850**	.942**	.972**	.975**	.975**	.993**	X		
	40km	.691**	.725**	.744**	.757**	.780**	.802**	.829**	.851**	.876**	.964**	.859**	.953**	.967**	.963**	.964**	.981**	.994**	X	
	45km	.718**	.756**	.766**	.777**	.801**	.825**	.854**	.873**	.895**	.977**	.873**	.952**	.941**	.931**	.935**	.953**	.972**	.991**	X
	50km	.755**	.793**	.800**	.810**	.834**	.860**	.887**	.904**	.922**	.988**	.895**	.952**	.925**	.914**	.920**	.935**	.955**	.978**	.995**

Correlation is significant at the 0.01 level (2-tailed).**

Table 8 shows the calculated F value which is less than the critical F value at α = 0.05. This means that there are no statistically significant differences between the performance times of the race stages in **WAC2019**.

Table 9 shows the calculated F value which is greater than the critical F value at α = 0.05. This means that there are statistically significant differences between the performance times of the race stages in **WRTC2018**.

Table 10 shows the significant differences between the performance times averages of each stage. It is noticed

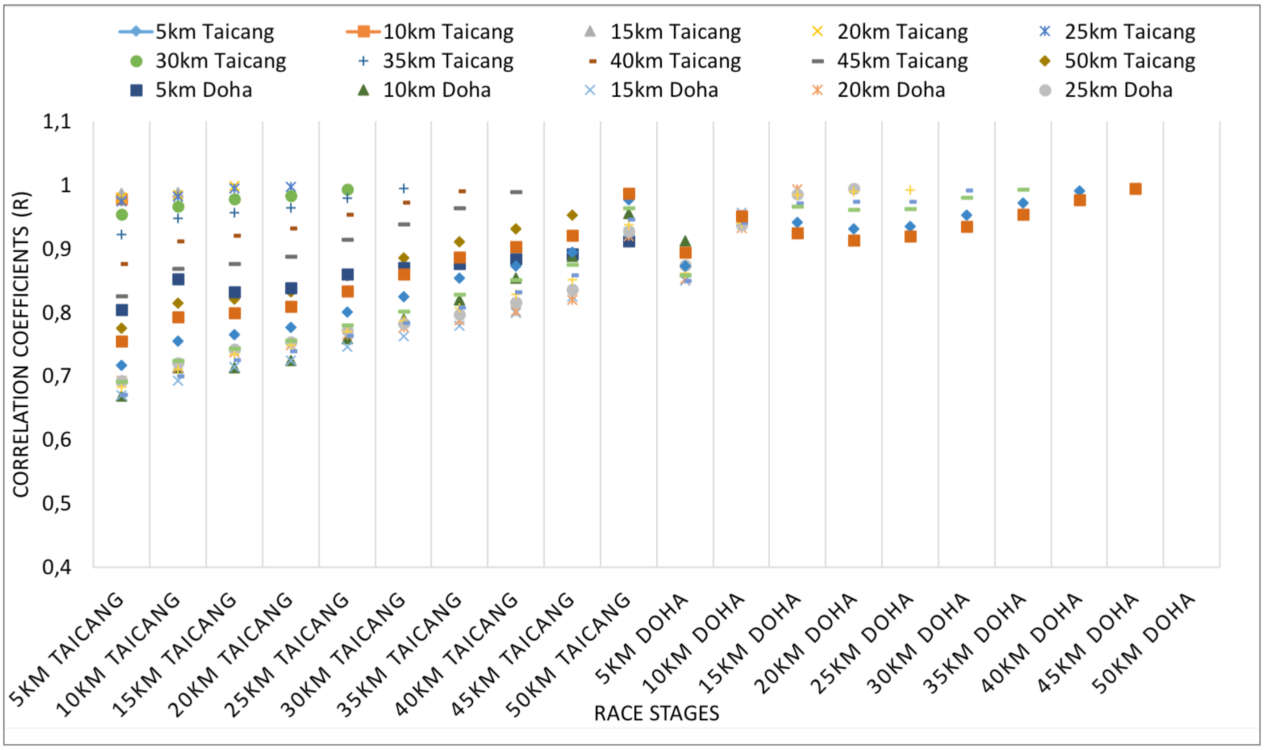

Figure 7. Correlation coeffici ts (r) between the performance times averages of the race stages in both Championships.

Table 8. Analysis of variance (ANOVA: Single Factor) between performance time averages of the race stages in **WAC2019.**

	Source of Variation	SS	df	MS	F	P-value	F crit
IAAF World Championships Doha 2019	Between Groups	26447.87	9	2938.652	0.571716	0.8185	1.947348
	Within Groups	719608.1	140	5140.058			
	Total	746056	149				

$F=0.571716 < 1.947348 = F_{0.05(9,140)}$

Table 9. Analysis of variance (ANOVA: Single Factor) between performance time averages of the race stages in **WRTC2018**

	Source of Variation	SS	df	MS	F	P-value	F crit
IAAF World Racewalking Team Championships Taicang 2018	Between Groups	137736.6	9	15304.07	3.991062	0.000147	1.947348
	Within Groups	536841.9	140	3834.585			
	Total	674578.5	149				

$F=3.991062 > 1.947348=F_{0.05(9,140)}$

that there are statistically significant differences between the performance time average of the (5th 5km) and that of (9th 5km) in favor of the (5th 5km). likewise, there are statistically significant differences between the performance time average of each stage (1st to 9th) 5km and that of (10th) 5km in favor of the stage itself (1st to 9th) 5km.

Table 11 shows the calculated T value which ranged between (5.55 – 29.216), which is greater than the critical T value at $\alpha = 0.05$). This means that there are statistically significant differences between the values of the stages between both championships. Except for the stage (10th 5km), where the calculated T value = (1,212) is less than the critical T value $T_{0.05}$=1.753.

Discussion

We can observe by analyzing the pacing strategy at 50km of racewalking. The average effort rating and average speed increased with the start of the race from the (1st 5km) to the (5th 5km). Then it began to decrease from the (6th 5km), and increased again in the (7th 5km), and decreased from the (8th 5km) to the (10th 5km) in

Table 10. The significant differences between performance times averages of each stage in **WRTC2018**.

	Race Stages	Mean(M) of performance time (sec)	LSD	1st 5km	2nd 5km	3rd 5km	4th 5km	5th 5km	6th 5km	7th 5km	8th 5km	9th 5km	10th 5km
IAAF World Racewalking Team Championships Taicang 2018	1st 5km	1546.1			18.87	22.47	26.60	28.80	14.00	19.67	6.07	-16.67	-77.87
	2nd 5km	1527.3				3.60	7.73	9.93	-4.87	0.80	-12.80	-35.53	-96.73
	3rd 5km	1523.7					4.13	6.33	-8.47	-2.80	-16.40	-39.13	-100.33
	4th 5km	1519.5						2.20	-12.60	-6.93	-20.53	-43.27	-104.47
	5th 5km	1517.3	44.70						-14.80	-9.13	-22.73	-45.47	-106.67
	6th 5km	1532.1								5.67	-7.93	-30.67	-91.87
	7th 5km	1526.5									-13.60	-36.33	-97.53
	8th 5km	1540.1										-22.73	-83.93
	9th 5km	1562.8											-61.20
	10th 5km	1624.0											

Table 11. T-test for performance time averages of each stage and final 50km between both Championships

Race Stages	WRTC2018		WAC2019		F	calculated T
	Mean(M) of performance time (sec)	Standard Deviation(SD)	Mean(M) of performance time (sec)	Standard Deviation(SD)		
1st 5km	1546.1	58.982	1684.1	13.344	12.63	10.925
2nd 5km	1527.3	52.075	1680.6	22.878	11.06	13.863
3rd 5km	1523.7	45.600	1671.4	34.096	8.64	17.108
4th 5km	1519.5	35.510	1662.8	34.262	5.80	24.700
5th 5km	1517.3	34.159	1652.9	48.295	7.66	17.684
6th 5km	1532.1	31.827	1657.6	59.448	11.95	10.503
7th 5km	1526.5	46.223	1671.7	79.725	13.19	11.015
8th 5km	1540.1	54.872	1690.2	99.378	19.40	7.737
9th 5km	1562.8	63.789	1695.0	118.097	23.82	5.550
10th 5km	1624.0	131.979	1665.7	110.982	34.43	1.212
Final 50km	15419.4	414.852	16732.0	571.024	44.93	29.216

critical $T_{0.05}$ =1.753

WRTC2018. The average speed took a strategy similar to the wave shape (M). The effort rate and average speed in **WAC2019** gradually increased with the start of the race from the (1st 5km) to the (5th 5km). Then it began to decrease from the (6th 5km) to the (9th 5km) and increased again in the (10th 5km). The average speed took a strategy similar to the letter shape (N). It is clear that the (5th 5km) stage is considered the fastest and best stage in the effort rate in both championships.

In addition, the (1st 5km) came in the eighth rank in the effort rate and average speed in both championships. This indicates that the racewalkers prefer to use a slow-start pacing strategy as mentioned in the literature. It is to reduce the rate of carbohydrate store depletion by reducing the contribution of the anaerobic glycolytic phosphorylation system [7]. Also, to limit the lactate accumulation and the amount of anaerobic energy reserve used during the beginning of the race to avoid early fatigue [17]. This procedure may become a success factor for the race.

The speed after those increases in a linear fashion from the (2nd 5km), continues to the (5th 5km). To improve the ranking by gradually increasing the effort rate and average speed in both championships. So, we can say that Cardio-respiratory endurance and special endurance play an important role in that phase. This requires successive effort from the start of the race to completing the 25km (i.e., half the race). This will enable the most efficient utilization of aerobic energy system, as well as a complete utilization of their anaerobic capacity [9].

Then a slight decrease in speed during the (6th 5km) for both championships to maintain the ranking achieved by the racewalkers. This decrease in speed is caused by fatigue and the formation of lactic acid in the muscles. As the muscle quickly gets rid of the lactic acid and returns to recovery again. After that, they increased their speeds again during the (7th 5km) in an attempt to improve the ranking. Then a gradual decline from the (8th 5km) to the end of the race (10th 5km) in **WRTC2018**. This is due to the arrival of the racewalkers to the beginning of the phase of fatigue, which would decrease the speed of walking. On the other hand, the effort rate and the average speed continued to decrease from the (7th 5km) to (9th 5km) in **WAC2019**. That is due to the beginning of the phase of fatigue. Then the last stage (10th 5km) increased in the average speed in an attempt to improve the ranking and finish the race.

We believe that a difference occurred in the speed strategy organization in the (7th 5km) and (10th 5km) stages between both championships. It is due to the racewalkers' fear that the race will not be completed due to the extreme temperatures and humidity during **WAC2019**. As the temperature was (30- 31) ° c and humidity was (70-74) % from the start of the race until the end [15]. As mentioned by researchers that playing sports in hot environments leads to physiological tension in the body. This is compared with temperate- and low-ambient temperatures [18], so this means that the pacing is affected by the climatic setting.

Comparing the average values of speed of the stages in both championships, there was a clear difference in the rate of change in speed in favor of **WRTC2018**. As the rates of change in speed ranged from 8% to 30% during the different stages of the 50km racewalking. We think that these differences are due to temperature, humidity, and location of the race.

The results of correlation coefficients indicate that there is a strong positive correlation between the performance time averages of all the stages in both championships. There was a high correlation coefficient between the successive stages, at distances between 15 and 20 km and between 20 and 25 km. This is because the 50km racewalkers must have high Cardio-respiratory endurance. While the time correlation coefficient between 5km to 10km was the lowest correlation coefficient between the successive stages. This means that the racewalkers started the race at a slow and suitable speed. That allowed them to reserve a place at the front of the race. Not to accumulate lactic acid in the muscles, thus avoiding the occurrence of early fatigue.

The results of the T-test indicated that there were statistically significant differences between the values of the stages between both championships, except for the (10th 5 km). In the (10th 5 km), the calculated T value = (1,212) was less than the critical value ($T_{0.05}$=1.753). The results of the variance analysis indicated that there are statistically significant differences between the performance time averages of stages and that of (10th 5km) in favor of all the stages in **WRTC2018**. This means that the last 10km have no major impact on changes for the final classification. So, we suggest changing the distance of this race for women in the World Championships scheduled to the 45km racewalking instead of the 50km racewalking.

From the discussion of all the previous results, we design a walking tactic by dividing the women's 50km racewalking into seven successive phases. The phases on which elite racewalkers depend for regulating the speed and the effort rate during the stages of 50km racewalking, which are as follows:

1- Slow start phase

It is the phase in which the racewalkers exert less effort as intensity ranged from (99.4: 99.7)% from the total effort rate of 50km racewalking. To limit the amount of anaerobic energy reserve during the beginning of the race to avoid early fatigue metabolite accumulation. This phase aims to start the race at a slow and suitable speed that allows the racewalkers to reserve a place at the front of the race. This stage continues for 5km.

2- Primary acceleration and speed regulation phase

It is the phase in which the racewalkers make more effort than the previous stage. This is done gradually as intensity ranged from (99.6: 101.2)% from the total effort rate of 50km racewalking. This phase aims to improve the ranking and obtain an advanced position in the race between the racewalkers. This phase is considered the most important one because it continues for 15km that is a long distance between all phases. Aerobic capacity exercises (e.g., long-distance run and racewalking exercise, water exercise, interval exercise, country aerobics, power stepping, step exercise, funk aerobics) play an important role in that phase for developing cardio-respiratory endurance. This is an addition to the acceleration exercises.

3- Maximum speed (speed plateau) phase

At this phase, the racewalkers achieve the highest speed and exert the highest effort as intensity ranged from (101.2: 101.6) % from total effort rate. This phase results in the formation of waste to accumulate waste of energy and lactic acid in the muscles. This affects the decrease in speed in the next phase. This phase aims to compete in obtaining an advanced position in the race, this phase continues for 5km. Anaerobic capacity plays an important role in that phase and there should be a constantly monitoring of the racewalker's (VO2max) and anaerobic capacity during train.

4- Transitional phase

It is the phase in which the speed is relatively reduced. The racewalkers exert less effort than the previous stage and more effort than the total effort of the race. To get rid of accumulated lactic acid in the muscles and return to the state of recovery again. As intensity ranged from (100.6: 100.9)% from the total effort rate of 50km racewalking. So that the racewalkers can continue to perform until the end of the race. This phase aims to preserve the level reached by the racewalkers; this phase continues for 5km. Anaerobic capacity exercises play an important role in that phase. While maximizing the racewalkers aerobic capacity in order to prevent premature termination. Also, there should be constantly monitoring of the racewalker's (VO_{2max}) and anaerobic capacity during train.

5- Final acceleration phase

At this phase, the racewalkers increase the speed and exerting more effort than the effort of the previous phase (fourth phase). As intensity ranged from (100.1: 101)% from the total effort rate of 50km racewalking. This phase aims to maintain the level and improve the ranking, this stage continues for 5km. Anaerobic and aerobic capacity plays an important role in that phase.

6- Deceleration phase

It is the phase in which the speed and effort exerted gradually decreases as intensity ranged from (98.7: 100.1)% from the total effort rate. This phase is considered an indication of the onset of fatigue, and this phase continues for 10km. Special endurance and aerobic capacity play an important role in that phase.

7- The finish phase

In this phase, the racewalkers begin to finish the race and intensity ranged from (95: 100.5)% from the total effort rate of 50km racewalking. This phase aims to compete for obtaining an advanced ranking among the racewalkers and achieve a new personal performance time. It continues for 5km, Speed endurance and performance endurance play an important role in that phase.

Conclusions

In this paper, we aim to design a walking tactic depending on pace strategy analysis for women's 50km racewalking at both championships (**WRTC2018, WAC2019**). The results of major variables used in this paper can be summarized in the following points:

- The coefficient of variation (cv) ranged between (0.792: 8.127) %, which is less than 30%, which indicates the homogeneity of the research sample.
- There are correlation coefficients between the successive stages. There is a strong positive correlation between the final 50km in both championships (r=0.988) and between performance times averages of stages.
- The average speed ranged between (3.295: 2.95) m/s in both Championships. The best average speed was 3.295 m/s for (5th 5km) at **WRTC2018**. The lowest average speed was 2.95 m/s for (9th 5km) **WAC2019**.
- The average effort was increased in **WRTC2018** during the (2nd to 8th) 5km and decreased during the (1st - 9th - 10th) 5km.
- The effort rate was increased during (3rd to 7th and 10th) 5km and decreased during (1st -2nd - 8th - 9th) 5km in **WAC2019**.
- The results of the T-test indicated that there were statistically significant differences between the values of the stages, except for the (10th 5km).
- The results of the variance analysis indicated that there are statistically significant differences between the performance time of all the stages and that of the (10th 5km) in favor of all the race stages in WRTC2018.

According to our analysis, the coaches and racewalkers seem to set clear times for each stage in the race. They should follow the specific pacing strategy during the training season, regardless of the level of the championship and the level of the racewalkers. The results also indicate that the pacing strategy followed in the race by the elite racewalkers was not based on a fixed rhythm. It rather depends on a variable pace strategy from the start of the race until the end. Therefore, racewalkers must appropriately and strategically distribute aerobic and anaerobic capabilities throughout the race. Also, we note that the last 5km have no major impact on changes for the final classification. So, we suggest changing the distance of this race for women in the world championships scheduled to 45km racewalking instead of 50km racewalking.

Finally, we could divide the race tactically into seven successive phases on which elite racewalkers depend for regulating the speed and the effort rate of the race. These phases are slow start, primary acceleration, and speed regulation, maximum speed (speed plateau), a transitional phase, final acceleration, deceleration, the finish).

Future work

In this paper, we took world championships into consideration, so that our analysis could be applied for 50km racewalkers. So, we seek to design a training program in light of the supposed seven tactic stages. And check its effects on the level of achievement for women and men in 50km racewalking.

Recommendations

We recommend coaches to train racewalkers on the phases of walking tactic, each phase separately. Also, train racewalkers on performance by linking two or more phases without decreasing the rate of speed. Racewalkers should continue to produce high intensity even in conditions of extreme fatigue during training. Training programs must be aimed at creating good aerobic power and the ability to perform pacing changes in conditions of fatigue**.** Anaerobic and aerobic capacities are critical components of 50km race walking performance and should be priorities within a training program.

Conflict of interest

The authors declare that there is no conflict of interest.

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ORIGINAL ARTICLE

Effects of low intensity interval training on physiological variables of university 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	This study was to investigate the effects of low-intensity interval training on the physiological variables of university students.
Material and Methods	Forty male sports science students aged 18-25 years were randomly assigned to the Experimental group (n=20) and the Control group (n=20). The Experimental group underwent low-intensity interval training for eight weeks, whereas the Control group did not. Measurements of physiological variables such as resting heart rate, respiratory rate, recovery heart rate, breath-hold time, maximal oxygen uptake, and blood pressure were obtained for all subjects before and after the intervention. To compare the mean physiological variables between the experimental and control groups, an independent samples t-test was used.
Results	Statistical significance was set at p 0.05. After the training intervention, the experimental group showed significantly better improvements than the control group in resting heart rate, respiratory rate, recovery heart rate, breath-holding time, maximal oxygen uptake, and blood pressure (p 0.05). Post intervention maximum oxygen uptake was statistically significant with t (38) = 3.086, p value 0.004. Post experiment systolic blood pressure was statistically significant with t (38) = -2.405, p value 0.021 for low intensity interval training and control group. Post experiment diastolic blood pressure was statistically highly significant with t (38) = 0.569, p value 0.001 for low intensity interval training and control group. The result of the study showed that there was a significant difference in post rest heart rate, respiratory rate, recovery heart rate, systolic blood pressure, diastolic blood pressure, breath holding and maximal oxygen uptake between the low intensity interval training and the control group (p 0.05).
Conclusions:	Thus, it was concluded that eight weeks of low-intensity interval training show significant improvement in physiological variables of university students.
Keywords:	blood pressure, breathe holding time, maximal oxygen uptake, resting heart rate, recovery rate.

Introduction

Interval training refers to the basic concept of alternating periods of relatively intense exercise with periods of lower-intensity or complete rest for recovery. Low-volume interval training refers to sessions that involve a relatively small amount of exercise [1]. Low-intensity interval training (LIIT) is the minimum exercise intensity threshold for improving aerobic capacity at a minimum 40 - 45% maximal oxygen uptake (Vo2max) [2-5]. Low-intensity resistance exercise provides successful results when performed with circulatory occlusion, even for a short duration of training [6].

Low-volume high-intensity interval training seems to be an efficient and practical way to develop physical fitness [7]. Low-intensity training consisted of treadmill running 3 days/week, 55 min/day, for 15 weeks, beginning and started 2 months post banding (≈10 months old) with gradually increasing intensity, as tolerated, until finally consisting of: 1) 5-min warm-up at 2 mph; 2) six 5-min sessions at 3 mph with five 3-min intervals at 4 mph in between; and 3) 5-min cool down at 2 mph [8-10].

Low-intensity interval training preserved normal coronary vascular function and smooth muscle cell Ca2 -sensitive IK+, illustrating a potential mechanism underlying coronary vascular dysfunction in a large-animal model of Left ventricular(LV) hypertrophy. Low-intensity interval training attenuated increased fibrosis, collagen deposition, and mitochondrial dysfunction. Low-intensity interval training preserved normal coronary vascular function in vivo and maintained coronary smooth muscle cell Ca2 -sensitive IK in miniature swine with LV hypertrophy [8].

The low-intensity exercise-induced decreases of resting heart rate (RHR) was positively related with the pre-interventional RHR and negatively with the average age of the participants. The exercise-especially endurance training and yoga-decreases RHR. This effect may contribute to a reduction in all-cause mortality due to regular exercise or sports [11]. The aerobic fitness was associated with RHR in both sexes, indicating that lower aerobic fitness values were associated with higher RHR values [12].

Low-intensity exercise training applied during chronic Doxorubicin treatment protects against cardiac dysfunction following treatment, possibly by enhancing antioxidant defenses and inhibiting apoptosis [13]. Low-intensity norm duration training significantly improved peak aerobic and sprint power output, efficiency and physical strain in able-bodied untrained individuals. Training at 30% recovery heart rate (HRR) (3- 6/week, 30

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min/session) may be appropriate in untrained individuals, such as novice wheelchair users at the start of their rehabilitation, to prevent early fatigue and overuse and enhance motivation [14].

Data suggest that high-intensity interval training was equally effective as endurance training in decreasing mean arterial pressure, Systolic blood pressure (SBP), diastolic blood pressure (DBP), and circulating C-reactive protein. High-intensity interval training was equally as effective as endurance training in improving V̇O2max. Importantly, these effects seen with high-intensity interval training occurred with substantially less total exercise time and volume than endurance training [15-17].

Low volume high-intensity interval exercise can considerably improve aerobic fitness, body composition, and cardio metabolic health in a variety of populations [18-20]. Low-intensity exercise training significantly delays the onset of heart failure and improves survival in female hypertensive heart failure rats without eliciting sustained improvements in blood pressure, cardiac function, or expression of several myocardial proteins associated with the cardiovascular benefits of exercise [21]. Chronic low-intensity interval training attenuates diastolic impairment by promoting compliant extracellular matrix fibrotic components and pre- serving extracellular matrix regulatory mechanisms preserve myocardial oxygen balance and promote a physiological molecular hypertrophic signalling the phenotype in a large animal model resembling heart failure with preserved ejection fraction [10].

Daily physical activity level was correlated with systolic blood pressure during resistance exercise at 20% and 40% 1 RM, and that systolic blood pressure during resistance exercise decreased after 6 wks of aerobic exercise training. These results suggest that habitual exercise decreases systolic blood pressure during low-intensity resistance exercise [22].

Children and adolescents are recommended to undertake at least 60 min of daily moderate to vigorous exercise [23]. However, studies with objective assessment of physical activity show a significant decline in physical activity in childhood and adolescence [24] and that few children and adolescents meet the recommended daily dose of physical activity [25, 26]. The goals of physical training are to increase the physiological potential of the athlete and to develop bio-motor skills at the highest level [27]. University students represent the future of families, communities, and countries. They are exposed to pressures as they try to achieve their academic goals and are likely to become future leaders in their society, whether in business, education, or politics. It has been argued that health is an important factor in academic success in school and higher education.

According to the above results on low-intensity interval training has a positive effect on physiological variables. The result of this study may be important to physical education teachers, fitness instructors, and coaches who should incorporate a variety of low-intensity interval training methods for physiological variables to improve the physical fitness level of their trainees.

Materials and Methods

Participants

There are currently 103 male sports science students in the study area. Out of them 40 sample students were selected using simple random sampling technique.

To achieve the purpose of the study, the untrained male sports science students were selected from those who were not in any playing or sports team or training program and also free from deformities and ailments. They were randomly divided into two groups, low-intensity interval training (LIIT) group (n=20) and control (C) group (n=20). The experimental (E) group was trained with LIIT and the control group received no training.

A true experimental design was used in this study. According to Guetterman et al., and Bryman, such design helps to generalize and predict from a sample population so that inferences can be made about the outcome of the study population [28, 29].

Therefore, the present study was conducted to investigate the effect of low-intensity interval training on selected physiological variables of Dilla University male sport science students.

The requirements of the project were explained to all subjects and all voluntarily agreed to undergo the testing and training program. A thorough orientation on the requirements of the experimental testing procedure as well as the exercise protocol was well explained to all participants to calm uneasiness and written informed consent was obtained from them.

Research Design

Blood pressure was recorded while students in are in a comfortable sitting position with the right arm fully exposed and resting on a supportive surface at the heart level; a mercury sphygmomanometer was used with an appropriately sized cuff. At the same time, three resting heart rate measurements (radial pulse) were taken after 5, 10, and 15 minutes of being in a sitting position, and the mean was calculated. Resting heart rate was recorded by a physician over a 1-min period [30].

Wash hands with soap and water to Gain the students in a comfortable position. Maintain a constant temperature remove bulky clothing and observing depth, symmetry, and pattern of breathing. If the students are sitting, their feet must be flat on the floor. Allow the students to rest, if possible, for 20 minutes before taking the measurement. When measuring respiratory rate the students were blinded to the specific aims of the study and the simulated students not specifically advised when the respiratory rate was being measured. Using a stopwatch with a second hand, count breaths (number of times the chest moves up and down) for a full minute. This length of time is needed as changes can occur in the respiratory pattern and rate. Record the respiratory rate on the recording paper [31, 32].

To measure breath-holding time primarily fill the plastic bag. With a nose clip in place, have the students take a large breath of room air and then exhale into a previously empty plastic bag, closing the bag so that it stays full. Once the bag is full of expired air, have the students resume normal breathing in and out of the closed bag. Have the time recorder start the stopwatch when the participant begins to rebreathe. The participant should continue to rebreathe until their depth of breathing causes the bag to collapse or until the students reach their limit of tolerance. The observer should terminate the test if the participant exhibits any signs or symptoms of discomfort or dizziness. In our experience, rebreathing should be limited to no longer than 2 min. The duration of rebreathing should be recorded in the data collection sheet, along with any observations of changes in rate and depth of breathing [33, 34].

Students consumed a light breakfast 2-3 hours before the test and refrained from any vigorous physical activity during this period. The students had no history of serious diseases and did not perform any physical conditioning program except for some recreational sports. The maximal oxygen uptake of each subject was determined by indirect methods. Subjects were asked to rest for at least half an hour before exercise. Subjects ran on a 400-meter track for a total duration of 12 min. They were highly motivated to run as many laps as possible. The total number of laps was counted and the finish point was marked. The total distance (in meters) covered in 12 min was calculated by multiplying the number of complete laps by 400 plus the distance (in meters) covered in the last incomplete lap. The distance in meters was converted to km and the following equation was used to predict VO2max.

VO_2max (ml · kg^{-1} · min^{-1}) = (22.351 × distance covered in kilometres) − 11.288 [34, 35].

Heart rate was measured in a supine, standing, during each minute of exercise, at maximum exercise, and in recovery at 1, 2, 3, and 5 min. Heart rate recovery was defined as (maximum heart rate — heart rate at a specified time period after exercise) and represented the drop in heart rate during that time interval [36, 37].

Statistical Analysis-

The data collected on the selected physiological variables in pre and post-test were analyzed, interpreted, and tabulated into a meaningful way by using IBM-SPSS version 20 (IBM, Armonk, NY, United States of America) and analysis of independent sample t-test was used. Mean difference and standard deviation was used in order to compare components of the variable levels among the experimental and control groups. For the study, the significance level for all data was $p < 0.05$.

Results

The demographic characteristics of the participants were explained in Table 1. The mean age, body mass, height and body mass index of the experimental groups were 21.15 years, 62.93 kg, 1.69 m and 22.34 respectively, while the control groups were 20.95 years, 62.45 kg, 1.69 m and 21.81 m tall respectively. Thus, the groups were well matched at entry. Various research findings suggest that body mass index is a useful tool to study the general population to determine health risks and recommended body mass. The acceptable body mass index for the general population ranges from 18.5 to 24.99 kg/m2 appearance her

After the Intervention between Group Comparisons

After eight weeks of the intervention, the effects of the mean physiological variables are described in Table 2. The result of the study shows that the mean of resting heart rate, respiratory rate, recovery rate, breath holding, Vo2max, systolic blood pressure and diastolic blood pressure had positive effects on both health and performance.

The mean RHR for LIIT was 63±6.88, while it was 74.1±7.09 in the control group. The respiratory rate was M= 17.65 for LIIT while it was M= 21.90 for the control group. The recovery rate for LIIT was M= 17.70, while for control group M= 38.50. The LIIT after intervention for breath holding was M= 45.41, while for control group 33.13. After exercise, the Vo2max for LIIT was M= 47.44, while for control group M= 39.64. The LIIT for systolic blood pressure and diastolic blood pressure was M= 114, 69, while for control group 120.5 and 78, respectively.

Results of between-group comparisons were explained in table 3. The result of the study showed that there was a significant difference in post-resting heart rate, respiratory rate (RR), recovery heart rate, systolic, diastolic blood pressure, breath-hold (BHT), vo2-max between LIIT and Control group ($p<0.05$).

Low-intensity interval training and control group of students resting heart rate has a statistically significant difference with $t(38) = -5.023$, p-value < 0.001. This indicates that LIIT had a lower resting heart rate after the intervention. Whereas after intervention respiratory rate there was a statistically significant difference between LIIT and control group of students with, $t(38) = -4.643$, p-value < 0.000. The recovery rate for LIIT and control group after exercising was statistically significant with, $t(38) = -6.286$, p-value < 0.000. Breath-hold for LIIT

Table 1. Participants demographic characteristics

Variables	N	Minimum		Maximum		Mean		Std. Deviation	
		Experimental group	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group	Control group
Age	20	19	19	25	24	21.15	20.95	1.872	1.669
Body mass	20	61.00	61.60	68.00	64.00	62.9300	62.4500	1.87311	.77832
Height	20	1.60	1.59	1.76	1.78	1.6800	1.6940	.04542	.04773
Body mass index	20	20.62	20.01	26.23	24.41	22.3375	21.8060	1.30126	1.15423

Table 2. The mean value between low-intensity interval training and control group within 8 weeks of follow-up.

Group Statistics					
Variables	**Group**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Resting heart ate	Low	20	63.00	6.882	1.539
	control	20	74.10	7.093	1.586
Respiratory rate	Low	20	17.65	3.014	.674
	control	20	21.90	2.770	.619
Recovery rate	Low	20	17.70	9.229	2.064
	control	20	38.50	11.569	2.587
Breath hold	Low	20	45.4145	16.24769	3.63309
	control	20	33.1335	14.35613	3.21013
Vo2max	Low	20	47.4400	6.78393	1.51693
	control	20	39.6350	9.05139	2.02395
Systolic blood pressure	Low	20	114.00	8.208	1.835
	control	20	120.50	8.870	1.983
Diastolic blood pressure	Low	20	69.50	6.863	1.535
	Control	20	78.00	8.335	1.864

Table 3. Changes in outcome between the intervention group doing Low-intensity interval training and the control group within 8 weeks of follow-up.

Independent Samples T Test of Male students' physiological variable test with Experimental and control group

Variables	**Levene's Test for Equality of Variances**			**t-test for Equality of Means**		
	Md.	**F**	**Sig.**	**T**	**Df**	**Sig.(2t)**
Resting heart ate	-11.10	0.007	0.934	-5.020	38	0.001
Respiratory rate	-4.25	0.049	0.827	-4.643	38	0.001
Recovery rate	-20.80	4.124	0.075	-6.286	38	0.001
Breath hold	12.281	0.330	0.569	2.533	38	0.016
Vo2max	7.805	0.556	0.460	3.086	38	0.004
SBP	-6.500	0.383	0.540	-2.405	38	0.021
DBP	-8.500	0.569	0.455	-3.521	38	0.001

t-Test, df- degree of freedom, sig- significant, MD- mean difference

and control group after the intervention was statistically significant with, t (38) = 2.533, p-value < 0.016. This indicates that the low-intensity exercises group were lower respiratory, recovery rate, breath-hold than the control group. Vo_2max after the intervention was again statistically significant with, t (38) = 3.086, p-value < 0.004. This also indicates that students who exercise low-intensity training were higher Vo_2max than the control group. After the experiment for LIIT and control group Systolic blood pressure was statistically significant with, t (38) = -2.405, p-value < 0.021. Diastolic blood pressure for LIIT and control group after exercising it was statistically highly significant with, t (38) = 0.569, p-value < 0.001. This implies that low-intensity the exercising group had lower SBP and DBP than the control group.

Discussions

The purpose of this study was to evaluate the effects of LIIT on physiological variables of university students. The results of the present study show that there was a significant difference in resting heart rate, respiratory rate, recovery heart rate, breath-hold, vo2-max, and systolic and diastolic blood pressure between LIIT and the control group.

The decrease in resting heart rate subsequent to endurance training may be attributed to a decrease in intrinsic rate augmented blood volume, enhance left ventricular ejection fraction, an increase in cardiac parasympathetic efferent activity, and a decrease in cardiac sympathetic efferent activity [38]. In agreement with previous reports the RHR significantly decreased more in the exercising group compared to the control group (all studies: −4.7% and −3.3 bpm resp., females only: −4.8% and −3.4 bpm, resp., males only: −6.4% and −4.3 bpm, resp., studies including both females and males: −3.6% and −2.6 bpm, resp.) [11].

Previous studies on resting heart rate reported that LIIT changes, resting heart rate [32]. This change may occur due to the effect of the training improved cardiovascular and performance capacity related to an increased stroke volume and cardiac output. The mechanisms also enhanced diastolic filling parameters at the highest heart rates associated with maximal exercise. There is also a component of peripheral blood flow adjustment to training that contributes to the enhanced exercise capacity post-training. A modest increase in the ability to extract oxygen as assessed by arteriovenous oxygen difference. These findings are similar to the current study. This is likely due to changes in the ability to preferentially re-route blood flow to active muscle tissues, a greater capillarization of active skeletal muscle beds, and the enhanced oxygen extraction capability of the trained muscle cells with greater numbers of mitochondria and oxidative enzymes. Therefore, increasing the efficiency of heart rate muscles, ventricular cavity size, and stroke volume, or neural adaptation to decrease sympathetic tone to the sinoatrial node and increase parasympathetic tone which plays a role in reducing the resting heart rate [32].

Similarly, this study illustrated a significant difference in respiratory rate between LIIT groups and the control groups following the eight-week intervention. This finding is in agreement with Low-intensity interval training may constitute an effective training protocol for improving VO2 max and cardiovascular endurance [39].

Previous studies indicate that Low-intensity interval training has positive improvement in respiratory rate [40-42]. This may be due to the effect of the training on improving ventilation pre-and post-training, at rest, and during low-intensity exercise and changes in tidal volume, respiratory rate, and ventilator volume of maximal aerobic exercise. Maximal respiratory rate and maximal tidal volume increase post-training for a profound effect upon maximal ventilator volume [43-45].

Based on different study findings, the effect of high-intensity interval training on recovery heart rate shows better efficiency on students' physiology. Longer recovery intervals resulted in a lower average heart rate and Maximum oxygen uptake over the training session [46-50].

In Sprint interval training protocols, similar beneficial performance outcomes were reported across a multitude of exercise modalities when recovery duration was increased between work intervals [51-54]. The main metabolic processes that take place during recovery from intense exercise, bouts are the repletion of phosphocreatine stores, the removal of hydrogen ions, and restitution of the acid-base balance of the exercising muscles. These processes proceed at different rates, with phosphocreatine having a much faster half- life (~30 s) and achieving complete restoration (~3 min), compared with blood lactate [BLa] and pH recovery (6-10 min) [55-57].

Thus, heart rate recovery contributed positively to the results for two reasons. First, the short recovery time would have meant that the anaerobic energy production systems would not have had sufficient time to fully recover. With each subsequent repetition, the aerobic system would have been required to make a greater contribution to energy production. If enough repetitions of this form of exercise are performed, energy production from the aerobic metabolism will be challenged regularly enough for a training effect to occur. Second, passive recovery has been found to be a more effective strategy when performing supramaximal high-intensity interval training.

For both participants, it was possible to maintain exercise intensity and perform larger workloads per effort using a passive rather than an active recovery strategy. Due to the high energy demands of supramaximal interval training, the oxygen demand for each subsequent interval is too high for oxygen to be consumed at all during the shorter recovery period. It can be postulated that the recovery strategy used in the current study contributed to the improvement in aerobic performance because, in theory, more oxygen was available to the subjects to maintain the required intensity. The shorter recovery time would have progressively required a significant contribution from the aerobic system to meet the energy demand [57, 58].

After the breath-holding test, the research data showed that high breath-holding capacity and significant improvement were observed in the LIIT group compared to the control group. This could be due to the improvement of respiratory muscle efficiency, which increases tidal volume and increases the number, size and metabolic capacity of mitochondria to increase the oxygen consumption of cells accordingly [44, 59].

The current literature has shown that a regular practice of yoga/breathing exercises can be useful in improving ventilator function. However, a short practice of deep breathing exercises can improve breath holding time [60]. The information described in the literature indicates that intermittent breath holding during moderate-intensity exercise provokes consistent changes in muscle oxygenation, leading to lower tissue oxygenation. The data also indicate that exercise with intermittent breath holding induces higher blood lactate concentration [61].

Much of the available literature demonstrates that better improvement in VO2 max was seen in the LIIT group when compared with the control group. This may be due to the intensity exercises enhances the activity of the cardiovascular system as well as the developed oxidative capacity of the skeletal muscles which leads to an increase in the delivery of oxygen to the working muscles. The above result was also confined to the study of [62-65].

The effect of the training on the vascularity of blood vessels or decreasing stiffness of arteries. The decreased resting blood pressure makes it easier for the left ventricle to pump blood because it must develop less force to eject blood into the peripheral circulation. A reduction in both systolic and diastolic blood pressure

(BP) may be due to the reduced sympathetic nervous activity as well as an increased nitric oxide-mediated vasodilation from exercise. It has been postulated that the mechanism involved in lowering blood pressure from undertaking aerobic exercise specifically, maybe be due to the hormone's norepinephrine and epinephrine, as regular exercise has been shown to reduce the level of norepinephrine, limiting vasoconstriction of the arteriole enabling reduced blood pressure. Furthermore, this reduction in the sympathetic neural activity that may help to reduce the blood pressure from undertaking aerobic exercise [47, 66-70].

Evidence supports the idea that physiological performance can be improved when individuals include LIIT in their training plan [39, 71].

The present study recommended that physical education teachers, fitness instructors, and coaches should incorporate a variety of low-intensity interval training methods to improve the performance of their trainees. Similar studies can be conducted involving female students by including other variables for better performance enhancement in selected physiological variables.

Conclusions

In conclusion, the study results show that eight weeks of low intensity interval training showed a positive effect on physiological variables, namely: resting heart rate, respiratory rate, breathe hold, vo2 max, diastolic and systolic blood pressure compared to the control group.

Conflict of interest

The author declare that there is no conflict of interest regarding the publication of this article.

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