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ORIGINAL ARTICLE

Physiological impact of wearing a surgical face mask during walking in the 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 Common use of surgical face masks is recommended for social and individual health due to the COVID-19 pandemic. However, there is no systematic report for responses of organism to wearing a surgical face mask during different exercises. In this context the purpose of this study was to examine the impacts of wearing a surgical face mask during a one-hour brisk walking.

Material and Methods A total of thirty male (n=16) and female (n=14) volunteers (mean age and BMI of 32±1.07 years and 25.1±0.68 kg/m^2, respectively) completed the protocol. This was a multiple cross-over trial for healthy volunteers. All participants took a one-hour brisk walking with and without a surgical face mask. Specific physiological measurements (HR - heart rate; BP - blood pressure, SaO_2 - arterial oxygen content) were compared before and immediately after two brisk walking. Each subject served their own control.

Results The evaluation found that there was no statistically significant difference between the mean HR and blood pressure values during the brisk walking with and without a surgical face mask, while there was a statistically significant difference in the SaO_2 values on behalf of no-mask-walking ($p<0.05$).

Conclusions: The use of surgical face masks in healthy volunteers causes a decrease in SaO_2 during brisk walking. However, it does not affect the mean pulse rate and blood pressure. Although there was a statistically significant decrease in the SaO_2 parameter during mask-walking, it is possible to state that brisk walking with a surgical face mask does not have a physiologically negative impact, because this decrease is in ranges that are accepted to be normal.

Keywords: brisk walking, Covid-19, surgical face mask, oxygen saturation

Introduction

The Covid-19 pandemic has greatly affected not only all areas of life [1] but also the exercise routine of people [2]. Yet still participating in some kind of physical activity or doing exercise regularly in a safe environment is an important means for a healthy life in this pandemic period [3]. Moreover since face masks are a clinically accepted method in reducing the transmission of virus; international, national and local administrations insistently recommend the use of face masks [4]. The public and sports clubs consider wearing a mask an inseparable part of physical activity to prevent contagiousness in daily life [5]. In addition this measure can be even more important during aerobic activities like running or bicycling, because some preliminary studies show that smaller droplets can be transmitted up to five meters while walking at 4 km/h speed and up to ten meters while running at 14.4 km/h speed [1].

It is thought that the mask obligation and other restrictions imposed by the Covid-19 pandemic, will also cause the increase of disorders like obesity, cardiovascular morbidity and depression by reducing physical activity [2]. Furthermore mask obligation and restrictions have caused professional and recreational sporters and sports club owners to face specific difficulties during this crisis [6, 7].

Despite all this information, people have not been able to obtain clear information on whether wearing a mask during exercise may pose a health risk or not. The World Health Organization has recommended social distancing instead of masks, because masks may decrease the ability of breathing freely and a mask which gets wet with sweat during exercise may obstruct breathing and encourage microorganisms to grow [8]. Also some experts have asserted that face masks obstruct breathing, a part of the carbone dioxide inhaled previously is inhaled in every respiratory cycle and these two phenomenon increase the frequency and depth of breathing [9]. They have stated that it is hard to do physical activity with a mask, because lungs need more oxygen to let the same amount of air in [10, 11]. In contradistinction to these, another study reported that it is safe to wear a mask during exercise and especially moderate and intense exercises do not affect respiration frequency, blood pressure, O_2 level and exercise burnout times [1].

In this context the study aimed to at least seek an answer to the question in the minds of people regarding whether the walking activity, which has proven to be useful for health and physical convenience, should be performed with or without a mask in order to protect the physical and mental health of people in this process.

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Material and Methods

Participants.

A total of 30 women (n=14) and men (n=16) who had similar exercise routines (doing aerobic exercise 75-150 minutes a week), did not smoke, had no chronic illness and did not take medication regularly, took part in the study voluntarily.

Research Design.

Demographic data was collected via the Inbody 270 body analysis measuring device. Height (cm) and weight (kg) were measured for each subject and body mass index (BMI) was calculated. This was a multiple cross-over trial for healthy volunteers. All participants took a one-hour brisk walking on a cinder path first without a mask and then with a Type 1 surgical face mask in EN 14683 standards every two days. During the no-mask-walking, it was tried to fix the maximal heart rate which is determined based on the intensity of exercise and age factor, on 50-55% range. The distance they walked was recorded and then in the mask-walking the participants were asked to walk the distance they had walked during the no-mask-walking, once again in an hour. Each subject served their own control. Before and immediately after the brisk walking taken with and without a surgical face mask, their systolic and diastolic blood pressure (mm/Hg) was measured via a digital sphygmomanometer branded OMRON-M2. During the brisk walking their oxygen saturation, SaO_2 (%) and pulse rate were measured via a pulse oximeter device (Choicemed MD300C12, South Korea). In order to determine the saturation accurately, the walking was taken on hours when the sunshine was weaker [12, 13] and the finger in which the probe was placed was kept dry and clean [14]. The participants were all asked not to change their nutrition order before the measurement day, not to participate in any intense physical activities 24 hours before, not to use alcohol 12 hours before and not to eat two hours before every test.

Statistical analysis

For the analysis of the data the SPSS 23.0 package program was used. In order to determine whether the numeric variables were normally distributed or not, the Shapiro-Wilk test was used. In order to determine whether there was a difference between the groups or not, the "Paired Samples T test" was used. All analyses were processed at the significance level of 0.05.

Results

Thirty volunteers successfully completed the study protocol (all the two brisk walking sessions). The mean age of the participants was 32±1.07 years. The mean height, weight and BMI were 171.9±1.5 cm, 75.7±2.72 kg and 25.1±0.68 kg/m2, respectively. Two brisk walking were performed after a minimally required rest of 24 hours and the mean time between the walking was 48 hours.

Environmental factors like temperature, moisture, elevation and noise and women's cycle may affect the intensity of responses which develop in basic physiological systems. Thus being unable to standardize these factors for all participants might have been the reason why there was no statistically significant difference between the mean systolic and diastolic blood pressures ($p>0.05$). In addition the fact that the participants had had similar ranges of blood pressure before the exercise, might have contributed to this outcome. Although not statistically significant, the 3-5% decrease which was observed in the systolic blood pressure parameters after the two exercises may be associated with a temperature increase occurring during exercise, an increase in the CO_2 amount caused by a decrease in the O_2 saturation and a decline arising from vasodilatation due to all these reasons. Table 1 shows the blood pressure values of the participants.

According to our findings it is possible to state that wearing a surgical face mask during brisk walking has no negative impact on healthy adults. Table 2 shows findings supporting this view.

There was no significant difference between the mask-walking and no-mask-walking groups in terms of the mean heart rate parameter (fig. 1, fig. 2). Although there was a statistically significant decrease in the SaO_2 parameter in the mask-brisk-walking group, it is possible to state that mask-walking does not create a physiological difference in general, because an oxygen saturation (SaO_2) value above 95% is accepted to be normal [15].

Table 1. The mean blood pressure values of all participants before and immediately after the walking

Group	Before Walking		After Walking	
	Mean±sd		Mean±sd	
	Systolic (mm/Hg)	Diastolic (mm/Hg)	Systolic (mm/Hg)	Diastolic (mm/Hg)
Mask-Walking Group (n:30)	123.4±2.03	76.6±1.49	117.1±1.68	77.1±1.22
No-Mask-Walking Group (n:30)	122.1±1.98	78.4±1.79	118.9±1.79	76.2±1.71

Table 2. Comparing the mean HR and SaO_2 values of the mask-walking and no-mask-walking group

Parameters	Group	Mean±sd	t	*p*
Mean HR (rate)	Mask-Walking Group (n:30)	111.8±1.18	*0.31*	*0.76*
	No-Mask-Walking Group (n:30)	111.6±1.35		
SaO_2 (%)	Mask-Walking Group (n:30)	97.02±0.09	*-8.79*	*0.00**
	No-Mask-Walking Group (n:30)	97.93±0.1		

*p<0.05

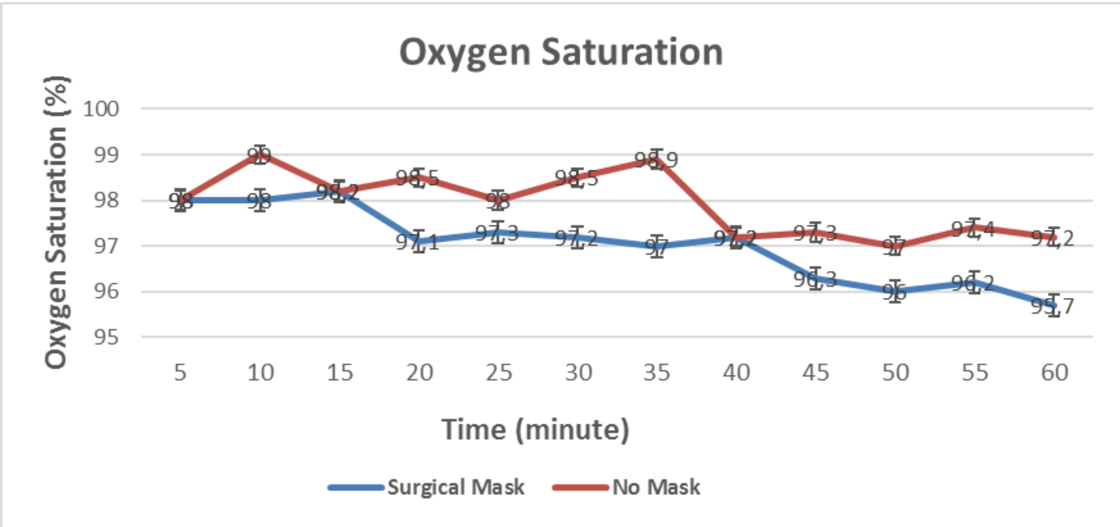

Figure 1. Mean changes in the oxygen saturation (%) values during the one-hour walking exercise performed by 30 subjects with and without a surgical face mask

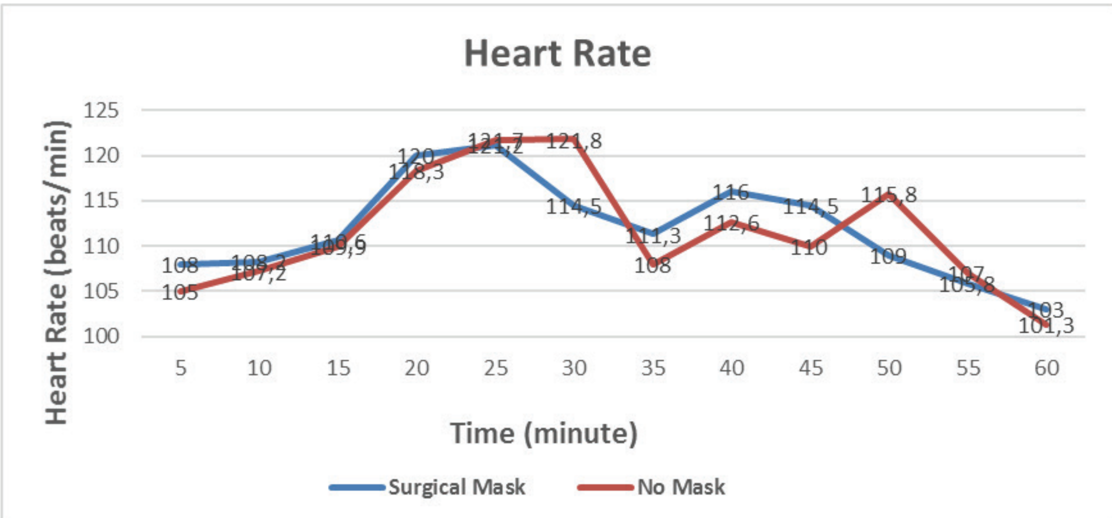

Figure 2. Mean changes in the HR (rate/min) values during the one-hour walking exercise performed by 30 subjects with and without a surgical face mask

Discussions

Examining similar studies in the literature; there is no clear information about whether wearing a mask during exercise is bad for health or not. However, one of the studies conducted specific to wearing a mask outside exercise, examined the impact of wearing a mask on respiration and physiological parameters and found that wearing an N95 mask four hours during hemodialysis significantly decreases the PaO_2 (arterial oxygen partial pressure) and has negative impacts on respiration in people with final-stage renal disease. Considering that the study was performed with renal patients and considering the technical properties of N95 mask; this result can be accepted to be normal [16]. Another study reported that

N95 masks obstructs breathing and gas exchange in healthcare professionals and places additional workload to the metabolic system, which is in agreement with these findings [17]. Another study which was conducted specific to surgical face masks reported that there was an increase in the pulse rate and a decrease in the SaO_2 values of 53 surgeons one hour after wearing surgical face masks during surgeries [18]. It is thought that these findings can also be associated with psychological factors created by surgical procedures conducted with masks. A study conducted by Fernando et al. with eight people measured the pulse rate, oxygen saturation and carbone dioxide values during a mask-exercise performed at 6-8 MET intensity and consequently found that there was a decrease in the O_2 intake and an increase in the CO_2 production. Furthermore the O_2 saturation value which was 97.6% ± 1.5 in the beginning of the exercise, dropped to 92.1% ± 4.12 after the exercise ($p<0.002$). It is thought that this dramatic decline may create a risk for health and can be associated with exercise intensity. Also the study reported that the oxygen level decreased 3.2% and the CO_2 level increased 20% [19].

A study conducted with 60 healthy males evaluated the physiological impacts of wearing a surgical face mask or an N95 mask during short-time tiring exercise and found that the masks were safe and practicable and they only had minor and insignificant impacts on physiological parameters during exercise, which is in agreement with our study findings [1]. Another study investigating the impact of wearing a mask during exercise from a different point of view reported that doing exercise with a mask causes physiological developments in the person. Person et al. and Chen reported that wearing a mask (surgical or N95) during short walking (5-6 minutes) will contribute to the development of respiratory muscles [20, 21, 22]. Other studies conducted from the same point of view reported that doing exercise with a mask decreases the performance in the beginning; however, there will be an adaptation in the course of time. In addition using a mask for weeks or months increases the power of lung muscles and thus, the performance may increase if the mask is taken off because the lungs will receive more oxygen [23]. What is stressed here is the training applications under hypoxic conditions, which have proven to be useful in the resiliency development for many years. Indeed our study also found that the saturation value decreased, which makes us ask whether it may contribute to the resiliency performance when applied for a long time.

Examining contrary studies; Fikenzer et al. indicated that medical face masks (especially N95) are tiring masks that significantly ruin physical and occupational activities, have a distinct negative impact on the cardiopulmonary capacity and they also significantly ruin the quality of life [24]. Porcari and Jaim stated that masks cause psychological disorders, slightly decrease the performance and require an adaptation period. Also they stressed that a wet mask increases the resistance against air flow to the lungs and there is a need for more effort for respiratory muscles. Yet still the masks are safe to use in all conditions and should be promoted in the COVID-19 period because they serve as a barrier against virus particles [25, 26].

Conclusion

In the light of all this information, according to the results of the literature and our study; surgical face masks have no negative impact on the pulse rate and blood pressure during aerobic exercises performed at moderate and lower intensity in healthy people and although the oxygen saturation significantly decreases during these exercises, this decrease has no negative impact on health. In addition since wearing a mask has scientifically proven to prevent the virus transmission, it is thought that exercises which are performed at moderate and lower intensity especially in crowded places should be performed with masks. Further studies can seek an answer to the question "Can wearing a mask have long-term useful impacts on resiliency by creating hypoxic conditions, outside health perspective?".

Conflicts of Interest

The authors declare no conflicts of interest.

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ORIGINAL ARTICLE

Improvement of coordination abilities of qualified athletes specializing in fencing

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Abstract

Background and Study Aim The aim of the research is to investigate the efficiency of designed complexes of training exercises aimed to improve the coordination abilities of qualified athletes in fencing.

Material and Methods 22 qualified athletes specializing in fencing aged from 15 to 18 took part in the research. The study design included the sequential pedagogical experiment that was realized through the several stages. At the first stage, the preliminary testing of the athletes' coordination abilities (n=22) was conducted. During the preliminary testing the following tests were applied: jumps to the line; shuttle run (4x9 m.); T-test, straight touch from en-garde position to the target of 10 cm in diameter from close range (10 attempts); straight lunge attack from en-garde position to the target of 10 cm (10 attempts). At the second stage of the pedagogical experiment two complexes of exercises aimed at developing the coordination abilities of the athletes were applied for 3 months. The experimental complexes of exercises were used twice a week. At the third stage, the efficiency of experimental complexes aimed at the developing of coordination abilities of qualified athletes in fencing was checked through a control testing. The Statistica 10 software created by the StatSoft Company was used for statistical processing of data.

Results It was established that during the process of coordination abilities development, the greatest attention should be given to the athletes' ability to control timing, spatial and physical parameters of moves and moves consistency. To improve the process of developing the coordination abilities of the qualified athletes in fencing two complexes of training exercises were developed. The results of the pedagogical experiment confirmed the statistical differences in the levels of the athletes' coordination abilities manifestation before and after using experimental training complexes ($p<0.05$).

Conclusions: It has been shown that specially developed training complexes could be used during the training process in order to develop and increase the level of coordination abilities of qualified athletes in fencing. The analysis of experts' opinion showed that the development of coordination abilities in fencing should be oriented towards the development of athletes' ability to control timing, spatial and physical parameters of movements.

Keywords: fencing, athletes' preparation, coordination abilities.

Introduction

Modern fencing is characterized by high intensity of training and competitive activities making specific demands on an athlete's organism. The modern sports theory accentuates that athletes' special working capacity and the efficiency of their organisms' functional systems during competitive activities, greatly depends on rationally planned and organized system of physical preparation [1].

The problem of enhancing the efficiency of physical preparation and development of motor skills of athletes in fencing is not new, though it does not lose its relevance being confirmed by a considerable number of recent researches [2-5].

Complex approaches to the organization of fencers' physical preparation are widely represented in the works of Tyshler et al [6] and Ryzhkova [7]. In their works, authors consider physical preparation of athletes in fencing as a multidimensional set of means and methods aimed to develop motor and psychophysiological qualities manifesting during a fencing bout.

A considerable number of researches were done in order to examine the different aspects of competitive activity in fencing [8-11]. A wide range of authors agreed that one of the most prominent qualities characterizing the elite level athlete and having a direct impact on efficiency of competitive activity is the level of fencer's speed abilities [2, 3, 5, 12]. Yet, the latent time of simple and complex hand-eye reaction stands the most prominent component of speed abilities manifestation among the fencers [5, 10, 13]. A. Sorel et al. emphasize that in the course of fencers' physical preparation the main focus should be put on development of the explosive strength, coordination and various components of speed abilities [14].

The results of our previous researches also show the importance of the development of motor skills among the athletes specializing in fencing. It was found that under the influence of the experimental complex of training and extra-training means more prominent changes in the speed of simple and complex visual-motor response were detected [15]. It was also shown that application of experimental training and extra-training means promoted considerable increase of the athletes' speed abilities that

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also positively reflected on the efficiency of competitive activity [11].

A considerably smaller number of scientific researches is devoted to peculiarities of development and improvement of strength, endurance, coordination abilities and flexibility among the athletes specializing in fencing [3, 4, 16].

di Cagno et al. researched the impact of eccentric workloads on the lower limbs strength indicators of qualified athletes specializing in fencing [3]. The results of the research demonstrated that application of additional workload using specially developed mechanical devices helped to increase the range of attacking moves during advance-lunge, having been reached through the increasing of hip flexors strength [3]. In their researches, J. Redondo et al. describe the impact of 12-week strength training program on the indicators of fencers' maximal and explosive strengths. The authors showed that given experimental program combined with special fencing training means led to the improvement of strength abilities that in its turn also positively affected the manifestation of speed abilities of fencers (single move speed) [4].

The analysis of relevant researches devoted to the peculiarities of physical preparation and development of motor skills among the athletes specializing in fencing demonstrated that researchers and coaches are in constant search of the means and methods that could improve the process of the athletes preparation. Along with that, the conducted analysis showed that in the system of the fencers' preparation there is a lack of scientific-based approaches aimed at developing of coordination abilities of qualified athletes in fencing. It forms the relevance of the research given below.

Hypothesis. Application the specifically developed training exercise sets can increase the level of coordination abilities of qualified athletes in fencing.

The aim of the research is to investigate the efficiency of designed training complexes aimed to improve the coordination abilities of qualified athletes in fencing.

Material and Methods

Participants.

22 qualified athletes specializing in fencing aged from 15 to 18 took part in the research. The parents of the participants aged from 15 to 17 and the participants aged 18 gave their consent to take part in the research.

Research Design.

The research included few stages. At the first stage, we studied the data of recent scientific researches on the peculiarities of physical preparation in fencing, particularly on the approaches of development of motor skills. In order to specify the content and orientation of experimental training complexes aimed to develop coordination abilities of qualified athletes in fencing, the questionnaire of fencing coaches (n=20) was conducted. The further stages of the research included conducting a sequential pedagogical experiment that allowed us to examine the working hypothesis. The choice of a sequential pedagogical experiment is related to the fact that the participants of the research are qualified athletes and it allowed us to achieve more informative samples for analyzing the achieved results. At the second stage, the preliminary testing of the athletes' coordination abilities (n=22) was made. During the preliminary testing the following tests were applied:

1. Jumps to the line (cm) [17].

Task conditions: participant stands on a 90cmhigh jumping box. On the signal "Go!" the participant jumps to the line drawn on the floor 1 meter away from the jumping box. The participant should land his heels as close as possible to the line. The distance from the participants' heels to the line is measured with the measuring tape. The best result of two trials is recorded.

2. Shuttle run 4x9 (s) [17, 18].

Task conditions: participants sprint back and forth between two parallel lines as fast as possible. Two lines are used as markings, two wooden blocks are put behind one of the lines. Starting position is at the line from the opposite side of the blocks. On the signal "Ready? Go!", the participants run to the other line and pick up a block, then they return to place it behind the starting line. After this, the athletes come back to pick up the second block, then they run with it back across the line. The stopwatch is stopped as the participant passes the line. The quickest of the two trails is recorded.

3. T-test (s) (Fig.1.) [18].

Task conditions: a participant starts at the start/finish line. On the signal "Ready? Go!", the participants sprint to cone A and touch the base of the cone with their right hand. Then they turn left, sprint to cone B, and also touch its base, this time with their left hand. Then they sprint to cone C and touch the base with their left hand. Then they sprint back to cone A and touch it with the right hand, then to sprint to the start/finish line. The stopwatch is stopped as the participant passes the finish line. The quickest of the two trails is recorded.

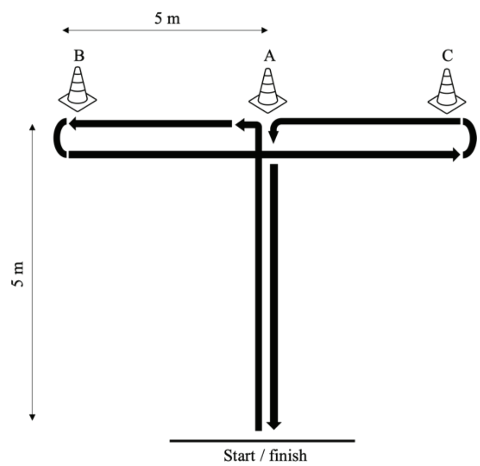

Fig.1. T-test

Besides, the following specialized fencing tests were used:

4. Straight touch from an en-garde position to the 10 cm target in diameter from close range (10 attempts) [19].

Task conditions: a participant stands in the "en-garde" position in front of the target with weapon in the leading hand at the close-range distance. A 10-centimeter circle is drawn in the middle of the target. When ready, the participant makes ten touches trying to place the tip of the weapon inside the circle. If the tip of the weapon lands outside of the circle, the touch does not count. The number of successful touches is recorded.

5. Straight lunge attack from an en-garde position to the target of 10 cm (10 attempts). [19].

Task conditions: the participant stands in the "en-garde" position in front of the target with weapon in the leading hand at the middle-range distance. A circle with a diameter of 10 centimeters is drawn in the middle of the target. When ready, the participant makes ten straight lunge attacks trying to place the tip of the weapon inside the circle. If the tip of the weapon lands outside of the circle, the touch does not count. The number of successful touches is recorded.

At the third stage, the experimental training complexes aimed to develop the athletes' coordination abilities are applied to a group of athletes.

The first complex of exercises includes exercises that should be performed with a special coordination ladder (by TRX) 10 m long, 50 cm wide, 20 boxes. The given complex includes following exercises:

1. Initial position is behind the ladder. An athlete runs down to the center of the ladder, with each foot coming in contact with boxes, then turns around and runs back to the starting position. Executed once.
2. Initial position is with both feet inside the first box of the ladder. An athlete runs forward with high knees, lifting knees to the waist level, arms are bended at 90 degrees and swinging back and forth to generate momentum. Executed once.
3. Initial position is behind the ladder. An athlete jumps into the first box of the ladder with the right foot, then jumps to the next box with both feet, then jumps to the next box with the left foot, then jumps with both feet again. The sequence continues till the end of the ladder. Executed once.
4. Initial position is behind the ladder. An athlete jumps into the first box of the ladder with both feet, then jumps forward and puts the feet on both sides of the next box, then jumps to the next box with both feet inside the box. The sequence continues till the end of the ladder. Executed once.
5. Initial position is behind the ladder. An athlete jumps into the first box with both feet performing 180-degree turn, then jumps to the next box with both feet performing 180-degree turn in opposite direction. The sequence continues till the end of the ladder. Executed once.
6. Initial position is on the right side of the ladder. An athlete steps sideways with the leading foot into the first box, then cross-steps with the rear foot behind the leading foot into the next box. The sequence continues till the end of the ladder. The exercise should be repeated in the opposite direction.
7. Initial position is on the right side of the ladder. An athlete jumps to the first box landing both feet into the center. Then jumps forward to the second box, spreading legs and landing, so that both feet are outside of the ladder, then jumps to the third box bringing feet back to the same middle position. The sequence continues till the end of the ladder. The exercise should be repeated in the opposite direction.
8. Initial position is on the left side of agility ladder. An athlete takes a lateral step to the right with the right foot into the first box, then immediately follows it with the left foot. Then steps laterally to the left side of the ladder with the left foot and moves the right foot to the next box. Then brings the left foot to meet right, then steps laterally to the right side of the ladder and moves left to the next box. The sequence continues till the end of the ladder. The exercise should be repeated in the opposite direction.
9. Initial position is with feet a little wider than hip-width to the right side of the agility ladder. An athlete steps sideways with the left foot into the first box, follows it right away with the right foot. Then steps sideways with the left foot into the second box, then brings the right foot into that box. The sequence continues till the end of the ladder. The exercise should be repeated in the opposite direction.
10. Initial position is behind the ladder. An athlete steps in with the lead foot, then in with the other foot, out with the lead foot, and out with the other foot. Both feet will touch every square of the entire ladder. The exercise should be repeated by switching the lead foot.
11. Initial position is behind the ladder. An athlete jumps into the first box of the ladder with the right foot and puts hands on the waist, then jumps to the second box with the same foot and puts hands up. The sequence continues till the end of the ladder. The exercise should be repeated with the left foot.
12. An athlete starts from the "en-garde" position with the leading foot in the second box and behind foot in the first box. The athlete advances forward by overstepping lines between the boxes. The exercise should be repeated in opposite direction.

While performing the exercises, the main attention should be paid to the development of correct sequence of movements and relationship among different elements of the given exercise. The understanding of dynamic and kinematic movement parameters should be formed. The athletes' attention was drawn to the rational relocation of body elements, sequence and number of efforts, as well as to tension and relaxation of different muscle groups.

The second complex includes elements of special fencing drills and exercises performed with a partner. This complex is aimed to develop hand motor skills, speed of switching from one action to another, and improving voluntary concentration among the athletes. The given complex includes following exercises:

1. Athlete starts from the "en-garde" position on the side of the fencing piste, holding a tennis ball in the

leading hand. While advancing, the athlete should throw the ball 50 cm up and then catch it. The exercise should be repeated in opposite direction.
2. An athlete starts from the “en-garde” position on the side of the fencing piste, holding a tennis ball in the leading hand. While advancing, the athlete should bounce the ball against the floor and then catch it. The exercise should be repeated in opposite direction.
3. Two athletes start from the “en-garde” position facing each other on a distance of 3 meters. Both athletes hold tennis balls in their leading hands. On the signal “Go!”, athletes should simultaneously throw the balls to each other and catch the ball thrown by the partner. The exercise should be executed 10 times.
4. Two athletes start from the “en-garde” position facing each other on a distance of 3 meters. One of the athletes holds a tennis ball in the leading hand (athlete A), another athlete has nothing in the hands (athlete B). On the signal “Go!”, the athlete A advances forward with one step simultaneously throwing the ball to the athlete B. The athlete B catches the ball simultaneously retreating with one step. Then athlete B throws the ball to the athlete A. The exercise should be executed for one minute.
5. Two athletes start from the “en-garde” position facing each other on a distance of 3 meters. One of the athletes holds a tennis ball in the leading hand (athlete A), another athlete has nothing in the hands (athlete B). On the signal “Go!”, the athlete A performs advance lunge attack simultaneously throwing the ball to the athlete B. The athlete B catches the ball simultaneously performing double retreat. Then, the athlete B throws the ball with advance lunge attack to the athlete A. The exercise should be executed for one minute.
6. An athlete starts from the “en-garde” position in the middle of the piste. A partner stands in front of the athlete on a distance of advance lunge attack with a tennis ball in his hand. On the signal “Go!”, the partner starts moving constantly changing speed and direction. The athlete should follow the partner keeping the distance of advance lunge attack. While moving, the partner should stop every 10-15 seconds and bounce the ball against the floor in front of him. The athlete should catch the ball with advance lunge attack before it falls to the ground after the bounce. The exercise should be executed for two minutes.

The exercises of the second complex performed with a partner are aimed to develop hand motor skills, speed of switching from one action to another, and improve voluntary concentration among athletes. While performing the exercises, the athletes’ attention was drawn to the ability of holding a few objects in sight and switching their attention from one stimulus to the others performing special fencing drills simultaneously. Such actions are related to motive reactions as well as spatial and time anticipations. They form the basis of the athletes’ actions in unexpected and unsteady situations.

The designed training complexes were included into the training process of qualified athletes in fencing (n=22) and were applied twice a week for three months in a row. The first complex was used as a part of warm-up routine. The second complex was applied at the beginning of the main part of training session. At the fourth stage, the control testing of the athletes’ coordination abilities was done, using the above-described tests. Control testing allowed us to check the efficiency of designed complexes aimed to develop athletes’ coordination abilities.

Statistical analysis. To determine statistical significance of the differences between the indicators of the coordination abilities manifestation level among the athletes specializing in fencing before and after using experimental training complexes, the non-parametric criteria for small samples were used (Wilcoxon test), as a sample distribution did not follow the normal distribution law. The significance level was considered p=0.05. The Statistica 10 computer software created by the StatSoft Company was used for statistical processing of data.

Results

To specify the content and peculiarities of coordination abilities development process among the qualified athletes in fencing, the questionnaire of fencing coaches was conducted.

The analysis of questionnaire data showed that 50% of coaches considered the regulation of dynamic as well as spatial and timing parameters of moves the most important component of coordination abilities among the athletes specializing in fencing. 31% of respondents noted that intramuscular and intermuscular coordination as the major feature of coordination abilities among fencers, 13% of respondents noted static and dynamic balance as the dominant manifestation of coordination abilities. Only 6% of fencing coaches considered spatial orientation as the most important component of coordination abilities.

To develop the coordination abilities among the qualified athletes in fencing, coaches usually use coordinately similar exercises with technical and tactical actions in fencing and exercises (including specialized ones) using additional training equipment. That was noted by 38% and 28% of coaches respectively. Apart from that, 22% of the surveyed coaches considered the varieties of running and jumping exercises as efficient means for developing the athletes’ coordination abilities. 10% of the surveyed used sports games as means of coordination abilities development, 3% noted that they relied on other training methods.

Taking into account the results of recent researches displayed in special scientific and methodological literature as well as the questionnaire results, two complexes of training exercises aimed to develop coordination abilities among the qualified athletes specializing in fencing were developed.

To check the efficiency of the designed training complexes aimed to develop coordination abilities among the athletes specializing in fencing, we conducted a sequential pedagogical experiment including a preliminary testing of the coordination abilities level

Table 1. The indicators of manifestation of the athletes' coordination abilities before and after using experimental training complexes

Test name	Testing results			
	Before using experimental complexes (n=22)		After using experimental complexes (n=22)	
	X̄	S	X̄	S
Jumps to the line, cm	8.91	5.81	3.32*	2.98
Shuttle run (4x9m), s	11.37	1.03	10.58*	0.8
T-test, s	9.57	0.54	9.41*	0.45
Straight touch from "en-garde" position, number of touches	9.05	0.84	9.45*	0.60
Straight lunge attack from "en-garde" position, number of touches	7.55	1.5	8.64*	1

Note: * – the differences are statistically significant compared to the data received before using experimental training complexes, of about $p<0.05$

among the athletes, implementation of experimental complexes into the training process and control testing of coordination abilities.

From the table 1 we can see that after using experimental training complexes, the improvement of indicators of coordination abilities manifestation are observed after all five tests ($p<0.05$). The control testing demonstrated that as a result of using of designed training complexes during the training process, the accuracy of completing the jumps to the line test increased by 5.59 cm ($p<0.05$). A considerable improvement in the results of the «Jumps to the line» test shows that after the application of experimental training complexes athletes managed to improve the processes of regulation of dynamic and spatial parameters of the movements. To evaluate the complex manifestation of the athletes' coordination abilities, the "Shuttle run" and "T-test"were used. The analysis of the "Shuttle run" results showed that after using the experimental complexes aimed to develop the athletes' coordination abilities the speed of completing the distance improved by 0.79 s ($p<0.05$) on average. The indicators of the "T-test" improved by 0.16 s ($p<0.05$) on average.

The comparative analysis of the results of specialized fencing tests showed that under the influence of experimental complexes, the accuracy of straight touch from the "en guard" position increased by 0.4 ($p<0.05$) on average. The accuracy of straight lunge attack to the target of 10 cm in diameter increased by 1.09 ($p<0.05$) on average.

Discussion

The development and improvement of coordination abilities take an important place in the system of qualified fencers' physical preparation. The level of coordination abilities plays an important role in the process of motor skills development, mastering technical and tactical actions and their realization in constantly changing conditions of competitive activity. In spite of the fact that the problem of coordination abilities development of athletes is not new [18, 20-22], there is a relevant need of searching various methodological approaches that could be applied in the system of qualified fencers' preparation. There is a lack of recent researches that cover the issue of the development of coordination abilities in fencing. A particular relevance of these issues is also related to the fact that different types of coordination abilities manifestation are sport specific. This fact should be taken into account during the development of specialized training complexes aimed to the improvement of coordination abilities of qualified athletes in fencing [6, 20].

The research presented in this article showed that the majority of coaches in fencing believed that among different types of coordination abilities, the most important for fencers were abilities to control timing, spatial and physical parameters of movements as well as a general movement coordination. We believe that this coaches' opinion is related to the specifics of competitive activity in fencing, which requires constant change of movements according to the uncertain conditions of the fencing match.

It is important to notice that the coaches' opinion correspond to the most prominent scientific researches in the field of motor skills development and athletes physical preparation, that shows the importance of coordination abilities in extreme conditions of competitive activity, especially in conditions of space and time deficiency [1, 18].

According to sports experts' opinion and scientific researches, coordination of movements is tightly connected to other types of coordination abilities and, first of all, to the ability of evaluating and regulating dynamic, spatial and timing parameters of movements [18, 20, 23]. The development of experimental complexes presupposed that selected training means should positively affect athletes' ability to evaluate and regulate dynamic and spatial parameters of movements. During the development of experimental training complexes, we also took into consideration the opinions of researchers in various kinds of sports noting that training the qualified athletes' coordination abilities would be efficient only if it was realized under conditions of a particular kind of sports [1, 10, 22, 24]. It is related to the fact that along with enhancing the athletes' qualification, the generalization and positive shifting in the sphere of abilities and motor skills reduces. General coordination exercises do not have the training effect that has been reached at the previous stages of sports training. Thus, our usage of special-preparatory exercises adding various complexities during their completion, let us to increase the efficiency of developing coordination abilities of qualified fencers.

It is worth noting that both complexes were based on exercises that require additional training equipment. The training impacts were chosen so that they would provide gradual increase of the demands towards the analyzers' activity related to the accuracy of spatial, timing and dynamic parameters of movements. It was taken into consideration that workload variability is an important element in coordination abilities development, which means that nature, duration and intensity of the exercises should not be the same at every training session [18, 23].

Application of experimental training complexes during the training process allowed us to intensify the functionality of athletes further than traditional means do, and on this basis, increase the level of coordination abilities of qualified fencers.

The conducted research completed the data on contemporary approaches to the organization of physical preparation and development of motor skills of qualified athletes specializing in fencing [2, 3, 13, 16, 25]. The results of the given research complete the data devoted to the issue of rational organization of qualified athletes' training process in Olympic sports [2, 6, 18, 20].

In our future research, it is expected to investigate the influence of training complexes aimed to develop the coordination abilities of qualified athletes on the efficiency of competitive activity in fencing.

Conclusions

It has been shown that specially developed training complexes could be used during the training process in order to develop and increase the level of coordination abilities of qualified athletes in fencing. The analysis of experts' opinion showed that the development of coordination abilities in fencing should be oriented towards the development of athletes' ability to control timing, spatial and physical parameters of movements. As a result of the research, it was shown that application of experimental training complexes during the training process of qualified athletes in fencing led to the improvement of the coordination abilities ($p<0.05$).

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Conflict of interests

The authors declare no conflict of interests.

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ORIGINAL ARTICLE

Effect of glutathione supplementation on swimmers' performance

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

Abstract

Background and Study Aim Continuously increasing the volume and intensity of the training sessions often leads to overtraining. It has been demonstrated that glutathione supplementation might improve the aerobic metabolism in skeletal muscle and reduce exercise-induced muscle fatigue. The aim of the study was to assess the effect of glutathione supplementation on fatigue, recovery processes, and competitive results of elite swimmers during a six-week training period.

Material and Methods Twenty-four elite swimmers (10 women and 14 men) from the Bulgarian national swimming team, with a mean age of 18.7±3.78 years, took part in this double-blind placebo control study. The swimmers from the experimental group were supplemented once a day with a capsule of 250mg glutathione, whilst the swimmers from the control group took a placebo once a day. The urine concentration levels of cortisol and cortisone, as well as the degree of overtraining, were evaluated on the 1st(T1), 14th(T2), 28th(T3), and 42nd(T4) days. Anthropometric measurements and a nutritional assessment were performed at T1 and T4.

Results The swimmers showed a gradual decrease of cortisol and cortisone during the study, with significantly lower concentrations in the experimental vs the control group at T4 (19.4 vs 42.5 ng/mL, $p < 0.05$). At the end of the study, the swimmers from the experimental group showed improvements in their time in 41 out of the 43 swimming events, whilst those from the control group had significantly smaller improvements (-1.66 vs -0.97%, $p < 0.05$).

Conclusions: In conclusion, glutathione supplementation at a dose of 250mg/day for six weeks improves the adaptation of elite swimmers towards training schedules, which is likely to lead to better sports results.

Keywords: glutathione, supplements, elite, swimming, performance

Introduction

The main goal of elite athletes is to achieve high results in their sport, which is accomplished by doing great amounts of training as part of the preparatory process. However, continuously increasing the frequency, volume and intensity of the training sessions often leads to overtraining, from which days and even weeks are required in order to recover. About 30% of elite adolescent athletes reported experiencing a state of fatigue at least once in their careers, indicating an average of two episodes of overtraining lasting for a period of around four weeks. Overtraining was also observed in 5% to 30% in swimmers during their sports season [1-4].

The appearance of overtraining in athletes is associated with the inducement of oxidative stress. Oxidative stress has a negative effect on cellular structures and their functions, and for athletes, these negative effects are mainly reflected in the change in muscle contraction functions and/or increased muscle damage and the rapid occurrence of fatigue [5-8]. Physical exercises increase oxidative stress throughout the body, and this outcome has been illustrated in a number of physical activities, including swimming [9-12].

Antioxidants can reduce the oxidative stress caused by high amounts and intensity of training workouts. A key non-enzymatic antioxidant is the reduced form of glutathione (GSH), which is the most widespread non-protein thiol in the cells, and it has a concentration of 1-10 mM [13]. GSH has a high electron donation capacity, which determines its significant cell-reducing power [14], and it can directly neutralize active forms of oxygen [15, 16], in addition to being involved in the reduction of other antioxidants in the cell, including vitamins E and C [17]. GSH is a major co-factor of the antioxidant enzyme glutathione peroxidase (GPX) [18]. When oxidative stress is observed, GSH decreases [19], and its oxidized form GSSG increases, followed by a decrease in the GSH : GSSG ratio [20].

GSH takes part in the detoxification of foreign substances in the body by interacting and neutralizing them. It also supports the structure of proteins, takes part in intracellular transport and chelation of copper, modulates neurotransmitter receptor activity, activates T-lymphocytes and polymorphonuclear leukocytes, and others [21-24].

It has been shown through studies that changes in GSH and GSSG concentrations in the blood of athletes are observed during physical exercises. A number of these studies demonstrated that continuous submaximal training led to a decrease in GSH and an increase in GSSG [25-27]. It is assumed that decreased plasma GSH concentrations following physical exercise demonstrate increased GSH consumption in skeletal muscle, resulting in a reduced export rate from muscle into plasma [28].

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Other authors reported only an increase in GSSG without significant change in GSH, thereby the GSH:GSSG ratio was reduced [29, 30].

The effect of increased levels of GSH on physical performance has been studied by applying N-acetylcysteine (NAC) [31-34]. NAC is a reduced thiol donor with antioxidant properties which supports glutathione synthesis, since the acetylation of cysteine is the rate-limiting step in glutathione synthesis [35].

Only a few human clinical trials evaluated the effects of oral GSH supplementation. Witschi et al. administered a single oral dose of up to 3 g of GSH, given to seven healthy subjects, and no increase in blood GSH levels was found [36]. Allen et al. 2011 conducted a study, which involved 40 healthy subjects who consumed oral glutathione capsules (500 mg twice per day) or placebo capsules for a period of four weeks. The results showed that there were no changes in the levels of GSH, GSH:GSSG ratio, and some indicators of oxidative stress [37].

Data on animals in vivo demonstrate that oral GSH is absorbed in rats [38, 39]. Specifically, Hagen et al. showed a doubling of plasma GSH from 15 to 30 μmol/L within 120 minutes after oral administration in rats, and suggested that dietary GSH is principally absorbed in the jejunum [39]. Kovacs-Nolan et al. demonstrated, in in vitro and ex vivo intestinal absorption models, that intact glutathione can be transported between human intestinal epithelial cells [40]. In addition, Park et al. reported that the plasma glutathione concentration is transiently elevated after oral glutathione supplementation, which suggests that exogenous glutathione can be absorbed into the body and act as an important glutathione supply [41].

In 2015, Aoi et al. demonstrated that glutathione supplementation improves the aerobic metabolism in skeletal muscle, leading to reduced exercise-induced muscle fatigue by elevating Peroxisome proliferator-activated receptor-γ coactivator-1α (PGC-1α) [42]. PGC-1α has been shown to be a key transcriptional co-activator, providing a mechanistic insight into nuclear regulatory pathways in the biogenesis of mitochondria in skeletal muscle [43].

The aim of the study was to assess the effect of glutathione supplementation intake on fatigue rate, recovery processes, and competitive results of elite swimmers during a six-week training period.

Material and Methods

Participants

Twenty-four elite swimmers (10 women and 14 men) from the Bulgarian national swimming team, with an average age of 18.7 ± 3.78 years (from 15 to 25 years), took part in this double-blind placebo control study. The research was performed in accordance with the Declaration of Helsinki for Human Researches [45]. The swimmers were familiarized with the details regarding the purposes of the study, and an informed consent was obtained from each participant.

Design of the study

The swimmers were divided into two comparable groups according to their competition results, gender, and age. Each group consisted of five women and seven men. The swimmers from the first group (experimental) were supplemented once a day with a capsule of 250 mg glutathione, whilst the swimmers from the second group (control) took placebo once a day (one capsule with 250 mg glucose).

The swimmers were tested for a six-week period, starting two weeks after the National Team Championship and finishing two weeks before the National Individual Championship (both in a 50 m long pool). The assessments were conducted each Monday in the mornings (after 60 hours of rest) every two weeks: on the 1st (T1), 14th (T2), 28th (T3), and 42nd days (T4). The swimmers' degree of overtraining was evaluated four times at T1, T2, T3 and T4 by the Training Distress Scale (TDS) and by assessing the urine concentration of cortisol and cortisone. Additionally, anthropometric measurements and a nutritional assessment were performed at T1 and T4.

Training programme

The swimmers were following a three-season planning in their annual programme. This study took place in the summer season (3rd macrocycle) from April to July, in which the swimmers were performing their training sessions in a 50 m long pool. The reported six-week period in this study is part of the general preparation phase, and it started right after the two-week recovery phase after the main competition. The swimmers trained twice a day from Monday to Friday performing a total of ten training sessions per week. During this period, the training process was associated with gradually increasing the training volume, starting from 40 km for the first week and finishing at 65 km for the last one. The main goals for this phase were to improve aerobic capacity and maintain anaerobic power and speed. The training has to produce central circulatory and respiratory adaptations which will improve the delivery of oxygen and nutrients to the muscles [45]. As a result of that, an increase of VO_2max is expected. The training programme applied in this research, including training volume (km) and training zones (% of all volume), is shown in Table 1.

Anthropometry

The anthropometric measurements of the swimmers were taken at the National Centre for Sports Medicine in Bulgaria. Height was taken with an accuracy of 0.1 cm, and body weight was recorded with an accuracy of 0.1 kg. Skinfolds were measured to the nearest 0.1 cm by using the Lange Skinfold Calliper, Beta Technology Inc, Cambridge, USA. Arm, thigh and calf circumferences was measured to the nearest 0.1 cm with the Lufkin W606PM tape measure. The percentage of body fat (Fat%) was determined by the sum of seven skinfolds, using Jackson and Pollock's equations [46]. The percentage of total body skeletal muscle mass (MM%) was calculated by using the Lee et al's equations [47].

Nutritional assessment

The food frequency questionnaire (FFQ) [48, 49], which was applied in this study to assess the nutrition of the swimmers, included questions about the weekly use

Table 1. Six-week training programme of the elite swimmers from this study

Week	**1**	**2**	**3**	**4**	**5**	**6**
Training zones/Volume (km)	40	45	50	55	60	65
I. Basic Endurance HR 120-150	59 %	59 %	59 %	50 %	50 %	50 %
II. Threshold Endurance HR 150-180	25 %	25 %	25 %	25 %	25 %	25 %
III. High performance endurance HR >180	4 %	4 %	4 %	8 %	8 %	8 %
IV. Anaerobic: Lactate tolerance + Lactate production + Race pace training	2 %	2 %	2 %	4 %	4 %	4 %
V. Sprint	3 %	3 %	3 %	3 %	3 %	3 %
VI. Recovery HR < 120	7 %	7 %	7 %	10 %	10 %	10 %

HR – heart rate in beats per minute (bpm)

of basic food products and questions about the age, sports experience, and number of training sessions per week. The composition and energy value of different groups of food were calculated based on the USDA National Nutrient Database - Release 28 [50]. The FFQ and the data tables needed for calculations are available on the internet [51].

Based on the results, the daily intake of proteins, carbohydrates and fats, relative daily protein intake per kilogram body mass (RDPI), relative carbohydrate intake (RDCI), relative fat intake (RDFI), and the energy contribution of each nutrient (E%), in addition to the total daily energy intake (kcal/24h) and relative energy intake (RDEN), were calculated. The basal metabolic rate (BMR kcal/24h) was calculated by using the equations of Harris and Benedict [52]. The estimated daily and relative energy needs (DEN and RDEN) were calculated by multiplying BMR by the coefficient of physical activity (k) according to the number of weekly training sessions (BMR kcal/24h x (1.2 + 0.08 x number of sessions) [52].

Recovery and overtraining assessment

The rate of recovery and the level of overtraining were assessed by using the Training Distress Scale (TDS), which was proposed and validated by Grove et al. [44]. It consists of nineteen questions, which evaluate the symptoms of distress in athletes. These symptoms include various statements related to changes in emotional state, general fatigue, concentration difficulties, physical discomfort, sleep and appetite disturbances. The swimmers responded to the questions, indicating the degree to which each symptom corresponds to their individual state during the last 48 hours. The grade was determined by a five-point bipolar scale, ranging from "none" (0 points) to "excessive" (4 points). The final result (TDS score) was the sum of the points from all nineteen questions.

Cortisol and Cortisone urine concentration assessment

The concentration of cortisol and cortisone was determined by the relative density of the urine specimens, from which the measured hormonal concentrations were adjusted. Samples were pre-treated, then analysed sequentially by a high-performance liquid chromatograph (HPLC) and a mass spectrometer.

Swimming results

The results achieved by the swimmers at the National Team Championships (two weeks before the start of the experiment) were compared to the results from the National Championships, which was held two weeks after the end of the experiment. From the results for each swimming event recorded in the first competition, we subtracted the results from the second competition, and the difference was presented as a percentage of the first time (negative values show an improvement in the achievements form the second competition).

Statistical analyses

The statistical analyses were performed by the SPSS Statistics 19 software (IBM, USA), using descriptive statistics and one-way ANOVA for dependent samples with the Bonferroni *post hoc* test. The data from the Training Distress Scale (TDS) did not show a normal distribution when using the Kolmogorov-Smirnov test of normality, and, therefore, non-parametric ANOVA for repeated measurements (Friedman test) was applied. The average improvement in performance was analysed by using Independent-samples t-test, and the improved swimming results and worsened swimming results were analysed by Chi-square test for frequency distributions. The results are expressed as mean values ± SD in the text and tables, and as mean ± SE in the figures.

Results

Anthropometry

The mean age of the swimmers from the experimental group was 17.6 ± 3.67 years, and in those from the control group was 18.4 ± 4.67 years. The anthropometric parameters of the swimmers in this study are presented in Figure 1. There were no statistically significant differences in the parameters, neither between the experimental and control groups, nor between the initial baseline (T1) and final measurements (T4).

Nutrition

No significant differences were found between the genders in all of the groups in this study in terms of their nutrition, and, therefore, the analyses were performed for both men and women together. The relative daily energy needs (RDEN) and relative daily energy intake (RDEI) of the swimmers in this study are presented in Figure 2. The data shows no significant differences between the estimated energy needs and the calculated energy intake, which was confirmed by the stable anthropometric

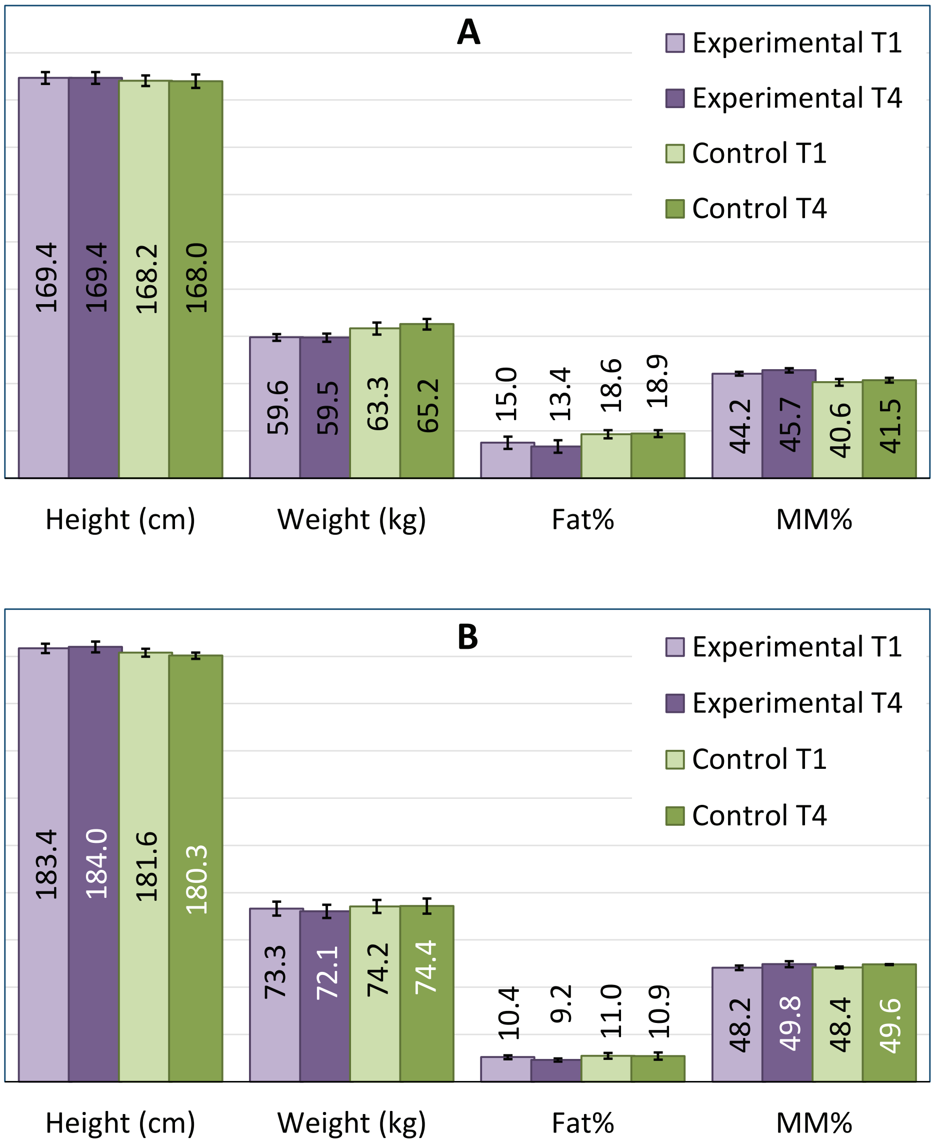

Figure 1. Anthropometric parameters of the female swimmers (A) and male swimmers (B) from the experimental and control groups on the 1st (T1) and the 42nd (T4) days of the six-week training period.

parameters over time (Figure 1). There were no significant differences between the experimental and the control group, nor between baseline (T1) and final nutritional assessment (T4).

The relative daily protein intake (RDPI), relative daily fat intake (RDFI), and relative daily carbohydrate intake (RDCI) of the swimmers are presented in Figure 3. There was a correlation between the amounts of the main macronutrients consumed by the swimmers in this study and the recommended norms for swimmers with similar training [54] in all four assessments. There were no significant differences in the relative amounts of the macronutrients between the experimental and the control groups, nor between the baseline (T1) and final nutritional assessment (T4).

Training Distress Scale (TDS)

The results of the TDS assessment showed a reduction in the frequency of the overtraining symptoms at the end of the six-week training period (Figure 4), which was contrary to our expectations. There was no significant difference in the TDS scores between the experimental and control groups at the final assessment (T4).

Hormones

The concentration of cortisol hormone in the morning urine of the subjects tested showed a gradual decrease during the six-week training period (Figure 5). A statistically significantly lower cortisol concentration was found in the morning urine of the swimmers from the experimental group at the final measurement (T4). The same dynamics were observed in the concentration of cortisone and the sum of the cortisol and cortisone concentrations (data not shown).

Competition results

The results of the swimmers at the National Team Championship, which took place two weeks before the start of the experiment, and the results at the National

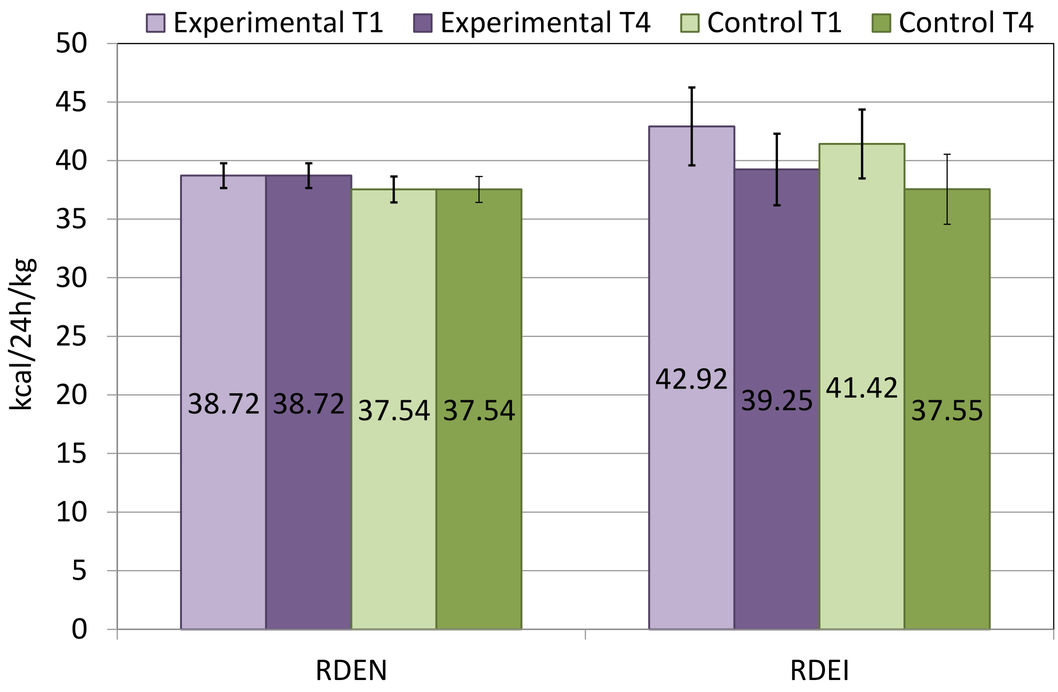

Figure 2. Relative daily energy needs (RDEN) and relative daily energy intake (RDEI) of the swimmers from the experimental (n=12) and the control (n=12) groups on the 1st (T1) and the 42nd (T4) days of the six-week training period.

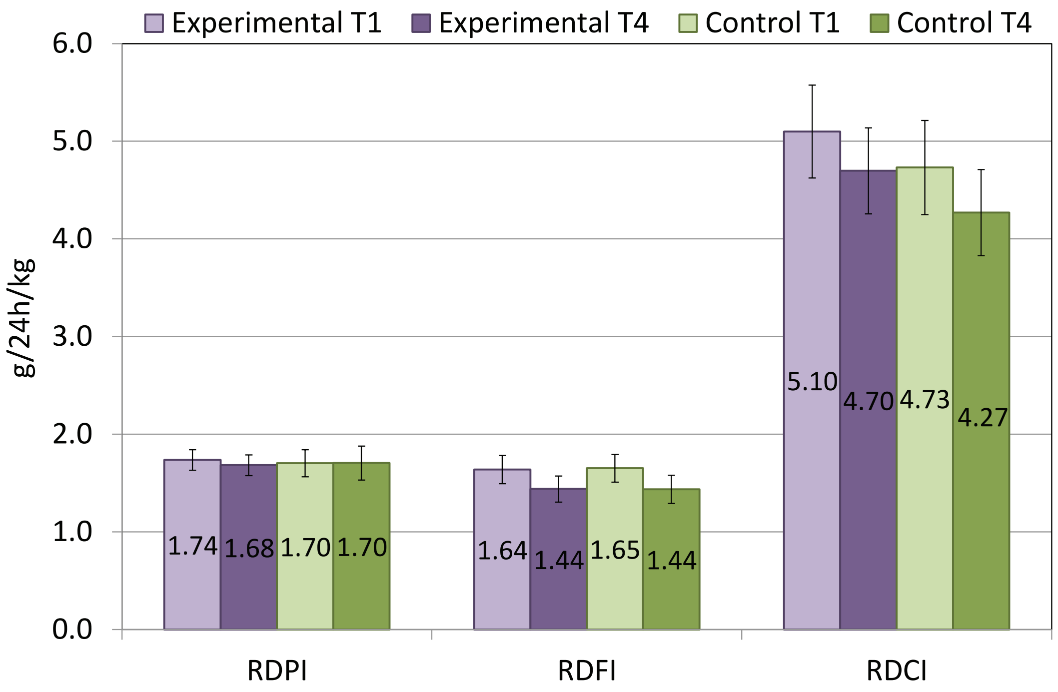

Figure 3. Relative daily protein intake (RDPI), relative daily fat intake (RDFI) and relative daily carbohydrate intake (RDCI) of the swimmers from the experimental (n=12) and the control (n=12) groups on the 1st (T1) and the 42nd (T4) days of the six-week training period.

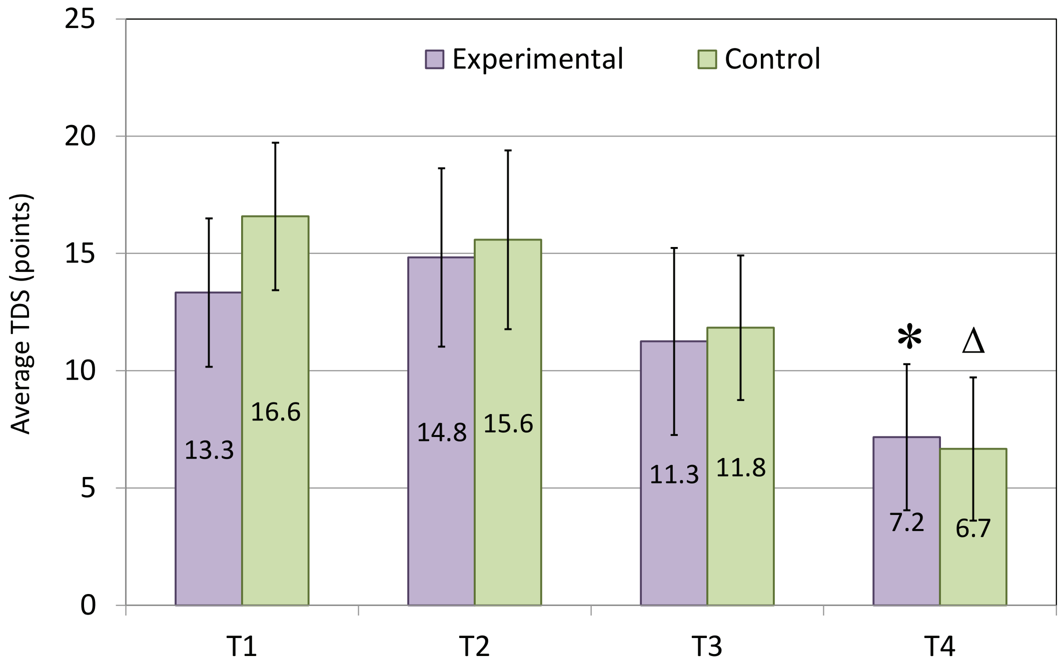

Figure 4. Training distress scores (TDS) of the swimmers from the experimental (n=12) and the control (n=12) groups on the 1st (T1), 14th (T2), 28th (T3) and 42nd (T4) days of the six-week training period. * - $p < 0.05$ vs Experimental T2; Δ - $p < 0.05$ vs Control T1 and Control T2

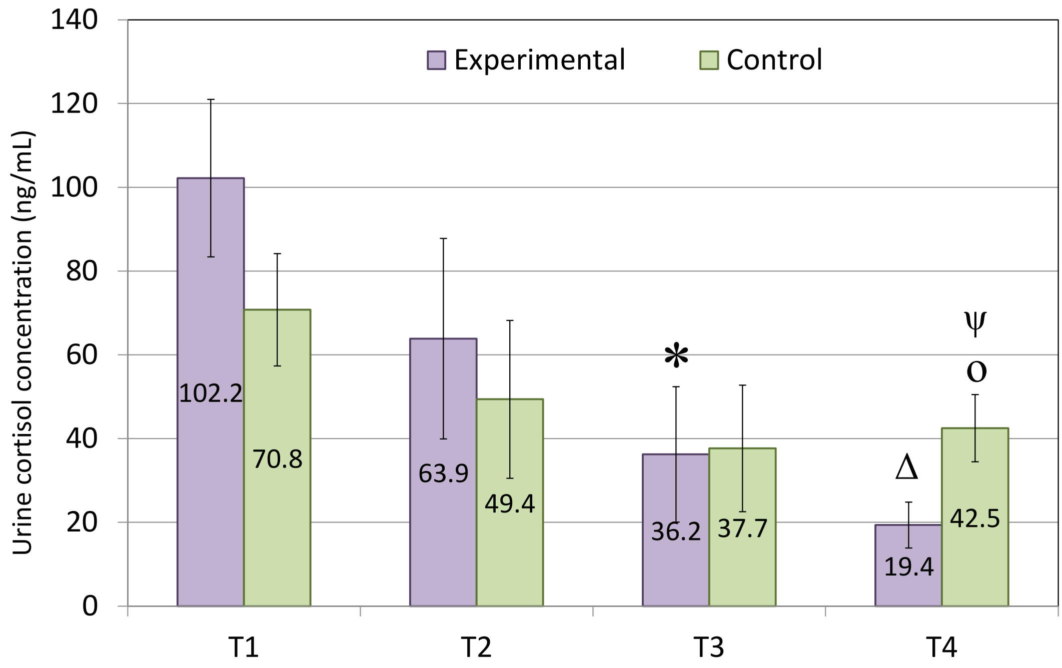

Figure 5. Dynamics of urine cortisol concentration of the swimmers from the experimental (n=12) and the control (n=12) groups on the 1st (T1), 14th (T2), 28th (T3) and 42nd (T4) days of the six-week training period. * - $p < 0.05$ vs Experimental T1; Δ - $p < 0.05$ vs Experimental T1 and T2; O - $p < 0.05$ vs Control T1; ψ - $p < 0.05$ vs Experimental T4

Table 2. Changes of competition results of the swimmers in this study.

Parameter	Experimental Group	Control Group	p
Number of swimmers	12	12	
Number of swimming competition events	43	42	
Average swimming results improvements (%)	-1. 66 ± 1.20	-0.97 ± 1.68	0.0329 a
Number of worsened swimming results	2	13	0.0004 b
Number of swimmers with worsened average results	0	4	0.014 b

a - t-test for independent samples; b - Chi-square test

Championship, which took place two weeks after the end of the study, were compared (Table 2). The swimmers from the experimental group took part in each event from both competitions (a total of 43 events), and showed an improvement in their time in 41 of them, with an average of -1.66 ± 1.20%. Moreover, none of them showed worse average results. On the contrary, the swimmers from the control group, who took part in both competitions in a total of 42 events, showed an improvement in only 29 events, with an average of -0.97 ± 1.68%, and four of the participants showed worse average results. The average improvement in performance (analysed with independent-samples t-test) and the distribution of both improved swimming results and worsened swimming results (analysed with Chi-square test), were all statistically significant in favour of the experimental group (Table 2).

Discussion

The stable anthropometric parameters, as well as the balanced nutrition consistent with the recommendations for elite swimmers, in addition to the decreased TDS scores and decreased values of cortisol and cortisone during this study, showed a very good adaptation amongst the swimmers towards the increasing training workload, with a good average recovery rate within each training week.

The greater progress in results from competitions, and the lower levels of stress hormones at the end of the study in the experimental group, suggest a positive role of the glutathione (GSH) as a supplement.

Our double-blind placebo control study supports the possibility of using glutathione supplementation in order to directly or indirectly increase the GSH levels in the body. These conclusions are in agreement with some authors who have researched the effects of GSH on experimental animals [38-40, 42], as well as other researchers who have observed an increase in plasma GSH levels in humans after an oral supplementation with a much higher dose of GSH (50 mg/kg body weight) [41] than the one in our study.

The limitation in our study was our inability to determine the plasma glutathione levels, as the ethical committee did not give permission for that. The reason for this was that some of the swimmers from our study were under the age of 18, and the number of the other participants was not sufficient to obtain reliable results.

To confirm the positive effect of glutathione supplementation and to reveal the mechanism of its action, additional biochemical studies on changes in GSH level and oxidative status in athletes with a high degree of exercise load are required.

Conclusions

The supplementation of glutathione at a dose of 250 mg per day for six weeks improves the adaptation of elite level swimmers towards training schedules, which is likely to lead to higher achievements as far as sports results are concerned.

Conflict of interests

The authors declare that there is no conflict of interests.

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ORIGINAL ARTICLE

The effects of single leg stance during daily toothbrushing on the balance skills of elderly adults

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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 was aimed to measure the effects of single-leg stance on measuring the individual postural limits and balance skills of elderly adults.

Material and Methods The present study involved a total of 360 elderly adults aged between 70 and 80 years. The participants were divided into two groups as 187 individuals in experiment group (99 women / 88 men) and 173 individuals in control (94 women / 79 men). In measuring the risk of fall and balance skills, the Functional Reach Test, Timed up and go Test, and Single Leg Stance Test were used. The participants in experiment group were asked to stand on one foot for a total of 4 minutes (2 minutes in morning and 2 minutes in evening) every day while brushing their teeth for 50 weeks. Since the data showed normal distribution, the independent samples t-test was used in determining the intergroup difference, whereas the dependent sample t-test was used in determining the intragroup pretest-posttest difference.

Results It was determined that there was a significant relationship between elderly adults' balance skills and 4-min/day single-leg stance practice ($p<0.05$). In all the tests, it was found that the balance skills of women and men have improved and men had better values in comparison to women.

Conclusions: It is thought that, via simple procedures such as lifting up one foot while brushing the teeth, the balance skills of elderly adults can be improved, the risk of fall can be reduced. They can be supported in terms of living an independent life.

Keywords: toothbrushing, elderly adults, balance, risk of fall, measurement, timing

Introduction

Aging, which is considered as a non-modifiable risk factor [1], is seen as a natural process [2]. This process is closely related with cell distribution [3]. Although developed countries used the term "elder" for the individuals aged 65 years or higher and receiving retirement salary, World Health Organization (WHO) defines the individuals turning 60 years of age as "elderly" [4]. Together with aging developing due to cell distribution, cognitive losses [1, 5], visual and hearing losses [1], degradations in the neural system and cardiovascular system, and decreases in muscular force are observed [6, 7]. These disorders negatively affect the balance by causing insufficiencies in the musculoskeletal system [8]. Together with aging causing degradation in motor development, losses are observed in endurance, strength, flexibility, and especially balance skills [5, 9]. The insufficiency of balance, which is among the motor skills, negatively affects the elderly adults' independent life and poses an important risk factor [10].

Balance plays a role in human life more important than thought [11] and is a fundamental requirement for posture and movement. Without a strong balance, it would not be possible to stand up, walk, run, or even climbing up the stairs [12]. The multilateral structure of balance caused the term "balance" to be defined in different ways in scientific disciplines such as chemistry, physics, medicine, and sports [13]. Chemistry defines balance as the temporally non-changing conditions of reacting materials [14, 15], whereas physics defines the concept of static and dynamic balance as the balance of an object or that of forces influencing the object [16]. In medicine, unlike physics and chemistry, balance is considered from physical and psychological aspects (13). Physical balance is defined as the constant condition of body in a stable or moving position, whereas psychological balance defines a mental condition characterized with emotional balance [13]. From the perspective of sports sciences, Fleishmann [17] structured the balance as static, dynamic, and object balancing. Static balance is characterized with body's return to its anatomic position after every movement [18], whereas dynamic balance refers to the protection of balance during a movement [19]. Balancing with an object refers to the effect of any object on the body for keeping the body in balance [13]. Considering the definitions provided, it is thought that balance has significant importance in human life, especially in old ages. The physiological changes brought by aging should be considered not only from the biological aspects but also from the temporal aspect. The biological changes that are not controlled by humans have 30% effect on aging, whereas the resting 70% is determined by the lifestyle of individual [20]. However, biological changes such as visual, hearing, taste, neural system, cardiovascular system, etc. having 30% effect in aging are thought to play a vital role for a healthy life by protecting the balance of body.

The prerequisite of stabilization of the balance is to have a strong sight [21]. Aging negatively affects the

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balance by causing many changes in the sight such as weakening visual capacity and perception [22].

The structural changes in the neuromuscular system decrease the reflex modulation, cause fatigue, and lead to loss of strength as a result of the decrease in muscle mass [6, 7] and, as a result of the loss of strength, the reflexes to external stimulants would not occur in coordination [23]. Moreover, together with the strength losses to occur, the postural system would need longer reaction times for compensating the loss of balance [24].

The changes in the neural system occur in forms of decrease in links between the nerve cells, a reduction in transmission and response time, a decrease in cognitive performance, and increasing fatigue [12, 25-27]. This limited performance in the neural system causes a decrease in balance, movement control, and reaction time [12, 25, 27]. The decrease in speed of the neural system lays the foundation for distortion of balance by being incapable of responding to the stimulants required for keeping the body balance [21] and it also decreases the reliability of coordination and concentration skills [28].

The changes in cardiovascular system cause hypertension, high levels of resting and exercising heart rates [12], vasoconstriction [29], and a decrease in adaptation capacity [30]. It is thought that the changes in the cardiovascular system would negatively affect the balance [12, 29].

The age-related decrease in coordinative skills occurs slower than conditional skills. It was reported that the decrease in balance skills starts at the age of early 40s and a significant decrease is reached since the age of 60 [19, 31-37] and these losses reach a remarkable level after the age of 80 [5, 9].

The performance decreases in elderliness are inevitable but regular physical activity and exercises might significantly delay the onset of balance problems and keep the balance skills at a high level [12]. Lack of exercise might cause a decrease in balance skills even at the ages of 30s or 40s; this problem may reach a higher level at the early 50s and, more importantly, this problem can be only slightly reversed through exercise after 50s [38].

Besides the age-related biological, physiological, psychological, and social changes, also the age-related changes in balance skill is thought to negatively affect the lives of elders and, together with these changes, the decrease in birth rate and increase in life expectancy might pose a problem for the balance skill. In Germany, the birth rates decreased since 2012 and the population aged 70 years and higher increased from 8 million to 12 million [39]; it can be seen that, especially because of the decrease in balance skills of individuals aged more than 70 years, rate of fall incidents increases and 53% of fall incidents occur while walking [23].

It was observed that 55% of the German population aged >70 years remain distant from exercise [40], that the elders not doing exercise constitute the majority of fall cases, and motivation and time problem come forefront as the reasons for not doing exercise [41].

Hypothesis: Standing on one foot for only 4 minutes a day while brushing teeth without making extra effort would improve the balance skills of elders and decrease the risk of fall.

Objective: In literature, there is no study examining to what extent standing on one foot for 4 minutes while brushing the teeth affects the balance. Based on this idea, it is aimed to bridge the gap in literature regarding the effects of single-leg stance for 4 minutes during tooth brushing on the balance skills of elderly adults and to examine the risk of fall.

Material and methods

Participants.

The present study involved a total of 360 elderly adults divided into two groups as 187 individuals in experiment group (99 women /88 men) and 173 individuals in control (94 women/79 men). The participants in experiment and control groups were randomly selected among the individuals registered in Rehabilitation Sports Program in Germany TV Eberbach Rehabilitation Sports Unit.

The individuals having dizziness, severe balance problem, bone loss, stroke, concurrently participating in another sportive test, having physical disorder preventing the independent movement capacity, having amputation history, and showing symptoms preventing single-leg stance were not involved in the study.

Data collection was performed in accordance with the provisions of "Federal Data Protection Law (Bundesdatenschutzgesetz)" (BDSG). The required approvals were obtained from relevant federation and Germany TV Eberbach e.V. Rehabilitation Sports Department (TVE/GS 2018-012900). The involvement is based on the principle of voluntariness. The participants were informed about the objective, content, and data protection of the study and their written consents were obtained.

Research Design

Activity Protocols: The period of 50 weeks was determined in accordance with the receipts prescribed by the physicians and the participation in the program was followed using a signature list. Pretest and posttest were used in determining and comparing the improvements in balance skills.

In determining the comparison groups, significant attention was paid to ensure achieve groups as homogeneous as possible in terms of age and fitness. None of the participants have done performance sports or active for a long time.

In experiment group, the participants were asked to stand on one foot during tooth brushing (2 minutes in morning and 2 minutes in evening) for 50 weeks. The 4-minute period was divided into 8 30-second parts. During 2-min tooth brushing in morning, the participants were asked to keep their eyes open and stand on their dominant leg for 30 seconds, then change the leg, and then repeat the process with their eyes closed. The same practice was repeated while brushing their teeth in evening.

Considering the risk of fall, the participants were asked to perform the eyes-closed process by getting support and, when needed, pass the eyes-closed process and perform the eyes-open one. In order to increase the motivation of participants, a follow-up table or label to be attached to the mirror while brushing the teeth was prepared. The participants were asked to mark the table after every tooth brushing and single leg stance procedure. In order to support participants to not forget the practice, a warning "open/close eye and lift up the leg" was added to the label. In order to prevent an effect on the results, the participants were asked to avoid standing on one foot except for the 4-min tooth brushing practices if possible and to continue their normal daily activities.

Control group received no special program and they maintained their normal daily lives.

Weight/height measurements: The measurements were performed using Seca 769 digital body weight/height measurement device automatically calculating body height, weight, and BMI values.

Data Collection Tools**:** In the present study, the static and dynamic balance skills were measured using Functional Reach Test [42], Timed up and go Test [43], and Single Leg Stance Tests. The data were collected between May 2018 and June 2020. Before the test, each test item was demonstrated in practice and attention was paid that participants were not tired.

Functional Reach Test (FRT): Developed by Pamela W. Duncan, an American researcher, in year 1990, FRT is a motoric function test used for measuring the personal posture limits in daily life (42) and this test is used while measuring the risk of fall due to the lack of balance. In determining the balance problems in elderly adults, it is a very easy, rapid, and practical single-item dynamic balance test scored with simple norm values. The subject stands upright nearby a wall while keeping legs at shoulder width and single arm extended at the shoulder height. The subject should be as close to the wall as possible without touching it. The extended hand is kept in fist form and the subject is asked to extend his fist as further as possible without losing balance. The distance reached is measured using a ruler from the upper bone of the middle finger. In order to achieve the maximum extension, the feet should be level on the floor, no step must be taken, and the hand should be kept at the level of ruler without touching the wall. In order not to influence the test result, turning the body is not allowed. The distances shorter than 15.2 cm refer to high risk of fall, whereas the distances between 15.2 and 25.4 cm refer to moderate risk, and the distances longer than 25.4 cm refer to a low risk of fall [44].

Weiner et al. [45] reported that individuals having extension lengths more than 25 cm have low risk of fall, and this risk increased by two folds for those with extension length of 15–25 cm and four folds for those having extension length of 5–15 cm, whereas those having 0 cm extension length have eight times higher risk. The longer the length is, the lower the risk of fall is [42]. The distance shorter than 17.5 cm refers to a limitation of movement and it is at a level that would negatively affect the daily life activities [42]. Every participant was given three chances and the best score was considered. For the individuals with risk of fall, cross belts were attached at the shoulder and back positions and interventions were made by pulling backwards in cases of any risk.

Timed up and go Test (TUG): Developed in 1986 [46] with the name of "Get up and Go", this test was modified by Podsiadlo and Richardson [43] as "Timed up and go" test.

Used in determining the mobility, body balance, and risk of fall occurring consequently, TUG can be applied easily and fast without need for any special instrument of field information. The subject is sat on a chair, which has approx. 46 cm of height, leaning back. Without any external help, the subject stands up, walks 3m distance, and comes and sits back again [47]. The duration of this process is recorded. Podsiadlo and Richardson [43] recommend making evaluations considering the following points.

- Duration shorter than 10 seconds: Elderly adults have unlimited mobility and they can independently move,
- 11 – 20 seconds: Elderly adults have a very slight limitation of movement,
- 20 – 29 seconds: Elderly adults have limitation of balance, walking, and function, support might be needed,
- Longer than 30 seconds: There is a significant movement disorder and intense support and care are needed [43].

A 46 cm-high chair has been used in the original test. However, considering the differences between participants' heights and in order to ensure the standards for each participant, a chair with adjustable height was used in order to obtain 90° angle between upper and lower legs in sitting position. In order to prevent slides, the chair was fixed on the floor and the test procedure was conducted with shoes on. Each participant was given a single chance and the time was measured using chronometer. When the test couldn't be understood or when there is an obvious problem (such as released shoelaces), the test was repeated. The measurement was started when the back left the backrest unit and ended when the hips contacted the chair.

Single Leg Stance Test (SLST): In addition to the tests performed, a single leg stance test was conducted with participants with eyes open and closed. Single leg stance has been implemented in many studies and has no standard. In the present study, both legs were separately tested with eyes open and closed. The studies have been carried out determining different durations such as 5 seconds [48], 10 seconds [49], 15 seconds [50], 20 seconds [51], 25 seconds [52], 30 seconds [53], 45 seconds [54], and the longest duration possible [55]. However, the test procedure remained similar in tests. The subject wearing no shoe lifts one leg on a hard floor and stands in that position for the requested time. The result is recorded as success or failure. In the present study, no second limitation was applied and the duration of keeping the position was recorded in seconds. The participant started the test with the leg they desired. The test was ended when the foot was lifted or moved. Every participant was given a single chance and the time was recorded using chronometer.

The tests were performed in the order of FRT, TUG, and then SLST. Test items were applied separately for every participant. One week before the test, the participants were asked to participate in the application with no fatigue, if possible. In order to minimize the errors, the participants were informed about each test item in practice, necessary explanations were made, and the questions of participants were answered. All the tests were performed without warming up or practicing.

Statistical Analysis

The data analyses (IBM SPSS 26-for Mac) were performed using descriptive statistical analysis (mean, standard deviation, minimum, and maximum) in order to define the characteristics of the study group. The skewness-kurtosis values were used in order to determine if the data were normally distributed. Since the normality test (Skewness-Kurtosis) yielded a result between -2 and +2 [56], the data distribution was accepted to be normal and the difference between experiment and control groups was analysed using independent sample Student-t test, whereas dependent sample Student-t test was used in examining the intragroup pretest-posttest difference. The statistical significance was set at $p<0.05$ for the comparisons.

Results

The study involved a total of 360 elderly adults aged between 70 and 80 years, 187 individuals (99 women/88 men) in experiment group and 173 individuals (94 women/79 men) in control group. Of the participating elderly adults, weight, height, age, and Body Mass Index (BMI) are presented in Table 1as mean/standard deviation and minimum and maximum values.

Given the values in Table 1, it can be seen that, in experiment group, the mean age and height values of women were higher than men, whereas women have lower mean weight and BMI values. In control group, men had higher mean body height and weight values and lower mean age and BMI.

The mean values and standard deviations obtained from intragroup pretests and posttests in experiment and control groups are presented in Table 2. According to the statistical analysis of intragroup comparisons in experiment group, in which the 4 min/day (2 minutes in morning and 2 minutes in evening) single leg stance practice was applied while brushing teeth at home for 50 weeks, no statistically significant difference was observed in *TUG* test among women in experiment group ($p>0.05$), it was determined that there were statistically significant differences in pretest-posttest comparisons in all the remaining tests *(FRT, eyes open right leg, eyes open left leg, eyes closed right leg, eyes closed left leg)* ($p<0.05$).

According to the pretest and posttest results, there was a statistically significant difference in *eyes open right leg* test in control group (p=.038), whereas there was no statistically significant difference in *FRT, TUG, eyes open left leg, eyes open left leg, eyes closed right leg, and eyes closed left leg* tests ($p>0.05$).

In Table 3, there are the independent sample t-test mean values and standard deviations obtained from pretest and posttests in experiment and control groups. The results suggested that there was no statistically significant difference between women and men in experiment and control groups in all the pretests ($p>0.05$), whereas there was a statistically significant difference in *TUG* posttest among women ($p<0.05$).

It was determined that there was no significant difference between men in *TUG* (p=.059*)* and *eyes open left leg* (p=.056) posttests, whereas there were statistically significant differences between the groups in *FRT, eyes open right leg, eye open left leg,* and *eyes closed right leg* tests ($p<0.05$).

In general, it was determined that the balance skills of women and men developed in all the tests and men had higher scores than women.

Table 1. Mean, standard deviation, minimum, and maximum height, weight, age, and BMI values of participants in experiment and control groups

		Experiment Group (Women n=99, Men n88)			Control Group (Women n=94, Men n=79)		
Items	**Gender**	**Mean±SD**	**Min**	**Max**	**Mean±SD**	**Min**	**Max**
Age (years)	Women	75.6±3.00	70.0	80.0	75.2±2.12	70.0	80.0
	Men	73.9±2.93	70.0	80.0	74.3±3.36	70.0	80.0
Height (cm)	Women	165.9±6.34	156.0	178.0	165.2±8.22	151.0	190.0
	Men	175±7.30	159.0	190.0	173.4±9.63	157.0	193.0
Weight (kg)	Women	72.6±8.68	58.00	98.0	73.6±11.1	55.0	106.0
	Men	76.7±6.42	66.00	96.0	75.4±9.27	58.0	94.0
VKI (kg/m^2)	Women	26.3±2.24	22.10	33.1	27.1±4.12	22.5	40.1
	Men	25.0±1.79	21.9	31.2	25.1±3.20	21.34	34.8

SD: standard deviation, BMI: Body mass index (weight/height^2), Min: Minimum, Max: Maximum

Table 2. Pretest and posttest results of experiment and control groups in FRT, TUG, eyes open right leg, eyes open left leg, eyes closed right leg, eyes closed left leg (Paired Sample t-Test)

Items	Gender	Experiment Group (n=187)				Control Group (n=173)			
		pretest	posttest			pretest	posttest		
		Mean±SD	Mean±SD	t	p	Mean±SD	Mean±SD	t	p
FRT (cm)	Women	20.0±4.21	23.4±3.44	-8.02	.000**	19.7±3.78	20.1±3.63	-1.69	.094
	Men	25.9±2.85	29.7±3.35	-8.86	.000**	26.3±3.02	25.9±2.85	1.97	.052
TUG (s)	Women	14.1±1.89	13.6±2.10	1.67	.097	14.3±1.92	14.2±2.26	.461	.646
	Men	12.8±2.28	12.1±2.43	2.64	.010*	12.6±2.19	12.8±2.43	-1.15	.251
Eyes open right leg (s)	Women	14.3±2.45	19.5±4.98	-9.25	.000**	13.9±2.24	14.5±3.63	-2.10	.038*
	Men	19.1±5.49	26.9±6.76	-8.34	.000**	19.8±5.28	20.1±5.11	-1.72	.089
Eyes open left leg (s)	Women	8.29±2.09	11.3±2.72	-10.1	.000**	8.45±2.13	8.34±2.11	.491	.624
	Men	10.2±3.24	12.3±2.69	-6.11	.000**	9.91±3.33	10.1±2.96	-1.06	.292
Eyes closed right leg (s)	Women	3.35±1.28	4.62±1.70	-5.47	.000**	3.22±1.40	3.12±1.40	1.57	.118
	Men	4.20±1.69	7.43±2.52	-11.7	.000**	4.43±1.63	4.50±1.73	-.668	.495
Eyes closed left leg (s)	Women	1.96±1.04	3.41±1.96	-6.57	.000**	2.15±1.11	2.08±1.08	.943	.348
	Men	4.02±1.87	4.65±2.02	-2.64	.10*	4.22±1.78	4.08±1.77	1.65	.101

*p<0.05, **p<0.001, SD: standard deviation, FRT: Functional Reach Test, TUG: Timed Up & Go test

Table 3. Independent sample t-test results of pretest and posttest in experiment and control groups (Women-Men)

Items	Gender	Test	Experiment Group Women n=99 Men n=88	Control Group Women n=94 Men n=79		
			Mean±SD	Mean±SD	t	p
FRT (cm)	Women	pretest	20.0±4.21	19.7±3.78	.421	.674
		posttest	23.4±3.44	20.1±3.63	6.55	.000
	Men	pretest	25.9±2.85	26.3±3.02	-.931	.353
		posttest	29.7±3.35	25.9±2.85	7.92	.000
TUG (s)	Women	pretest	14.1±1.89	14.3±1.92	-.837	.403
		posttest	13.6±2.1	14.2±2.26	-1.80	.073
	Men	pretest	12.8±2.28	12.6±2.19	.663	.508
		posttest	12.1±2.47	12.8±2.43	-1.90	.059
Eyes open right leg (s)	Women	pretest	14.3±2.45	13.9±2.24	1.04	.296
		posttest	19.5±4.98	14.5±3.63	7.87	.000
	Men	pretest	19.15±5.49	19.8±5.28	-.854	.394
		posttest	26.9±6.76	20.1±5.11	7.30	.000
Eyes open left leg (s)	Women	pretest	8.29±2.09	8.45±2.13	-.540	.590
		posttest	11.3±2.72	8.34±2.11	8.41	.000
	Men	pretest	10.2±3.24	9.91±3.33	.687	.493
		posttest	12.1±2.69	10.1±2.96	4.55	.000
Eyes closed right leg (s)	Women	pretest	3.35±1.28	3.22±1.40	.670	.503
		posttest	4.62±1.70	3.12±1.40	6.63	.000
	Men	pretest	4.20±1.69	4.43±1.63	-.873	.384
		posttest	7.43±2.52	4.50±1.73	8.64	.000
Eyes closed left leg (s)	Women	pretest	1.96±1.04	2.15±1.04	-1.22	.222
		posttest	3.41±1.96	2.08±1.08	5.77	.000
	Men	pretest	4.02±1.87	4.22±1.78	-.721	.472
		posttest	4.65±2.02	4.08±1.77	1.92	.056

*p<0.05, **p<0.001, SD: standard deviation, FRT: Functional Reach Test, TUG: Timed Up & Go test

Discussion

In general, the lower level of body oscillation is related to a high level of postural control [57]. By applying the accurate tests, this association can be analyzed at the highest level and, by determining how a program should be prepared, it might be useful in reducing the health risks [58, 59]. It was reported that the balance skill decreases with advancing age [12] and the static balance level of an elderly adult at 60-70 years of age equals to a 10-year-old child [19], it should be considered that the difficulty of the test applied to determine the balance skills of elderly adults might positively or negatively affect the results [20, 6]. When compared to other motor skills, the balance skill can be trained faster [60] and it might be advantageous if the practices performed during balance training are in form of non-tiring exercise for elderly adults [20, 55]. It was stated that the reduction in balance skill depending on the motor skills degrading with advancing age might be compensated via regularly performed balance exercises [12, 19, 20, 61, 62]. In the present study, it is found that a simple exercise by standing on one leg for 4 minutes a day while brushing the teeth for 50 weeks positively contributes to the balance skills of elderly adults aged between 70 and 80 years.

In their studies, Aksay [20], Belurosova [63], Espenschade and Eckert [64], Heidemann [55], Rikli and Edwards [65] and Wydra [50], reported that coordination exercises yielded very good results in terms of improving the balance skills and these results are similar to those reported in the present study.

In their study, Weiner et al. [45] examined the elderly men's risk of fall by using *FRT* and they reported that those reaching forward by 25 cm have a low risk of fall. The results obtained showed that men can reach forward by 29.7 cm and this finding indicates that they have a low risk of fall.

Duncan et al. [66] reported that the longer the distance covered in *FRT* test is, the lower the risk of fall is and that the values lower than 17.5 cm negatively affect the mobility and daily life activities. The FRT scores obtained in the present study were higher than 17.5 and it can be interpreted that the mobility and daily life activities of participating elderly adults are not negatively affected. Similarly, Rookwood et al. [67] carried out a study on a group with a mean age of 78.1 years and they reported similar results by determining the FRT score to be 29 cm. However, in their study on a group with a mean age of 81.4 years, Thomas and Lane [68] reported the FRT scores to vary between 15.5 and 19.4 cm a, which were lower than the results obtained in the present study.

There are remarkable differences between the TUG results reported in previous studies. Rookwood et al. [67] reported 12 seconds for a group with a mean age of 78.1 years, whereas Thomas and Lane [68] reported a time of 29 seconds for a group with a mean age of 81.4 years. The results obtained in the present study were in parallel with those reported by Rookwood et al. [67] and lower than the results reported by Thomas and Lane [68].

It can be stated that different durations were applied in assessing the single-leg-stance test in literature. It can be seen that, in the previous studies, the assessments were performed over 30 seconds and it was reported that elderly adults with single leg stance duration longer than 30 seconds have higher balance capacity and lower risk of fall [54, 69, 70] and this rate is higher among elderly individuals aged older than 70 years [71]. Lower values of single leg stance were obtained in the present study in comparison to the previous studies.

However, in their study carried out on 316 subjects, Vellas et al. [48] took 5-sec as a basis and they reported that 267 subjects could stand on one leg for 5 seconds unassisted, whereas 49 subjects could less than 5 seconds and showed that they have a higher risk of fall [48]. The data obtained from the present study were higher than those reported by Vellas et al. [48] and it can be assumed that the participating elderly adults have a low risk of fall.

Similarly, in their study carried out with 482 elderly adults with a mean age of 74 years and having a risk of fall, Vellas et al. [72] reported that single leg stance exercises can positively contribute to the balance skills of elderly adults and they reported results that are similar to the results reported in the present study.

In their studies, Bohannon et al. [70] and Verma et al. [73] reported that there was no difference between right leg and left leg. However, in the present study differing from the previous ones, it was determined in the posttests of experiment group that women's score in *eyes open right leg* was 7 seconds higher than *eyes open left leg* and the difference was 14 seconds for men.

In the present study, it was observed in the single leg tests that the participants had lack of confidence and this lack of confidence was, as expected, at a higher level in *eyes-closed* practices. Woollacott and Jensen [37] reported that, when compared to young individuals, elderly adults had a slower transmission of sensorial information in the eyes-closed exercises and, thus, the balance performance decreased with increasing lack of confidence. Similarly, Bernstein [74] pointed out that the optic analyzers become more important as the age advances, while Meusel [12] emphasized that the balance performance of elderly adults significantly decreased when visual control was shot down and, from this aspect, the risk of fall increased at low light or at darkness. In tests performed with eyes closed, Verma et al. [73] obtained lower scores when compared to the tests performed with eyes open. The results obtained in the present study show that, in parallel with the results reported in previous studies, the values obtained from the exercises performed with eyes closed were lower.

Conclusion

In conclusion, implementing target-oriented simple practices to be performed on regular basis was found to have a statistically significant relationship with balance skill improvements of elderly adults. Besides that, undoubtedly, the uncertainties in balance increase with advancing age and, consequently the risk of fall increases. Based on the data obtained, it can be assumed that, by making use of simple exercises in daily life such as lifting one leg while brushing the teeth, the balance skills of elderly adults can be improved without making an extra effort, the risk of fall can be reduced, and they can be assisted for an independent life. For this reason, the balance training to be added to the exercise program of elderly adults should be considered as an integral part of the program.

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ORIGINAL ARTICLE

Combined impact method in the preparatory period of the annual macrocycle of female volleyball players aged 18–19 years old

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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 work aim is to develop and experimentally test the combined impact method performance in the preparatory period of the annual macrocycle of 18–19 year old volleyball players (girls).

Material and Methods The study involved volleyball players (girls) aged 18–19 years old (n = 24, training experience – 9 years). Volleyball players (girls) were divided into control (n = 12) and experimental (n = 12) groups.

Results The method contributed to a higher rate of growth of most parameters of special readiness among volleyball players (girls) of the experimental group. A significant improvement in special readiness ($p < 0.05$) was revealed for all parameters in both groups. In the experimental group, an improvement ($p < 0.001$) was observed for 8 out of 11 parameters. In the control group, a significant improvement in the results ($p < 0.001$) occurred in 3 cases out of 11. A significant improvement in speed and strength training parameters ($p < 0.001$) was revealed: in 3 out of 4 cases (experimental group); in 1 out of 4 cases (control group). The quality of performance of the game basic techniques improved by: 4–22% ($p < 0.04$–0.001 in experimental group) 4–11% ($p < 0.05$–0.02 in control group).

Conclusions: It is advisable to devote more time to the development of more significant motor abilities of volleyball players (girls) (speed, speed and strength, dexterity and coordination). It is advisable to improve endurance in combination with the development of other motor abilities and in the process of technical and tactical improvement. In the physical training of volleyball players (girls), it is advisable to use as many training means as possible, which are similar to the main game techniques according to spatio–temporal and dynamic characteristics. Movements with load contribute to the development of intermuscular coordination and allow to quickly form the correct idea of the trained motor action.

Keywords: female volleyball players, method, abilities, macrocycle, training.

Introduction

Modern elite sport makes more and more stringent demands on athletes. The success of training athletes in modern conditions depends on the effectiveness of organization, management and control methods.

The level of sports achievements in volleyball depends on the technical, physical, psychological and tactical readiness of the athlete. To demonstrate high sports results, it is important to achieve a certain level of development of these sides of readiness and ensure their integral manifestation in the process of competitive activity [1, 2].

Technical training is one of the main sections of athletes training in volleyball. The process of technical improvement is associated with exceptional difficulties. This is especially true for the stage of preparation for higher achievements. The first is the need to constantly improve the technique and constantly bring it in line with the level of physical, tactical and psychological readiness. This complex interaction of different sides of an athlete's motor readiness is reflected in the process of forming and improving motor skills of volleyball players (girls) [3, 4].

Kumar et al. [5] believe that at the present stage of development of sports games, the correct athletes training process design at the stage of preparation for higher achievements (age 17–19 years) is of great importance. At this stage, the share of special training means in the total volume of training work significantly increases. Competitive practice focused on achieving high results, is sharply increasing. The training process is characterized by the widespread use of means that can cause a stormy course of adaptation processes. It is fundamentally important that the period of the athlete's maximum predisposition to achieve high results coincides with the period of the most intense training loads [6-9].

The preparatory period in volleyball is a long–term structural unit of the training macrocycle. This is where the functional base is laid, which is necessary to cope with large volumes of special loads. These loads are aimed at direct preparation of the motor and vegetative spheres of the body for effective competitive activity. Such loads help to improve motor skills, develop physical qualities, and tactical and psychological preparation. Various tasks of special training are solved during the entire preparatory period. This approach ensures the successful performance

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of the athlete in important competitions [2, 9, 10].

The modern training of volleyball players (girls) in the preparatory period is based on the material of exercises that create physical, mental and technical prerequisites for further special training. Exercises in nature and structure can differ significantly from competitive ones. The main task at this stage is the wide use of a variety of auxiliary and special preparatory exercises. During the preparatory period, the ratio of training means of various predominant orientation is systematically changing. At the beginning of the period, the main content of the training process is made up of fundamental (basic) exercises. Gradually, the ratio changes towards an increase in the proportion of special preparatory and competitive exercises [11, 12]. The preparatory period is divided into two stages: general preparatory and special preparatory. The ratio of the duration of these stages largely depends on the type of macrocycle and the qualifications of athletes. In the process of training highly qualified athletes, a relatively short general preparatory stage and a long special preparatory stage are usually planned. For athletes with low qualifications, the opposite ratio is reported [13, 14].

Zaciorskij and Kraemar [15] point to a direct connection between physical (functional) and technical–tactical readiness of volleyball players (girls). Physical training of a volleyball player shall create the level of motor qualities required for the formation of effective technique and tactics. It shall also ensure their development on a wide range of skills and abilities that are characteristic of this sport. This will allow to organically link physical fitness with motor memory. This approach contributes to the creation of the basis for the manifestation of physical qualities in a variety of motor actions that are characteristic of competitive activity in volleyball. The wider the circle of special exercises and motional actions, the more favourable the preconditions for the formation of new forms of motional activity and the improvement of those trained earlier. The combination of the processes of physical and technical training ensures the organic relationship between the sports technique and the motor qualities of volleyball players (girls) [16-18].

The method of combined impact is based on the systematic use of traditional exercises, methods and techniques in conjunction with non–traditional means – training devices and simulators [19]. This method is used in the context of sequential (physical exercises create preconditions for further development of physical qualities and mastering motor skills) and parallel (exercises simultaneously affect various components of psychomotor, conditioning and coordination abilities) impact on the physical and technical readiness of athletes [20].

Research analysis indicates the need to apply the method of combined impact in the preparatory period of the training macrocycle of 18–19 year old volleyball players (girls). This approach is a required condition for increasing the effectiveness of the competitive activity of volleyball players (girls). This determines the practical and scientific relevance of the study problem.

Hypothesis. It is assumed that the introduction of the developed methods of combined actions into the training process of volleyball players (girls) of 18–19 years old will significantly increase the level of their special preparedness and the effectiveness of competitive activity.

Study aim is to develop and experimentally test the effectiveness of the methods of combined actions in the preparatory period of the training macrocycle of 18–19 year old volleyball players (girls).

Material and Methods

Participants. The experiment involved volleyball players (girls) aged 18–19 years old (n = 24, training experience – 9 years). Volleyball players (girls) were divided into control (n = 12) and experimental (n = 12) groups. The created groups were identical in terms of physical fitness and technical and tactical skills. All volleyball players (girls) provided their written consent to participate in the experiment. The study protocol was approved by the ethical committee of Ivano–Frankivsk National Technical University of Oil and Gas (Ukraine) (No. 03621 dated 03.03.2021).

Study organization. The pedagogical experiment lasted 4 months. To determine the level of physical and technical readiness of volleyball players (girls), motor tests were used [21]. Testing was carried out at the beginning and at the end of the experiment. In the study course, the level of development of speed, speed–strength abilities, special endurance, dexterity and coordination was determined:

Test 1: "92 m running with changing direction";
Test 2: "9–3–6–3–9 m running";
Test 3: "Standing long jump";
Test 4: "Standing vertical jump";
Test 5: "Running vertical jump";
Test 6: "Finger–tip push–up for 10" (s)";
Test 7: "1 Kg Overhead Medicine Ball Throw (MBT)".

To determine the level of technical and tactical readiness of volleyball players (girls), the following parameters were used:

Test 1 (fig. 1): Exercises for overhead passes with two hands from against the wall (the athlete stands with her face and then with her back to the wall). At a height of 4 m, a control line is made on the wall. The athlete is positioned at a distance of 3 m from the wall. When performing the exercise, she shall strive to maintain the distance from the wall and the pass height. The athlete consistently passes the ball that bounces off the wall. The exercise sequence:

– Athlete throws the ball overhead to the wall;
– Athlete passes the ball overhead;
– Athlete returns 180º (with her back to the wall) and passes the ball into the wall;
– Athlete returns 180º and passes the ball into the wall (with her face to wall).

This sequence of passing the ball is one series. The maximum number of series is taken into account [22, 23].

Test 2 (fig. 2): Tests for the ball pass accuracy. Each player has 5 attempts. She shall serve the ball to a specific area of the court. These sites are as follows:

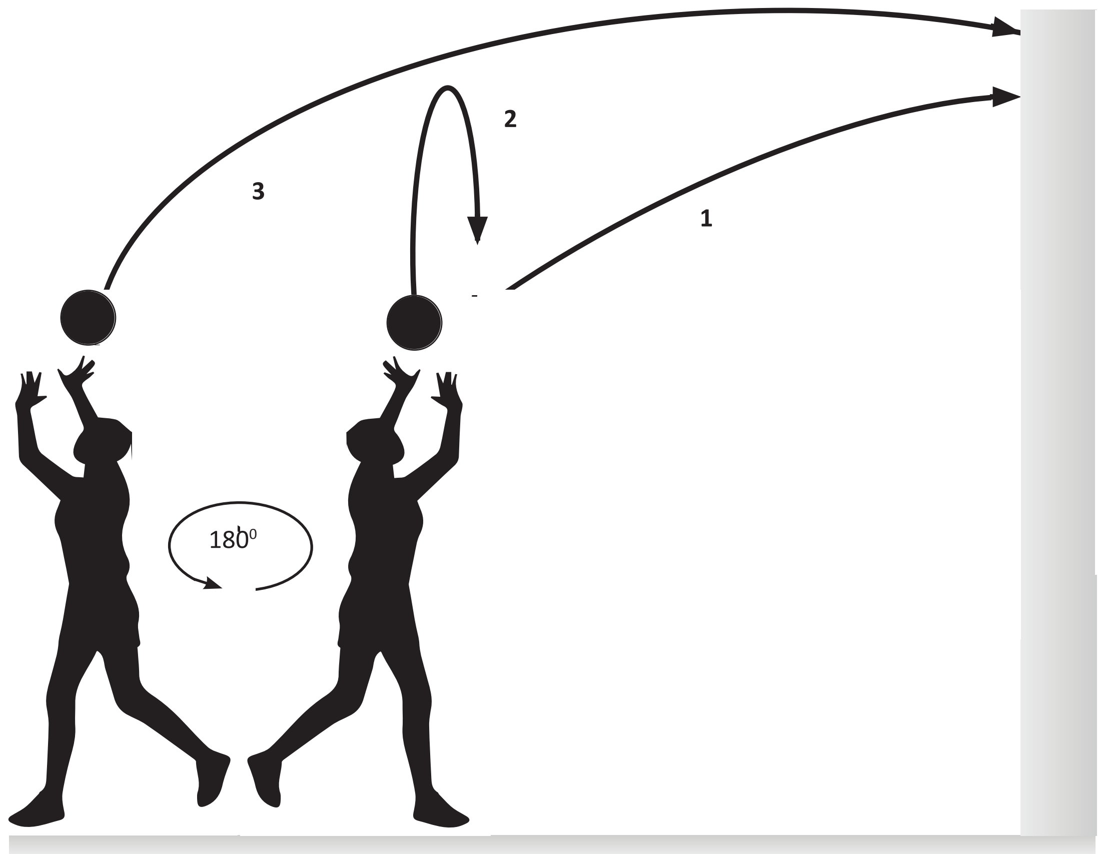

Fig. 1. Scheme of the test "Ball passing against the wall with two hands overhead"

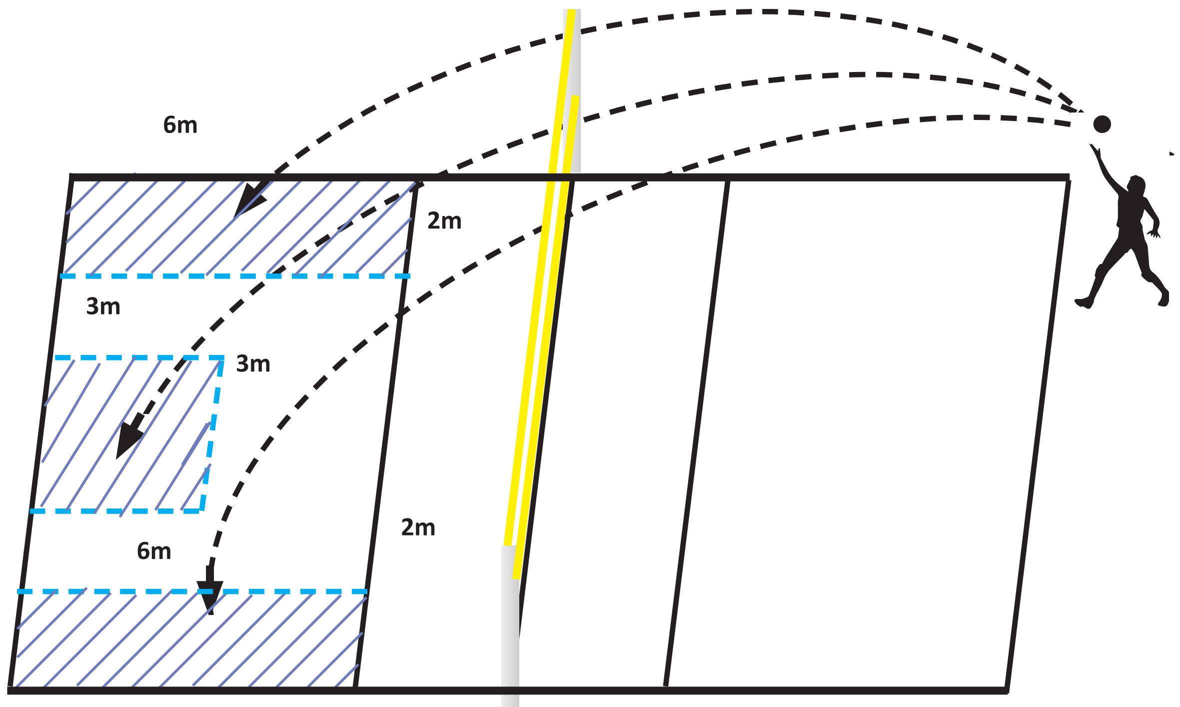

Fig. 2. Scheme of the Ball Serving Accuracy Test

– right/left half of the court, zones 4–5 (1–2);
– area at the side lines in zones 5–4 (1–2); dimensions 6x2 m;
– area in zone 6 at the front line; dimensions 3x3 m.

Test 3 (fig. 3): Spike accuracy tests. The requirements in this test are reduced to the quality (technically correct) performance of the spike. In this case, the ball shall be sent with a certain accuracy. During spikes from zone 4 to zones 4 – 5, the hit area is limited by: front, side lines, attack line at a distance of 3 m from the side line. During strikes from zone 4 to zone 1, the hit area is limited by the side line and a line parallel to it at a distance of 2 m. Athletes can use the same scheme to execute a spike from zone 2. Each player has 5 attempts.

Test 4 (fig. 4): First pass (ball reception) accuracy test. The tests are intended to determine the degree of the skill of receiving the ball after serving. A serve is made to the area where the athlete is located (only under this

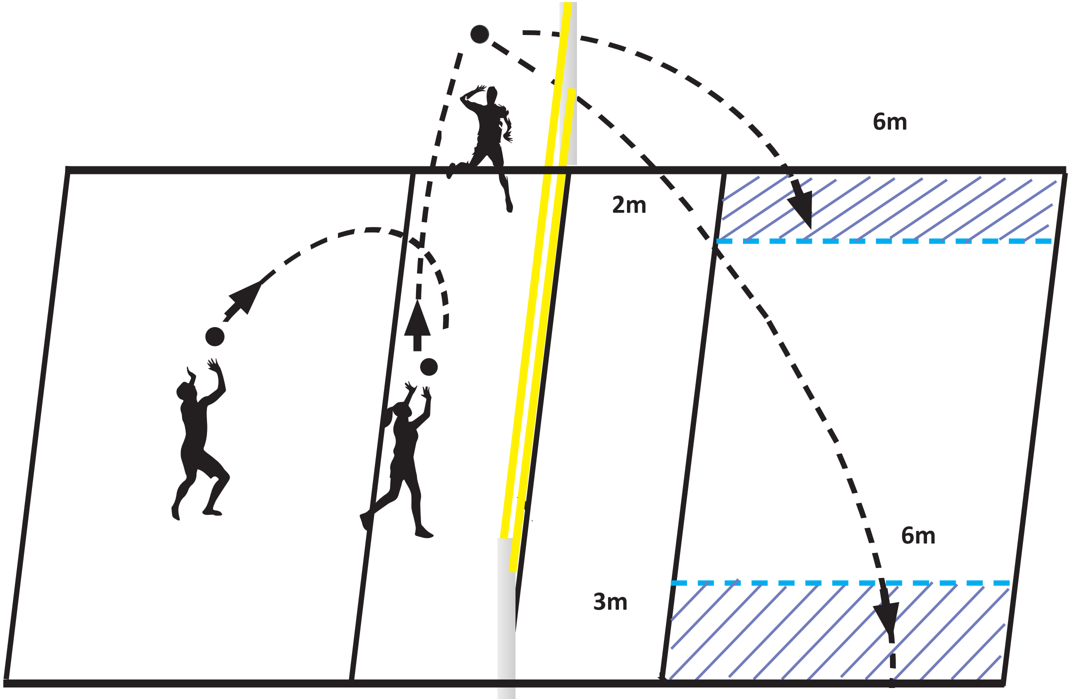

Fig. 3. Scheme of the Spike Accuracy Test

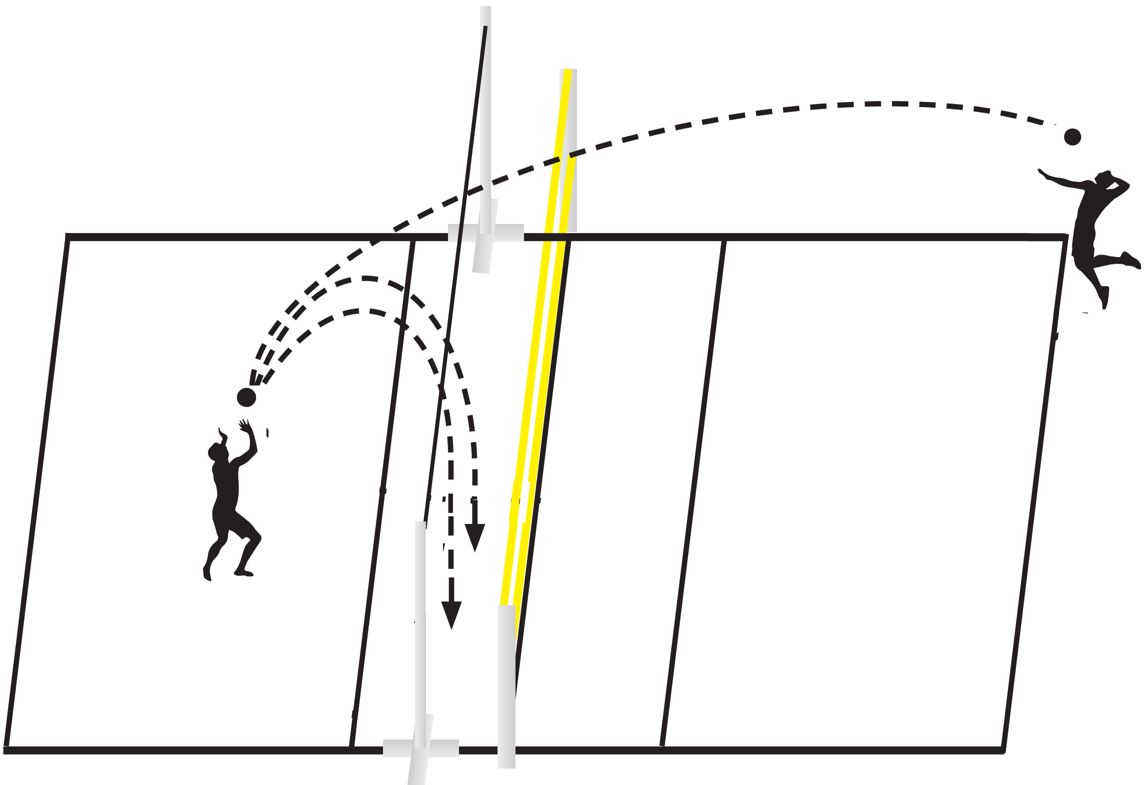

Fig. 4. Scheme of the test “Accuracy of Ball Receiving After Serving”

condition, attempts are counted). The athlete receives the ball in zone 6 (5): the athlete shall direct the ball over the tape into zone 3 or 2. The tape is located at a distance of 1.5 m from the net and at a height of 3 m. If the ball goes outside the specified area or hits the net, then such an attempt is not counted.

The control and experimental groups trained 6 times a week for 2–2.5 hours. The content of the sessions and training loads were similar in both groups. The only exception was the method of applying combined actions, which was based on the individualization of local difficulties. In the control group, the improvement of motor abilities and technical–tactical readiness was carried out in the traditional way [19]. In the experimental group, a program of special exercises was applied. These exercises were similar in structure to the main athletic movements. The exercises fully corresponded to the regime of muscular efforts in the main phases of the motor action. Initially, these exercises were performed with great difficulty and at a slow pace. Gradually, the pace increased, and the magnitude of the difficulties decreased. At the end of such a series, the athlete received tasks: to perform a special exercise in light conditions faster and more powerfully than she performs a competitive exercise. This procedure contributed to a positive transfer of training from an auxiliary special exercise to a competitive one [24].

To develop static strength and strengthen the ligamentous–articular apparatus in the experimental group, static exercises were widely used. At the same time, the position of the body and its parts were as close as possible to those encountered in competitive activity. Also, in the training process of volleyball players (girls) of this group, the method of combined–sequential loads with different prevailing orientation of the training action were applied [25]. At the same time, the previous loads created a morpho–functional basis for the effective impact on the athlete's body of the following loads. To develop the maximum speed of movement during the spike, weight was used that did not exceed 20% of the maximum. The attention of the players was focused on the maximum movement speed. During the performance of the test for the speed of a complex reaction, adhere to the following: movements of the athletes shall exactly correspond to the competitive movements in form and muscle coordination. The athletes' attention was focused on a very abrupt onset of effort in response to a visual signal.

During the movement speed development, the fact that all its manifestations (time of a simple and complex motor reaction, individual movement speed, movements tempo) were not related to each other, was taken into account. Particular attention was paid to the development of the individual movement speed, since effective defensive play is based on it. For the local development of speed strength of individual muscle groups, two ranges of weight were used, 30–50% of the maximum (when a slight external resistance is overcome in the competition), 50–70% of the maximum (with a more significant external resistance). In order to significantly increase the spike force, both ranges were used (moreover, with different accents of motor activity in different articular angles). For the development of endurance in combination with the development of other motor abilities in the experimental group, the method of circular training was used twice a week. Usually it was 2–3 series x 10 stations (30 s of physical activity and after 30 s of rest). Rest between episodes for 4 minutes. Exercises of "combined" impact on coordination and conditioning abilities were also used in the experimental group. Considerable attention was paid to the improvement of coordination abilities in close connection with the improvement of technical skills.

Statistical analysis. Statistical data processing was carried out using Microsoft Excel "Data Analysis" and SPSS. For each parameter, the following was determined: arithmetic mean (X), standard deviation (S), standard error (m), confidence interval (Δx), assessment of the differences significance by Student's t–test with the corresponding level of significance (p). Differences were considered significant at a significance level of $p < 0.05$. The Kolmogorov–Smirnov test was used to estimate the distribution parameters.

Results

Prior to the beginning of the pedagogical experiment, no statistically significant differences were found between the parameters of the experimental and control groups. It was revealed that the use of the combined actions method contributed to a higher rate of growth in the level of development of most parameters of special readiness among volleyball players (girls) of the experimental group. Significant improvement in special readiness ($p < 0.05$) was revealed in almost all parameters in both groups. However, in the experimental group an improvement ($p < 0.001$) in 8 of 11 parameters (Table 1) was observed. In the control group, a significant improvement in results ($p < 0.001$) occurred only in 3 cases out of 11.

Training sessions held for 3 months (in the amount of 12–14 hours per week) resulted in a significant improvement in both groups: special endurance parameter (test "92 m running with changing direction"); special speed manifestation parameter ($p < 0.001$). It was revealed that the use of the combined impact method contributed to a higher rate of increase in the level of speed–strength abilities development in volleyball players (girls) in the experimental group. At the end of the experiment, a significant improvement ($p < 0.001$) in the experimental group was revealed in 3 out of 4 parameters of speed–strength readiness. In the control group, such an improvement in results ($p < 0.001$) was found in 1 out of 4 cases (Table 2).

The results analysis showed that the special method of combined actions resulted in a more significant increase in technical readiness parameters. For 4 parameters of technical skills (ball reception, attack, serving, passing), the volleyball players (girls) of the experimental group significantly improved ($p < 0.05$–0.001) their results. The volleyball players (girls) of the control group also improved the results in this type of training. However, the significant changes were less noticeable. Significant

Table 1. Changes in the parameters of special readiness of volleyball players (girls) of the experimental group (n = 12) during the pedagogical experiment

N	Parameter	Before the experiment		After the experiment		Δx	t	p
		X	s	X	s			
1	92 m running with changing direction	25.7	1.1	25.4	1	0.63	5.5	0.001
2	«9-3-6-3-9 m running» , s	8.49	0.48	8	0.48	0.28	9.9	0.001
3	«Standing long jump» , s	211	13.3	219	14.3	7.8	9.7	0.001
4	«Standing vertical jump», s	49	5.9	52	5.6	3.5	6.2	0.001
5	Running vertical jump, s	53	6.9	57	6.9	4.1	7.5	0.001
6	Finger-tip push-up for 10 s	10.7	1.8	12.7	2.2	1.1	4	0.002
7	1 Kg Overhead Medicine Ball Throw (MBT)";	13.9	1.3	15	1.3	0.8	6.9	0.001
8	Ball passes (alternation)	9.6	2.2	10	2.6	1.3	2.4	0.038
9	Ball serving	3	0.9	3.8	0.9	0.53	6.7	0.001
10	Spike	3.2	0.6	4.1	0.9	0.36	5.6	0.001
11	Ball reception after serving	3.1	0.7	3.7	1	0.41	4.2	0.002

Table 2. Changes in the parameters of special readiness in volleyball players (girls) of the control group (n = 12) during the pedagogical experiment

N	Parameter	Before the experiment		After the experiment		Δx	t	p
		X	s	X	s			
1	92 m running with changing direction	26.8	1.07	26.6	1.2	0.6	2.97	0.014
2	«9-3-6-3-9 m running» , s	8.88	0.48	8.71	0.55	0.28	6.33	0.001
3	«Standing long jump» , s	207	15.4	209	15.6	9.1	5.16	0.001
4	«Standing vertical jump», s	43.2	8.1	44.2	8.4	4.8	2.47	0.033
5	Running vertical jump, s	47.3	8.2	48.4	8.6	4.8	3.83	0.003
6	Finger-tip push-up for 10 s	11.4	2	12.1	2.2	1.19	2.67	0.024
7	1 Kg Overhead Medicine Ball Throw (MBT)";	14.4	0.75	14.7	0.85	0.57	5.8	0.001
8	Ball passes (alternation)	9	1.8	9.4	2.4	1.08	1.79	0.104
9	Ball serving	3.2	0.9	3.6	1.3	0.51	2.2	0.05
10	Spike	3.5	1.03	3.9	1.2	0.61	2.9	0.016
11	Ball reception after serving	3.3	0.9	3.6	1.1	0.49	2.4	0.038

improvement ($p < 0.05$) was found for 3 parameters. There was no statistically significant improvement in the results of the test "Alternation When Ball Passing to the Wall with Two Hands Overhead" in the control group volleyball players (girls) ($p > 0.05$).

Discussion

A high level of playing technique is the determining factor in the competitive activity of volleyball players (girls). According to Bernstein [26], there is a certain functional relationship between the level of development of motor abilities and the degree of motor skills mastery. Taking into account the leading role of the content in relation to the form, experts adhere to the position of the leading role of motor abilities. Hence it follows that the formation of skills can be successful only if this process is preceded by the process of purposeful development of motor abilities [27, 28]. Therefore, the organic relationship of physical and technical training of volleyball players (girls) is considered as one of the leading principles of sports improvement. Its essence lies in the fact that the purposeful development of motor abilities simultaneously contributes to the improvement of sports technique. This requires the selection of special exercises, similar in structure and nature of execution to the main exercise. Obviously, this contributes to the unity of the development of special abilities and skills [29-32].

After the pedagogical experiment, a significant improvement in the parameters was revealed, characterizing the level of development of most of the motor abilities of volleyball players (girls) in both groups ($p < 0.05$). This can be explained by the fact that in the preparatory period there is a large volume of training loads of general developmental orientation. In this regard, Zaciorskij et al. [15] and Platonov [12] note that at this stage the foundation of physical and functional readiness of volleyball players (girls) is created. At this stage special training is based. The authors also emphasize that the partial tasks of this stage are versatile physical development and health promotion, further development of the strength of various muscle groups, stimulation of recovery processes, and improvement of psychological readiness.

The conducted studies showed a more reliable increase in speed–strength abilities in volleyball players (girls) of the experimental group. In our opinion, this is a consequence of the use of special weight in the process of developing the strength of various muscle groups, taking into account the individual characteristics of volleyball players (girls). Also, the distribution of time for the development of motor abilities significantly influenced the final result. In this group, the endurance was developed in combination with the development of other motor abilities and in the process of tactical and technical improvement. Time for the development of this quality was directed to improve speed–strength readiness. In contrast, the control group had separate time for endurance development. The obtained results of the study confirmed the opinion and experimental data of other authors [33-35] about the prevailing development of certain types of motor abilities according to their importance in the structure of special readiness of volleyball players (girls).

If we talk about changes in technical readiness parameters, they turned out to be more significant in the experimental group. The quality of performing the basic techniques of playing volleyball players (girls) from the experimental group improved by 4–22% ($p < 0.04$–0.001). While the improvement of these techniques among volleyball players (girls) of the control group occurred by 4–11% ($p < 0.05$–0.02). In addition, the increase in the efficiency of ball passing in the control group was not significant ($p > 0.05$). We see the reason for a more significant improvement in technical readiness parameters among volleyball players (girls) in the experimental group in the wide use of special physical training means. These exercises were similar to the main techniques not only in structure, but also in the regimen of muscular efforts in the main phases of the motor action. In addition, in the experimental group, the improvement of coordination abilities occurred in close connection with the improvement in the techniques implementation. The choice of these areas of sports training is consistent with the recommendations of other studies [36-38]. Modern researchers recommend using weights as a way of additional mobilization of analysers to improve special physical and technical readiness, increase coordination abilities. Weighted movements contribute to the development of intermuscular coordination, which is required for the rational organization of dynamic accents of the motor action coordination structure. Complications contribute to additional excitation of the corresponding nerve centers and an increase in the number of motor units involved in the work of muscles. Optimal weighted movement reduces the variability of the structure of muscle work and brings it closer to the most rational pattern. The authors argue that the use of weights contributes to a faster formation of correct ideas about the motor action being trained. As a consequence, this approach contributes to a faster mastery of the game technique elements in general [20, 39].

In our opinion, the data obtained on a significant improvement in the parameters of speed–strength and technical readiness of volleyball players (girls) indicate the importance of using combined consecutive weights. This method provided for their consistent growth. At the same time, training means were selected that reflected the structural features of techniques. They created a morpho–functional basis for the effective impact on the athlete's body of the following more specialized training influences. The intensification of the organism's work regime provided for morphological and other quantitative and qualitative changes, which form the basis of its long–term adaptation to the conditions of sports activity. Such changes make it possible to stabilize the functionality of volleyball players (girls) at the achieved level. They act as prerequisites for their further improvement [18, 36]. This can be fully ensured only with such an organization of physical training, taking into account the specific patterns of the organism development process of adaptation to this mode of muscular work [40]. It is necessary to approach the solution of improving the movements technique issues of a volleyball player taking into account the organic relationship of physical and technical sides of motor activity, individual characteristics of an athlete [41, 42]. After all, the close interaction of these two sides of the athletes' readiness is conditioned by biomechanical, anatomical, physiological patterns, commonality of the reflex mechanism underlying the athlete's motor skills and motor abilities. Moreover, this relationship takes different forms, different quantitative and qualitative features, which differ significantly in different sports and at different stages of technical mastery [43].

Thus, the results obtained by us allow us to reveal the comparative effectiveness of two methods of planning the process of training volleyball players (girls) for the competitive season. At the same time, priority should be given to the improvement of more significant types of motor abilities and to the selection of training means that are similar to the competitive exercise in form and content. This approach will contribute to the maximum manifestation of the volleyball player's entire motor potential in the process of playing activity. Along with this, further studies are required to experimentally test various options for constructing the process of preparing volleyball players (girls) for the playing season. It seems that it is necessary to pay more attention to the development of training means for the development of those muscle groups that are directly involved in the implementation of the volleyball technique elements. This will help to improve the techniques effectiveness and prevent injury.

Conclusions

1. In the preparatory period of the annual training cycle, it is advisable to devote more time to the development of the motor abilities of volleyball players (girls), which are more significant for successful game activity (speed, speed–strength, dexterity and coordination). It is advisable to improve endurance in combination with the development of other motor abilities and in the process of technical and tactical improvement.

2. In the process of physical training of volleyball players (girls), it is advisable to use as many training means, which are similar to the basic techniques of playing volleyball in terms of spatio–temporal and dynamic characteristics, as possible. During the reaction speed development in volleyball players (girls), it is recommended to use movements that are similar to those of competition in form and muscle coordination.

3. Weighted movements contribute to the development of intermuscular coordination and allow to quickly form the correct idea of the motor action being trained. The method of combined impact is advisable to be used in the context of sequential and parallel impact on the physical and technical fitness of athletes.

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Conflict of interests

The authors declare that there is no conflict of interests.

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ORIGINAL ARTICLE

Causal attributions for success and failure among athletes: Validation of the Croatian version of the revised Causal dimension scale (CDS-II)

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Abstract

Background and Study Aim Researchers since the late 1970s have been interested in finding out the reasons attributed to outcomes. To facilitate attribution research in Croatia we translated and validated The Revised Causal Dimension Scale (CDS-II) and examined its invariance when attributing most and least successful competition performances.

Material and Methods To achieve our stated aim, 384 kinesiology students completed the translated CDS-II. To test the latent structure of the questionnaire, we used CFA and tested two alternative models (orthogonal solution and model with correlated latent variables). Additionally, we examined the CDS-II invariance when attributing the most and the least successful competition performance in sport using longitudinal CFA. The reliability was tested using Cronbach alpha coefficients. Lastly, we tested differences in latent means between most and least successful performance using pairwise t-test.

Results Similar to the originally published findings, CFA indicated the CDS-II structure with correlated latent variables had an adequate and better fit than the orthogonal solution in both situations. Furthermore, we confirmed configural, metric and scalar invariance, as well as partial strict invariance since one item's residuals differed significantly from the others. Cronbach alpha coefficients were adequate across both situations. Lastly, athletes attributed their most successful performances to more internal, stable and controllable reasons than their least successful performances.

Conclusions: We confirmed that the Croatian version of the CDS-II has adequate psychometric properties and is therefore suitable for research in sport situations.

Keywords: reasons, achievement, competition, performance, causal attributions

Introduction

In life, we face many outcomes. When we do, we are usually interested in finding the reasons behind the outcomes so that we can influence similar situations in our future [1]. Attribution theory explains the process of how we try to explain reasons behind different life outcomes [2].

Kelley and Michela [3] described an attribution process as follows: we can recognize antecedents (beliefs, information, and motivation), attributions (perceived cause) and consequences (expectations, emotions, and behaviour). Weiner [1, 4] developed a model considering all three components of this model in which he claimed that causes behind the behaviour can be placed on three dimensions: (1) *locus* which locates from where the cause is coming from (inside or outside the person), (2) *stability* which defines causes on a stable or unstable continuum, and (3) *controllability* which describes perceived level of control over the cause (controllable vs. uncontrollable). Weiner [1, 4] suggested that interpretation of the causes behind the behaviour can vary over time, from situation to situation, and from person to person, but the dimensions are invariant. Therefore, it is essential to find a way of measuring attribution dimensions.

Over the years researchers developed different methods to measure attribution dimensions. In traditional approaches, researchers [5] placed the causal attributions made by participants on the attribution dimensions, thus making what Russel [6] named "fundamental attribution researcher error". This error represents the idea that the author of the research perceives the causes in the same way as the participant who made them. Weiner [1] in his theory suggests that attributions represent the perception of the person who is making them. Therefore, the above-mentioned way of coding attributions may not be appropriate. The solution was to develop a methodology in which participants themselves place the reasons on the attribution dimensions. Russell [6] developed the CDS (Causal Dimension Scale) to measure participant's

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perception on how causes are placed on three attribution dimensions: locus, stability and controllability. This questionnaire was used in numerous studies [7 - 9] and although Russell and colleagues [10] confirmed the psychometric properties of the scale, studies also reported inconsistent reliability and validity results. The most worrisome subscale being the controllability one as low levels of internal consistency has been reported, as well as the high correlations between controllability and locus subscale [9, 10]). Also, the original control subscale in CDS offered bipolar answers from "controllable by you or other people" to "uncontrollable by you or other people" which means participants could only place the cause as controllable or uncontrollable [6]. However, McAuley and his colleagues [11] suggested that participants could view outcome as both controllable or uncontrollable by the person and controllable or uncontrollable by other people. As an answer to the problems with controllability subscale, McAuley et al. [11] suggested that this dimension should be divided into two separate subscales (a) personal control and (b) external control therefore creating the Revised Causal Dimension Scale (CDS-II).

The authors of the CDS-II questionnaire pointed out adequate levels of internal consistency with confirmed factorial structure in laboratory settings, real sport competition, physical and motor skills, and academic situations [11]. The adequate levels of internal consistency for all subscales as well as confirmation of the original four factor structure of the CDS-II were also reported [12]. However, Watkins and Cheng [13], in their study with Hong Kong students attributing their academic test performance, reported concerns about reliability of the external control subscale. Also, they concluded that there was extensive overlap between personal control and locus of causality subscales. This extensive overlap resulted in their confirmatory factor analysis suggesting the best fit for the three-factor solution: stability, external control and locus plus personal control. Watkins et al. [14] found the same overlap on Nepalese students attributing their academic test performances with the best fit for success outcomes again being those same three factors: external control, stability and locus plus personal control. Furthermore, they found that none of the models investigated in their study offered the adequate fit for failure outcomes as well as all subscales having barely adequate internal consistency. Crocker and colleagues [15] in their study reported that the four-factor oblique model suggested by McAuley et al. [11] provided an acceptable fit for the adolescent athletes involved in team sports. However, the fit for the athletes involved in individual sport showed some concerns, especially around the changeable-unchangeable stability item (item 11) which was problematic in the team sample and in the gender invariance analysis. Poor reliability was also found in a study [16] but this time for the stability subscale while the other subscales were all highly reliable. Taken together, the findings suggest there still is a need for further studies testing the psychometric properties of CDS-II questionnaire.

Considering the importance of investigating attributions, the first step is to have appropriate questionnaires with adequate psychometric properties. Previous researchers in the field [14] implied that further studies should test the validity of the CDS-II as well as the underlying model of attributions for success and failure outcomes. Given that the CDS-II questionnaire is dominantly used measure of state casual attributions even in the relatively recent studies [17, 18] which has not yet been translated to Croatian, as well as mixed results of the previous studies concerning psychometric properties, an extensive study is needed to facilitate attribution research in Croatia. Since there is an evident lack of attribution questionnaires in Croatian language, the aim of this study was to validate the Croatian version of the CDS-II questionnaire as well as to investigate differences in attribution for the most and least successful performances of Croatian athletes.

Material and Methods

Participants

The 384 athletes participated in this study. Their mean age was 20.43 years (*SD*=1.03) and there were more male (60.4%) than female (39.6%) participants. All participants were kinesiology students who reported practicing different team (62.83%; e.g. soccer, handball, volleyball, basketball) and individual (37.17%; e.g. swimming, tennis, gymnastics) sports at some point in their life at regional (13.46%), national (36.68%) or international levels (49.86%). 45.8% participants reported still being actively involved in competitive sport at the time research was conducted.

Instruments.

Causal attributions. The CDS-II is a 12-item measure consisting of four subscales (3 items each): locus of causality, stability, external control and personal control [11]. The items are rated on a bipolar scale ranging from 1 to 9. The higher results represent more internal, stable, personally and externally controllable attributions. For the original version, authors of the CDS-II scale reported alpha reliability of .67 for locus and stability subscales, .79 for personal control and .82 for external control [11]. In this study the CDS-II Croatian translated questionnaire was used twice: once for the most successful competition performance and once for the least successful competition performance. The direction at the beginning of the questionnaire was: "Please try to remember the competition in which you had your least successful performance. In the space below, please enter what you think is the main reason for your failure in this competition." for the least successful performance. In the most successful performance condition, the parts of the sentence mentioning failure were replaced with those mentioning success. After writing the main reason on the designated place, participants were instructed to fill the questionnaire keeping this reason in mind.

Procedure

CDS-II was translated to Croatian using back translation procedure. Both translators agreed that the second translation matched the original message and no meaningful differences between the two were present. Following the institutional ethical approval, the participants were approached after their lecture at their university. They were informed about the withdrawal procedure and asked to sign the informed consent form before completing the questionnaire.

Statistical Analysis.

To test the latent structure of the questionnaire, we used CFA and tested two alternative models (orthogonal solution and model with correlated latent variables). Additionally, we examined the CDS-II invariance when attributing the most and the least successful competition performance in sport using longitudinal CFA. The reliability was tested using Cronbach alpha coefficients. Lastly, we tested differences in latent means between most and least successful performance using pairwise t-test.

Results

Descriptive statistics

All analyses were conducted using a programming language for statistical computing *R* v.3.6.0 [19], using packages psych v1.9.12.31 [20] and *lavaan* v.0.6-5 [21]. In Table 1 we present descriptive statistics for individual items of CDS-II scale, both in the context of remembering the most and the least successful sport performance. Values of skewness (all $SI < 3$) and kurtosis indices (all $KI < 8$) indicate that the distributions of observed data do not deviate from the theoretical normal distributions [22]. Furthermore, we examined Mardia multivariate skewness and kurtosis indices, which indicated that multivariate normality was not met in both most successful ($MS = 1006.99$, $p < 0.01$; $MK = 19.40$, $p < 0.01$), and least successful ($MS = 986.54$, $p < 0.01$, $MK = 16.24$, $p < 0.01$) performances' evaluations.

Before testing latent structure of CDS-II, we calculated Pearson product-moment correlations which are presented in Table 2. These correlations were further used to test the latent structure of Croatian translation of the questionnaire.

Confirmatory factor analysis

To test whether the latent structure of Croatian translation of CDS-II is the same as the original English version we applied confirmatory factor analysis (CFA). We tested two alternative models described by McAuley et al. [11] with four latent variables: locus of causality, stability, personal control and external control. In one model we tested an orthogonal solution, and in another, presented in Figure 1, we allowed latent variables to be correlated. Both models were examined for the attributions of the most and the least successful performance.

All models were estimated using maximum likelihood estimation with robust standard errors and a Satorra and Bentler [23] scaled test statistic, and alternative models were compared using scaled difference chi square test [23]. Moreover, model fit for each iteration was evaluated using root mean square error of approximation together with its 95% confidence intervals (RMSEA) [24], standardized root mean residual (SRMR) [25], Tucker-Lewis index (TLI) [26] and comparative fit index (CFA) [25]. An adequate model fit is characterized with low χ^2 (ideally insignificant, albeit it is heavily influenced by the sample size), RMSEA (< .06) and SRMR (< .06) and high values of TLI and CFI (> .95). Fit indices from all of four tested CFA models are presented in Table 5.

It has been shown that a model with correlated

Table 1. Descriptive statistics of results on individual CDS-II items obtained when remembering the most and the least successful sport performance

	Sport Performance									
	Most successful					Least successful				
Item	*M*	*SD*	*SI*	*KI*	*SE*	*M*	*SD*	*SI*	*KI*	*SE*
1	6.2	2.2	-0.62	-0.42	0.11	5.0	2.8	-0.02	-1.42	0.14
2	6.6	2.0	-0.73	-0.21	0.10	5.1	2.5	-0.08	-1.14	0.13
3	5.8	2.1	-0.33	-0.66	0.11	3.5	2.2	0.51	-0.68	0.11
4	6.4	1.9	-0.57	-0.21	0.10	5.5	2.4	-0.22	-1.03	0.12
5	4.2	2.3	0.16	-1.12	0.12	4.0	2.4	0.31	-0.97	0.12
6	7.1	1.7	-0.93	0.69	0.09	5.9	2.4	-0.49	-0.66	0.12
7	5.2	2.2	-0.09	-0.70	0.11	3.7	1.9	0.22	-0.60	0.10
8	4.6	2.3	-0.04	-1.14	0.12	4.4	2.4	0.13	-1.14	0.12
9	7.2	1.7	-1.04	1.09	0.08	6.4	2.2	-0.74	-0.31	0.11
10	6.9	1.9	-0.95	0.25	0.10	5.9	2.4	-0.43	-0.89	0.12
11	4.4	2.2	0.11	-0.79	0.11	3.2	2.1	0.72	-0.25	0.11
12	4.3	2.2	0.00	-1.00	0.11	4.2	2.4	0.21	-0.98	0.12

Note: *M* = mean; *SD* = standard deviation; *SI* = skewness index; *KI* = kurtosis index; *SE* = standard error of the mean

Table 2. Pearson correlation coefficients between CDS-II items

Item	1	2	3	4	5	6	7	8	9	10	11	12
1		0.35*	0.24*	0.29*	-0.14*	0.52*	0.21*	-0.16*	0.41*	0.29*	0.02	-0.15*
2	0.44*		-0.06	0.78*	-0.15*	0.31*	0.10**	-0.13*	0.23*	0.66*	-0.11**	-0.16*
3	0.40*	0.37*		-0.13**	0.05	0.14*	0.46*	0.10**	0.12**	-0.05	0.49*	0.14*
4	0.38*	0.75*	0.50*		-0.09	0.23*	0.08	-0.08	0.22*	0.69	-0.19*	-0.11**
5	-0.29*	-0.22*	-0.14*	-0.26*		-0.20*	0.03	0.70*	-0.30*	-0.05	0.13**	0.65
6	0.52*	0.46*	0.33*	0.43*	-0.28*		0.16*	-0.20*	0.64*	0.30*	0.08	-0.23*
7	0.36*	0.30*	0.48*	0.31*	-0.11**	0.29*		0.07	0.10**	0.05	0.36*	0.06
8	-0.35*	-0.23*	-0.25*	-0.24*	0.70*	-0.21*	-0.16*		-0.33*	-0.06	0.12**	0.74*
9	0.45*	0.37*	0.23*	0.38*	-0.32*	0.50*	0.20*	-0.30*		0.33*	-0.02	-0.29*
10	0.33*	0.62*	0.36*	0.65*	-0.19*	0.41*	0.29*	-0.18*	0.40*		-0.20*	-0.06
11	0.23*	0.14*	0.41*	0.20*	0.00	0.18*	0.47*	-0.10	0.13**	0.09		0.18
12	-0.24*	-0.12**	-0.16*	-0.13**	0.61*	-0.16*	-0.07	0.67*	-0.25*	-0.11**	-0.01	

Note: $^{**}p < 0.05$; $^{*}p < 0.01$; Note: Values below the diagonal refer to attributions related to the most successful performance, while the values above the diagonal refer to attributions related to the least successful performance.

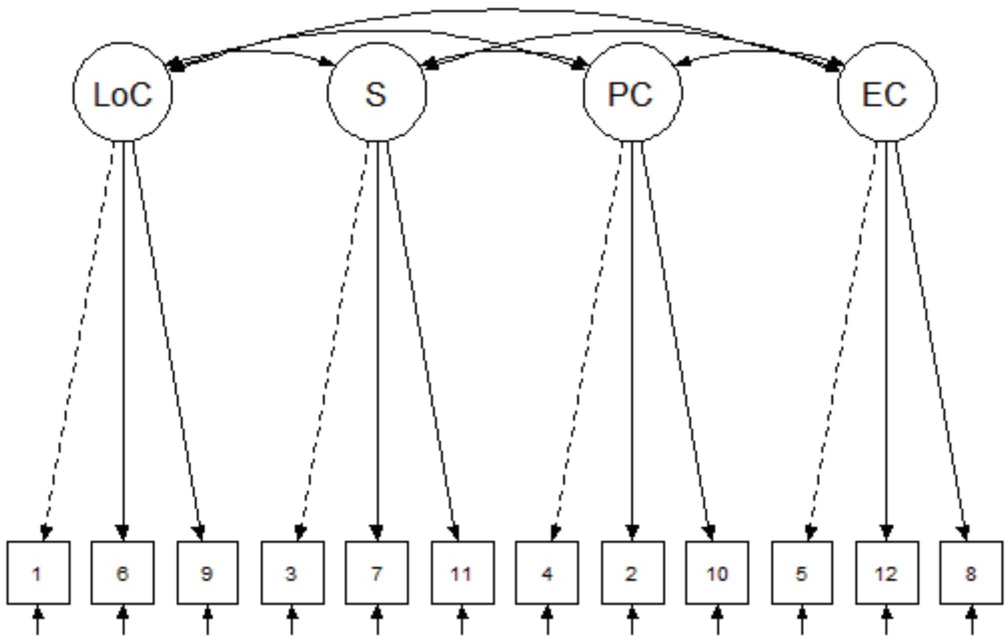

Figure 1. Model specification of CDS-II structure [11], with correlated latent variables. Numbers in manifest variables boxes represent item number; LoC- Locus of Causality; S- Stability, PC- Personal control; EC- External control.

latent variables showed a significantly better fit both when participants attributed the most successful sport performance ($\Delta\chi^2$ = 255.12, df = 6, p < 0.01), and the least successful sport performance ($\Delta\chi^2$ = 96.714, df = 6, p < 0.01). Fit indices indicated a good fit for the model of attributions of the most successful sport performance, and good to moderate fit for the model of attributions of the least successful sport performance. For both models, all items had high loadings (≥ .56, [22, 27]) with their hypothesized latent variables (Table 3). Correlations between factors are presented in Table 4.

Testing for measurement invariance

Next, we examined if CDS-II measures the same constructs for both attributing the most and the least successful sport performance. For that we tested measurement invariance using longitudinal CFA following steps described in Brown [28], and we used Cheung and Rensvold's [29] recommendations for dealing with partial invariance. First, we tested for configural invariance, a test of the same item configurations for attributions of different events. This model is tested by specifying the same model on two occasions, leaving all loadings and intercepts to vary freely. If fit indices indicate a good fit for configural invariance, then it is possible to conclude that the latent structure of the measure is the same in two instances. Next, we examined metric invariance, which examines if factor loadings are the same across two measurements. Third, we tested for scalar invariance by constraining item intercepts to be equal across two measurements. Lastly, we examined a strict invariance by forcing error variance to be equal. Differences between successive models were assessed by ΔCFI, for which a change of CFI between models less than 0.01 indicate that the invariance is established, while values greater than 0.01 indicate that examination of partial invariance is needed. Finally, all fit indices and model comparisons are presented in Table 5.

Test for configural invariance showed a good fit ($\chi^2 = 379.65$, $df = 212$, $p < 0.01$; RMSEA [90% CI] = 0.049 [0.041, 0.056]; SRMR = 0.051; TLI = 0.938; CFI = 0.950) indicating the same item configuration in attributing the most and the least successful sport performance. Furthermore, next steps indicated that metric (ΔCFI = 0.003) and scalar (ΔCFI = 0.007) invariances are established. However, testing for strict invariance indicated that residuals in both models differ significantly (ΔCFI = 0.013). To explore this difference, we relaxed constraints of equal residuals for each item at the time to test for partial strict invariance. It has been shown that Item 1 had greater variance in attributing the least successful (4.89, [*SE* = 0.432]) than the most successful sport performance (2.53, [*SE* = 0.274]). After accounting for this difference partial strict invariance was established (ΔCFI = 0.006).

Reliabilities and differences in latent means

Cronbach alpha reliability coefficients were calculated for all three-item scales for attributions of different sport performances. Reliabilities for attributions of the most successful sport performance were adequate (locus of causality, $\alpha = .73$; stability, $\alpha = .70$), to good (personal

Table 3. Factor loadings of Croatian CDS-II items in orthogonal and oblique models for attributions of the most and the least successful sport performance

		Sport Performance			
		Most successful		Least successful	
Factor	Item	Orthogonal	Oblique	Orthogonal	Oblique
Locus of causality	1	.68	.72	.57	.62
	6	.76	.72	.90	.83
	9	.66	.65	.71	.76
Stability	3	.64	.75	.80	.81
	7	.74	.69	.57	.56
	11	.63	.56	.61	.61
Personal control	2	.88	.88	.91	.89
	4	.85	.85	.86	.87
	10	.73	.74	.77	.78
External control	5	.80	.81	.79	.79
	8	.77	.76	.83	.84
	12	.87	.87	.90	.89

Table 4. Correlations between factors

	Locus of causality	Stability	Personal control	External control
Locus of causality		.23**	.41**	-.35**
Stability	.59**		-.12	.17*
Personal control	.69**	.57**		-.15*
External control	-.47**	-.25**	-.29**	

Note: ***p* < 0.01; **p* < 0.05; Values below the diagonal refer to attributions related to the most successful performance, while the values above the diagonal refer to attributions related to the least successful performance.

Table 5. Fit indices for CFA and measurement invariance models

CFA model	χ^2	df	RMSEA	90% CI	SRMR	TLI	CFI	ΔCFI
Most successful (orthogonal)	368.49	54	.123	[.113, .135]	.231	.747	.802	
Most successful (oblimin)	114.78	48	.060	[.047, .073]	.050	.940	.956	
Least successful (orthogonal)	236.48	54	.094	[.083, .106]	.151	.863	.888	
Least successful (oblimin)	133.26	48	.068	[.056, .081]	.060	.932	.950	
Configural	379.65	212	.049	[.041, .056]	.051	.938	.950	
Metric	399-36	220	.049	[.042, .057]	.055	.936	.947	.003
Scalar	431.75	228	.051	[.044, .059]	.054	.930	.940	.007
Strict	621.59	241	.070	[.064, .077]	.065	.869	.887	.013
Partial strict	461.93	239	.053	[.046, .060]	.056	.926	.934	.006

control, α = .88, external control, α = .88), according to interpretative guidelines [30]. Similarly, adequate (locus of causality, α = .76; stability, α = .70) to good (personal control, α = .88, external control, α = .88) reliability coefficients were found for attributions of the least successful sport performance.

Finally, we calculated latent means based on a partial strict invariance model and compared differences in attributions between the most and the least successful sport performances using pairwise t-test. Locus of causality was higher ($t(378) = 11.02$, $p < 0.01$, $d = 0.57$) while remembering the most successful ($M = 6.19$, $SD = 1.22$) compared to least successful sport performance ($M = 5.02$, $SD = 1.85$) with moderate effect size. Stability was higher ($t(378) = 18.06$, $p < 0.01$, $d = 0.92$) while remembering the most successful ($M = 5.73$, $SD = 1.59$) compared to least successful sport performance ($M = 3.53$, $SD = 1.55$) with large effect size. Next, personal control was higher ($t(378) = 10.21$, $p < 0.01$, $d = 0.52$) while remembering the most successful ($M = 6.49$, $SD = 1.49$) compared to least successful sport performance ($M = 5.33$, $SD = 2.01$) with moderate effect size. Lastly, statistically significant difference was not found ($t(378) = 1.44$, $p > 0.05$, $d = 0.07$) between attributions of external control while remembering the most ($M = 4.18$, $SD = 1.67$) and the least successful sport performance ($M = 4.04$, $SD = 1.82$).

Discussion

One of the aims of this study was to test whether the latent structure of Croatian translation of the CDS-II questionnaire is the same as the original version. To test that we applied confirmatory factor analysis (CFA) and tested two alternative models (orthogonal and correlated solution) which were described by McAuley et al. [11] in their original study. The results suggested that the model with correlated latent variables showed a better fit both in most and least successful competition performance situations. In that model, fit indices showed good fit for the most successful competition performance and good to moderate fit for the least successful competition performance. For both models in both situations all items had high loadings with their hypothesized latent variables. From these results it can be concluded that Croatian version of the CDS-II [11] showed satisfactory construct validity and therefore can be considered appropriate to use in future studies. However, we have to notice that the fit indexes in the least successful situation indicate somewhat poorer fit, so we suggest that in the future studies researches could consider formulating the question about the least successful competition performance differently. When the athletes are asked about their least successful competition performance maybe they have different ideas about what that really is as compared to asking them, for example, about their worst competition performance. The same could be done for the most successful performance. Furthermore, high correlations between factors in CDS-II questionnaire was one of the concerns reported in a study conducted by Crocker et al. [15] on adolescent athletes, especially the high correlation (>.80) between locus and personal control subscales. In our study, correlation between locus and personal control was .69 in the most successful performance situation which is similar but slightly lower than the correlation reported in original study (.71) conducted by McAuley et al. [11].

Second aim of this study was to examine if Croatian version of the CDS-II questionnaire measures the same construct in both most and least successful competition performance situations. In order to do that, we used longitudinal CFA to test measurement invariance. Results show that the test for configural invariance showed a good fit which means there is the same item configuration when attributing most and least successful competition performance. Also, metric and scalar invariances were established. However, when testing for strict invariance the residuals in both models differ significantly, so we tested for partial strict invariance. When accounting for the greater variance of Item 1 in the least successful performance compared to the most successful performance, partial strict invariance was established. In general, it can be concluded that the strict invariance is not achieved since residuals are different on the first item where athletes have a wider range of the answers when attributing the least successful performances. In other words, there is an evident problem with calculating arithmetic mean on the locus of causality subscale because variances of the first item are not equal in both situations. This means we are bringing an error when calculating arithmetic mean from the start. However, since we achieved scalar invariance, we have a right to compare latent means [31]. Therefore, we suggest that, in those two contexts, attributions should be compared by using latent means.

Following that suggestion, we calculated latent means based on a partial strict invariance model and compared differences in making attributions for the most and least successful sport competition performance using pairwise t-test. The results indicated that athletes in our study made more internal, stable and personally controllable attributions for the most successful sport competition performance compared to the least successful one with no significant difference on external control subscale. This is in line with previous study conducted by Hamilton and Jordan [32] which reported results in the same direction. On the other hand, Santamaria and Furst [33] found the significant differences in the same direction as the ones found in our study but only for the locus and personal control subscales. In line with our findings was also the study conducted by Russell [6] who found that success in different achievement situations was attributed to more internal, stable and controllable causes than failure. Furthermore, some studies found that winners in sport tend to make more internal, stable and controllable attributions than losers [9, 34] while others found the differences in the same direction but only on the stability and controllability dimensions [8]. However, De Michele et al. [35] reported that winners in wrestling made more internal, stable, personally and externally controllable reasons compared to losers. Our results on athletes from different sports and different levels of participation can contribute to further understanding the differences in attributing success and failure in sport.

Finally, the reliability coefficients obtained in this study are somewhat low (locus success.73; locus failure .76; stability success .70; stability failure .70; personal control success .88; personal control failure .88; external control success .88; external control failure .88). However, we can attribute that to the fact that each subscale in the CDS-II questionnaire has only 3 items. On the other hand, the reliability indexes in this study are higher than those in the original study (locus .67; stability .67; personal control .79; external control .82) conducted by McAuley et al. [11] and also mostly higher than those obtained in the study conducted by Watkins and Cheng [13] (locus .72; stability .71; personal control .76; external control .57) and Dong et al. [17] (locus .76; stability .66; personal control .83; external control .70).

As any other research, this one as well has some areas which should be improved in future studies. One of such areas is the order of situations. In this study all the athletes filled the attribution questionnaire regarding the most successful competition performance first, and then they filled the questionnaire regarding their least successful competition performance. We suggest that future studies rotate the order of the questionnaires. Furthermore, current study didn't examine gender or type of sport invariances which were addressed as problematic in previous studies [15]. Future studies could focus on further investigating those concerns.

Conclusions

In general, it can be concluded that Croatian version of the CDS-II [11] in this study showed satisfactory construct validity and therefore can be considered appropriate to use in future studies. Also, the reliability indexes of the subscales were adequate to good. Furthermore, from the longitudinal CFA it can be concluded that CDS-II questionnaire measures the same construct when examining attributions for the most and least successful sport performances. When comparing the two situations using pairwise t-test and latent means the results indicated that athletes in this study made more internal, stable and personally controllable attributions for their most successful competition performance compared to the least successful one.

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ORIGINAL ARTICLE

Strength abilities: pattern recognition method in the management of the cumulative effect of strength loads in 8-year-old boys

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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 was to determine the peculiarities of using pattern recognition method in the management of the cumulative effect of strength loads in 8-year-old boys.

Material and Methods The study participants were 48 boys aged 8. The experiment was conducted using a 2^2 factorial design. The study materials were processed by the IBM SPSS 22 statistical analysis program. Discriminant analysis was performed. The study examined the impact of four variants of strength load on the formation of the cumulative training effect of three, six, nine, and twelve classes in 8-year-old boys.

Results The discriminant analysis provided information about the impact of four orthogonal variants of strength loads on the formation of the cumulative training effect of strength exercises of three, six, nine, and twelve classes in 8-year-old boys. The obtained data make it possible to choose a load mode at each step of the CTE formation and to manage schoolchildren's strength training.

Conclusions The verification of the obtained discriminant functions shows their high discriminative ability and value in interpretation with respect to the general population ($p < 0.05$). It was found that the formation of the CTE of three classes is most influenced by the third load variant, six classes – by the third load variant, nine classes – the third load variant, twelve classes – the first load variant. The discriminant function structure coefficients made it possible to identify the factor structure of the CTE of 3, 6, 9, 12 classes, to find that the CTE3, CTE6 are associated with the work at the first place "Exercises to strengthen arm muscles", the CTE9, CTE12 – with the work at the third ("Exercises to strengthen back muscles") and the fourth ("Exercises to strengthen leg muscles") places. The CTE of three, six, nine, and twelve classes depends on the modes of strength exercises and has different focuses. The CTE3 – speed and strength focus; CTE6, 9 – comprehensive focus; CTE12 – explosive-strength focus. The obtained values of centroids for the CTE of 3, 6, 9, 12 classes enable the management of schoolchildren's strength training.

Keywords: 8-year-old boys, cumulative training effect, strength loads, discriminant analysis.

Introduction

One of the factors that ensure the effectiveness of physical education and sports training is the assessment and management of training effects in the process of teaching and developing motor abilities [1-3].

Motor skills formation [4, 5] and motor abilities development depend on the number of repetitions and rest interval [6-8]. Luz et al. [9], Krivolapchuk et al. [10], Krutsevich et al. [11] point out the importance of studying the impact of physical loads on the functional state of primary schoolchildren. The results obtained show a positive effect of high-intensity exercises on the body of children aged 5-6 and 6-7 years [10].

Polevoy [12], Smits-Engelsman et al. [13], Veremeenko et al. [14] focus on the process of developing strength and coordination abilities in schoolchildren's physical education. It was found that primary schoolchildren's indicators of speed-strength and coordination abilities significantly improve, if special exercises are used during physical education classes [12], the level of schoolchildren's motor fitness depends on their coordination and speed-strength fitness [14].

Pattern recognition methodology is one of the technological approaches to studying the processes, the data of which represent time series at each step of discretization [15, 16]. In research on the effectiveness of strength development, there is a problem of studying single-factor and multi-factor impacts on the formation of the cumulative training effect of a series of classes. An aspect of research is studying the laws of regulating strength exercises which result in the cumulative training effect of a series of classes, and the obtained data represent time series at each step of discretization [7, 17, 18]. It was found that the effectiveness of pattern recognition increases with the use of active 2^k experiments [2, 18]. However, there are few studies aimed at investigating multi-factor impacts on the formation of the cumulative training effect of 3, 6, 9, 12 classes in primary-school-aged children. Most studies consider the impact of 2-, 4-, 6-, 8-, and 16-week training on strength development in young people [19-21].

Thus, the problem of assessing the cumulative training effects of a series of classes and managing strength training of primary schoolchildren is relevant and requires further research.

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The purpose of the study was to determine the peculiarities of using pattern recognition method in the management of the cumulative effect of strength loads in 8-year-old boys.

Materials and Methods

Participants

The study participants were boys aged 8 (n = 48). The children and their parents were fully informed about all the features of the study and gave their consent to participate in the experiment. The study protocol was approved by the Ethical Committee of H. S. Skovoroda Kharkiv National Pedagogical University.

Research Design

To solve the tasks set, theoretical and empirical methods were used: analysis and generalization of scientific and methodological literature; modeling, pedagogical observation and experiment, discriminant analysis.

To determine the dynamics of strength training effects in boys aged 8, the study carried out an experiment according to the plan given in Table 1. Variant I of the combined method was used to strengthen arm and shoulder muscles (place I), abdominal muscles (place II), back muscles (place III), and leg muscles (place IV). At each place, the following methods were used: dynamic effort method, maximal effort method, isometric effort method, repeated effort method. The modes of performance for each group, for the indicated places are given in Table 1.

The study examined the impact of four variants of strength load on the cumulative training effect (CTE) of 3, 6, 9, and 12 classes in 8-year-old boys:

CTE3: I mode → II mode → III mode → IV mode
CTE6: I mode → II mode → III mode → IV mode
CTE9: I mode → II mode → III mode → IV mode
CTE12: I mode → II mode → III mode → IV mode

At each station, the following exercises were performed:

Station I. Exercises for arm and shoulder muscles.

1. Dynamic effort method. Knee push-ups. The exercise is performed as quickly as possible.
2. Maximal effort method. Weighted push-ups (stuffed ball).
3. Isometric effort method. Knee push-ups. The exercise is performed with two stops and fixation of joint angles (5 s).
4. Repeated effort method. Knee push-ups.

Station II. Exercises to strengthen abdominal muscles.

1. Dynamic effort method. Sit-ups. The exercise is performed as quickly as possible.
2. Maximal effort method. Hanging 90-degree leg raises on wall bars.
3. Isometric effort method. Decline bench 90-degree leg raises. The exercise is performed with two stops and fixation of joint angles (5 s).
4. Repeated effort method. Decline bench leg raises to plow.

Station III. Exercises to strengthen back muscles.

1. Dynamic effort method. Trunk lift. The exercise is performed as quickly as possible.
2. Maximal effort method. Trunk lift on a pommel horse with feet supported under wall bars.
3. Isometric effort method. Trunk lift with two stops and holding each static position for 5 s. The exercise is performed with two stops and fixation of joint angles (5 s) (hold positions in the upper point and horizontally).
4. Repeated effort method. The same starting position. Trunk lift.

Station IV. Exercises to strengthen leg muscles.

1. Dynamic effort method. Squats. The exercise is performed as quickly as possible.

Table 1. Factorial design in studying the influence of different modes of the combined method of strength development (variant I) in primary schoolchildren (X1 — number of repetitions in a set; X2 — rest interval, s)

No. of strength load variant	Method	X_1	X_2
I	Dynamic effort method	3-	30-
	Maximal effort method	1-	30-
	Isometric effort method	3-	30-
	Repeated effort method	6-	30-
II	Dynamic effort method	5+	30-
	Maximal effort method	3+	30-
	Isometric effort method	5+	30-
	Repeated effort method	12+	30-
III	Dynamic effort method	3-	60+
	Maximal effort method	1-	60+
	Isometric effort method	3-	60+
	Repeated effort method	6-	60+
IV	Dynamic effort method	5+	60+
	Maximal effort method	3+	60+
	Isometric effort method	5+	60+
	Repeated effort method	12+	60+

2. Maximal effort method. Weighted squats (stuffed ball, dumbbells).

3. Isometric effort method. Weighted squats with stops. The exercise is performed with two stops and fixation of joint angles (5 s) (90°, 135°).

4. Repeated effort method. Squats.

During the experiment, the study recorded the results of the following tests: 1. Push-ups. 2. Speed push-ups, 3 times. 3. Sit-ups in 30 seconds. 4. Trunk lift in 10 seconds. 5. Standing long jump.

On the first day before the experiment, the study recorded the results of Test 2 “Speed push-ups, 3 times”, Test 1 “Push-ups”, Test 3 “Sit-ups in 30 seconds”, Test 4 “Trunk lift in 10 seconds”, Test 5 “Standing long jump”. Twenty-four hours after 3, 6, 9, and 12 classes – Tests 2, 1, 3, 4, 5. The dynamics of test results was determined as a percentage relative to the initial level.

Statistical analysis

The study materials were processed using the IBM SPSS 22 statistical analysis program. In the process of discriminant analysis, a prognostic model for group membership was created. This model builds a discriminant function (or, when there are more than two groups – a set of discriminant functions) in the form of a linear combination of predictor variables, which ensures the best division of groups. These functions are built according to a set of observations, for which their group membership is known. These functions can continue to be used for new observations with known values of predictor variables and unknown group membership.

For each canonical discriminant function, the study calculated: eigenvalue, dispersion percentage, canonical correlation, Wilks’ Lambda, Chi-square.

Results

The discriminant analysis provided information about the impact of four orthogonal modes of strength exercises on the CTE of three, six, nine, and twelve classes (Table 2).

CTE3: statistically significant changes are observed in the dynamics of the results of Test 2 “Speed push-ups, 3 times”, load variant I helps to increase the speed of performing the test task, variants II-IV lead to an increase in the time of performing the exercise (p = 0.013).

CTE6: the dynamics of the results of Tests 1-3, 5 statistically significantly depends on the modes of strength exercises.

CTE9: the dynamics of the results of Tests 1-5 statistically significantly depends on the modes of strength exercises.

Table 2. Results of the impact of strength exercises modes on test results of boys aged 8 years (%)*

No	Indicators	Variants of performing exercises									
		I		II		III		IV			
		X	s	X	s	X	s	X	s	F	p
		CTE of 3 classes									
1	Push-ups	100.00	5.02	103.62	4.19	106.31	39.71	96.65	9.87	.496	.687
2	Speed push-ups, 3 times	98.60	3.85	101.31	10.20	110.22	10.61	103.11	7.81	4.045	**.013**
3	Sit-ups in 30 seconds	99.30	3.71	100.08	2.46	98.53	9.80	101.67	6.38	.551	.650
4	Trunk lift in 10 seconds	100.11	4.83	100.86	6.35	98.43	9.49	98.66	5.91	.345	.793
5	Standing long jump	99.51	.72	97.92	1.68	99.61	3.01	97.97	5.48	.980	.411
		CTE of 6 classes									
1	Push-ups	109.44	7.89	106.15	6.83	86.23	20.77	105.24	16.35	6.566	.001
2	Speed push-ups, 3 times	90.31	13.20	98.70	6.88	108.16	11.37	97.77	13.52	4.815	.006
3	Sit-ups in 30 seconds	104.10	6.50	101.52	5.94	95.91	6.25	105.09	4.52	5.919	.002
4	Trunk lift in 10 seconds	100.23	5.07	100.23	3.31	102.06	5.85	97.15	4.22	2.245	.096
5	Standing long jump	100.67	2.21	96.87	2.87	99.33	4.06	99.09	2.32	3.399	.026
		CTE of 9 classes									
1	Push-ups	100.44	7.44	105.22	13.22	91.65	13.23	87.07	19.60	4.121	.012
2	Speed push-ups, 3 times	94.14	5.20	100.50	5.54	110.39	14.36	101.95	12.75	5.027	.004
3	Sit-ups in 30 seconds	97.54	5.31	94.90	10.27	102.09	4.26	92.83	9.92	3.059	.038
4	Trunk lift in 10 seconds	100.10	4.83	107.99	12.24	102.59	7.88	89.29	5.95	10.927	.000
5	Standing long jump	103.20	1.99	96.41	4.17	98.16	3.27	93.81	5.03	13.134	.000
		CTE of 12 classes									
1	Push-ups	110.34	3.59	104.42	9.06	102.66	3.12	107.30	18.86	1.180	.328
2	Speed push-ups, 3 times	94.05	11.21	97.73	6.89	102.04	3.69	92.87	11.03	2.659	.060
3	Sit-ups in 30 seconds	101.72	2.55	101.84	3.66	102.12	3.73	99.37	7.10	.920	.439
4	Trunk lift in 10 seconds	101.51	3.53	103.71	6.49	101.51	3.53	97.43	3.78	4.040	.013
5	Standing long jump	101.97	2.52	99.53	2.39	99.28	2.39	98.18	2.01	5.620	.002

Note: *initial level – 100%

CTE12: the dynamics of the results of Tests 2, 4, 5 statistically significantly depends on the modes of strength exercises.

Thus, the formation of the CTE of three, six, nine, and twelve classes depends on the modes of strength exercises and has different focuses. The CTE3 – speed and strength focus; CTE6, 9 – comprehensive focus; CTE12 – explosive-strength focus.

Tables 3-6 show the results of discriminant analysis of a set of data for the CTE of three, six, nine, and twelve classes after four modes of strength exercises.

CTE3: The first canonical function explains 76.2% of the variation of results, the second one – 12.5%, which indicates a high informativeness of the first canonical function (r_1 = 0.634) (Table 3, CTE3).

The verification of the first function shows its high discriminative ability and value in interpretation with respect to the general population (λ_1 = 0.490; p_1 = 0.011; Table 4, CTE3). The first function characterizes the impact of strength load variants I-IV on the CTE3.

Structure coefficients indicate that the most significant changes in the CTE3 are associated with the work at the first place "Exercises to strengthen arm muscles", Test 2 "Speed push-ups, 3 times", (r = 0.583; Table 5, CTE3).

Table 3. Eigenvalues. Boys aged 8

CTE	Function	Eigenvalue	% of Variance	Cumulative %	Canonical correlation
	1	.672[a]	76.2	76.2	.634
CTE3	2	.110[a]	12.5	88.8	.315
	3	.099[a]	11.2	100.0	.300
	1	.845[a]	62.2	62.2	.677
CTE6	2	.383[a]	28.2	90.3	.526
	3	.132[a]	9.7	100.0	.341
	1	1.405[a]	49.9	49.9	.764
CTE9	2	.936[a]	33.2	83.2	.695
	3	.474[a]	16.8	100.0	.567
	1	.900[a]	55.0	55.0	.688
CTE12	2	.676[a]	41.3	96.3	.635
	3	.061[a]	3.7	100.0	.240

Table 4. Test of function(s). Boys aged 8

CTE	Test of function(s)	Wilks' Lambda	Chi-square	df	Sig.
	1 through 3	.490	30.300	15	.011
CTE3	2 through 3	.819	8.465	8	.389
	3	.910	4.011	3	.260
	1 through 3	.346	45.054	15	.000
CTE6	2 through 3	.639	19.030	8	.015
	3	.884	5.259	3	.154
	1 through 3	.146	81.857	15	.000
CTE9	2 through 3	.351	44.555	8	.000
	3	.678	16.485	3	.001
	1 through 3	.296	51.776	15	.000
CTE12	2 through 3	.562	24.487	8	.002
	3	.942	2.528	3	.470

Table 5. Structure matrix. Boys aged 8

No	Indicators	CTE3			CTE6			CTE9			CTE12		
		Function			Function			Function			Function		
		1	2	3	1	2	3	1	2	3	1	2	3
1	Push-ups	.195	-.151	-.240	-.683	.090	.620	.221	.053	.666	.023	.334	-.270
2	Speed push-ups, 3 times	.583*	.449	.504	.548	.263	-.607	.075	.388	-.640	.176	-.423	.727
3	Sit-ups in 30 seconds	-.146	-.081	.477	-.690	-.016	-.081	.331	.003	-.340	.241	-.123	.055
4	Trunk lift in 10 seconds	-.076	-.353	-.243	.349	-.143	.569	.565	.393	.567	.438	-.309	-.787
5	Standing long jump	.114	.490	-.564	-.063	-.761	-.229	.574	-.651	.270	.556	.385	-.282

Table 6. Functions at group centroids. Boys aged 8

Terms of recording	CTE3	CTE6	CTE9	CTE12
I mode	-0.748	-.622	.651	.964
II mode	0.039	-.027	.124	.204
III mode	1.263	1.442	1.098	.324
IV mode	-0.554	-.793	-1.873	-1.492

CTE3 – 54.2%; CTE6 – 68.8%; CTE9 – 83.3%; CTE12 – 66.7%.

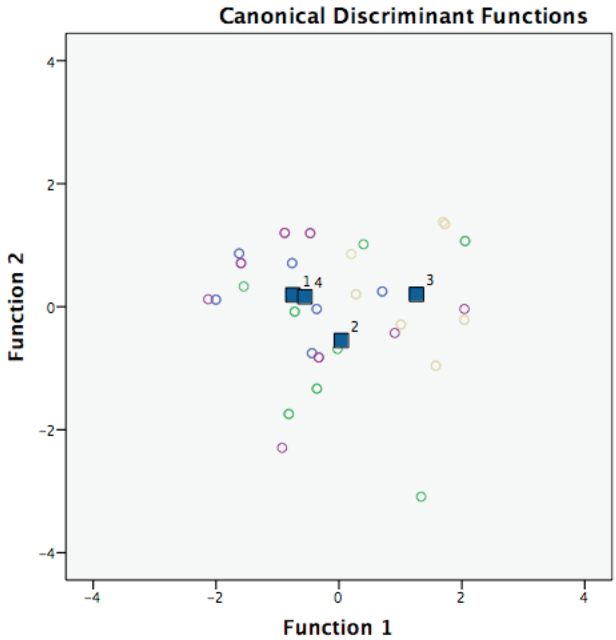

Fig. 1. Dynamics of test results in boys aged 8. CTE3: 1 – load variant I, 2 – load variant II, 3 – load variant III, 4 – load variant IV

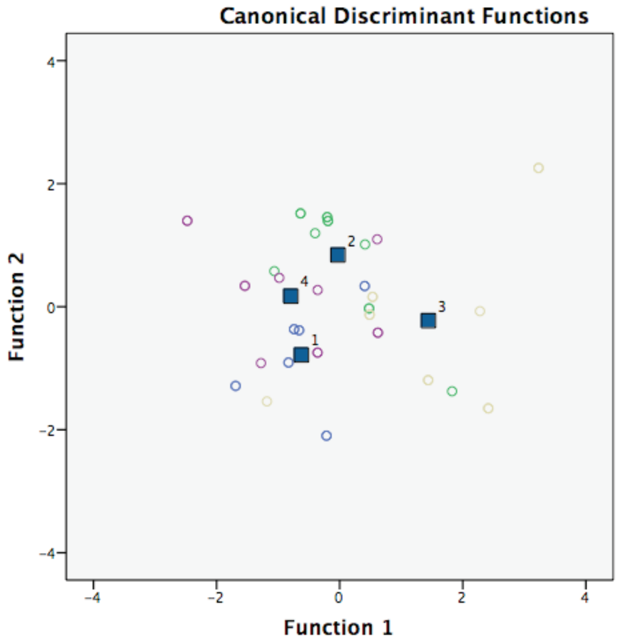

Fig. 2. Dynamics of test results in boys aged 8. CTE6: 1 – load variant I, 2 – load variant II, 3 – load variant III, 4 – load variant IV

During a discriminant analysis, it was found that 54.2% of cases were classified correctly. The analysis of group centroids for the CTE3 shows that at the positive pole of the first function, there are the centroids of state after load variant III, at the negative pole – the centroids of state after load variants I and IV. Thus, the third variant of strength load has the greatest overall impact on the CTE after 3 classes (Table 6, Fig. 1). Strength load variant I can be recommended for developing speed strength.

CTE6: The first canonical function explains 62.2 % of the variation of results, the second one – 28.2%, which indicates the informativeness of the first and second canonical functions ($r_1 = 0.677$; $r_2 = 0.526$; Table 3, CTE6).

The verification of the functions shows their high discriminative ability ($\lambda_1 = 0.346$; $p_1 = 0.000$; $\lambda_1 = 0.639$; $p_1 = 0.015$; Table 4, CTE6).

Structure coefficients indicate that the most significant changes in the CTE are associated with the work at the first place “Exercises to strengthen arm muscles” and the second one “Exercises to strengthen abdominal muscles” (r_1 = -0.683, r_2 = 0.548, r_3 = -0.690; Table 5, CTE6). During a discriminant analysis, it was found that 68.8% of cases were classified correctly. The analysis of group centroids for the CTE6 shows that at the positive pole of the first function, there are the centroids of state after load variant III, at the negative pole – the centroids of state after load variants I, II and IV. Thus, the third variant of strength load has the greatest overall impact on the CTE after 6 classes (Table 6, Fig. 2).

CTE9: The first canonical function explains 49.9% of the variation of results, the second one – 33.2%, the third – 16.8%, which indicates the informativeness of the canonical functions ($r_1 = 0.764$; $r_2 = 0.695$; $r_3 = 0.567$; Table 3, CTE9).

The verification of the functions shows their high discriminative ability and value in interpretation with respect to the general population ($\lambda_1 = 0.146$; $p_1 = 0.000$; $\lambda_2 = 0.351$; $p_2 = 0.000$; $\lambda_3 = 0.678$; $p_3 = 0.001$; Table 4, CTE9). The first function characterizes the impact of strength load on the dynamics of test results after 9 classes.

Structure coefficients indicate that the most significant changes in the CTE are associated with the work at the third and fourth places (Table 5, CTE9). During a discriminant analysis, it was found that 83.3% of cases were classified correctly. The analysis of group centroids for the CTE9 shows that at the positive pole of the first function, there are the centroids of state after load variant III, at the negative pole – the centroids of state after load

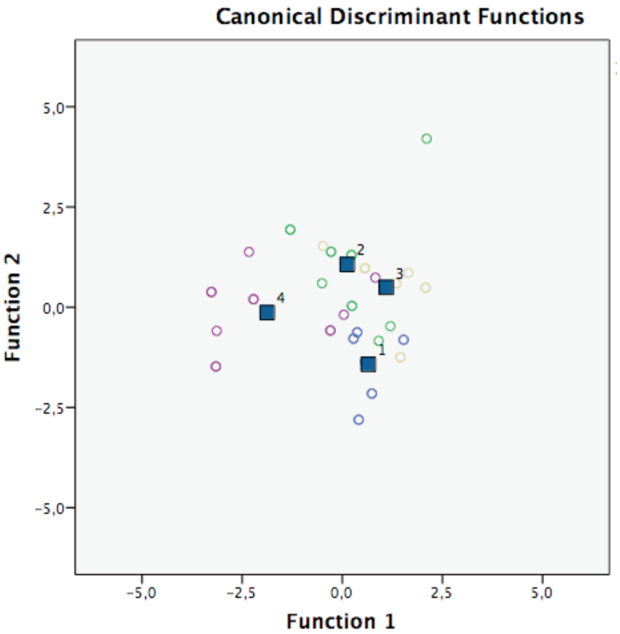

Fig. 3. Dynamics of test results in boys aged 8. CTE9: 1 – load variant I, 2 – load variant II, 3 – load variant III, 4 – load variant IV

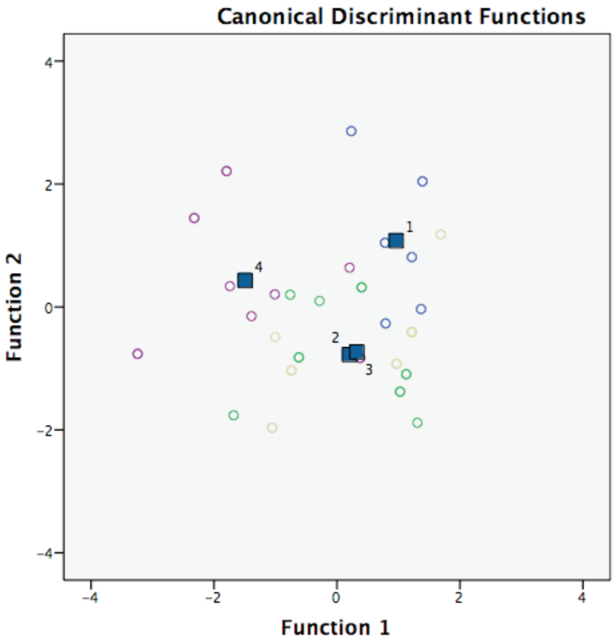

Fig. 4. Dynamics of test results in boys aged 8. CTE12: 1 – load variant I, 2 – load variant II, 3 – load variant III, 4 – load variant IV

variant IV. Thus, the third variant of strength load has the greatest overall positive impact, and the fourth variant has the greatest negative impact on the CTE after 9 classes (Table 6, Fig. 3).

CTE12: The first canonical function explains 55.7% of the variation of results, the second one – 41.3%, which indicates the informativeness of the first and second canonical functions (r_1 = 0.688; r_2 = 0.635; Table 3, CTE12).

The verification of the first and second functions shows their high discriminative ability and value in interpretation with respect to the general population (λ_1 = 0.296; p_1 = 0.000; λ_2 = 0.562; p_2 = 0.002; Table 4, CTE12). The first function characterizes the impact of strength load on the dynamics of test results after 12 classes.

Structure coefficients indicate that the most significant changes in the CTE12 are associated with the work at the third and fourth places (Table 5, CTE12). During a discriminant analysis, it was found that 66.7% of cases were classified correctly. The analysis of group centroids for the CTE12 shows that at the positive pole of the first function, there are the centroids of state after load variants I-III, at the negative pole – the centroids of state after load variant IV. Thus, the first variant of strength load has the greatest overall positive impact on the CTE12, negative impact – the fourth variant of strength load (Table 6, Fig. 4).

Discussion

The study assumed that the formation of the CTE of three, six, nine, and twelve classes has its peculiarities depending on the mode of strength exercises. It was found that the formation of the CTE of three classes is most influenced by the third load variant, six classes – by the third load variant, nine classes – the third load variant, twelve classes – the first load variant.

In studying the impact of the mode of strength exercises on the CTE using the scheme:

I variant: CTE3 → CTE6 → CTE9 → CTE12;
II variant: CTE 3 → CTE6 → CTE9 → CTE12;
III variant: CTE3 → CTE6 → CTE9 → CTE12;
IV variant: CTE3 → CTE6 → CTE9 → CTE12,

it was found that after the first variant of strength exercises the greatest overall training effect is observed after nine classes, the second variant – after nine classes, the third variant – after three classes, the fourth variant – after six classes [7]. The data obtained using the scheme:

CTE3: I variant → II variant → III variant → IV variant
CTE6: I variant → II variant → III variant → IV variant
CTE9: I variant → II variant → III variant → IV variant
CTE12: I variant → II variant → III variant → IV variant

provided an opportunity to assess the total impact of each variant of strength exercises on the dynamics of the CTE of 3, 6, 9, 12 classes and to clarify their peculiarities.

If the analysis of data using the first scheme revealed how each of the load variants affects the CTE, then the analysis of data using the second scheme answered the question as to which load variant is the best for developing a separate CTE of 3, 6, 9, 12 classes and what its focus is.

The obtained data make it possible to choose a load mode at each step of the CTE formation and supplement the information about the results of analysis of the impact of strength loads: on the dynamics of the immediate and delayed training effect [3, 17, 22]; on strength development in a two-week training cycle [19, 23]; on strength development in a four-week training cycle [14, 20, 24]; on strength development in a six-week training cycle [25, 26]; on strength development in an eight-week training cycle [27].

The discriminant function structure coefficients made it possible to identify the factor structure of the CTE of 3, 6, 9, 12 classes, to find that the CTE3, CTE6 are associated with the work at the first place "Exercises to strengthen arm muscles", the CTE9, CTE12 – with the work at the third and fourth places. The CTE of three, six, nine, and twelve classes depends on the modes of strength exercises and has different focuses. The CTE3 – speed and strength focus; CTE6, 9 – comprehensive focus; CTE12 – explosive-strength focus. The obtained data supplement the information on the formation of training effects of strength loads in primary schoolchildren [2, 3, 22].

The results of the study can be used to plan and control strength training in physical education classes in junior school. For planning, the data given in Table 1 are recommended, taking into account the values of group centroids (Table 6, Fig. 1-4). The main method of strength development is the combined method according to the first variant. Exercises at one place are performed in the following order: dynamic effort method, maximal effort method, isometric effort method, repeated effort method. The development of strength is seen as a condition for successful formation of motor skills. The results given in Table 1 can be used as guidelines for monitoring the formation of the CTE.

Conclusion

The verification of the obtained discriminant functions shows their high discriminative ability and value in interpretation with respect to the general population ($p < 0.05$).

It was found that the formation of the CTE of three classes is most influenced by the third load variant, six classes – by the third load variant, nine classes – the third load variant, twelve classes – the first load variant.

The discriminant function structure coefficients made it possible to identify the factor structure of the CTE of 3, 6, 9, 12 classes, to find that the CTE3, CTE6 are associated with the work at the first place "Exercises to strengthen arm muscles", the CTE9, CTE12 – with the work at the third ("Exercises to strengthen back muscles") and the fourth ("Exercises to strengthen leg muscles") places. The CTE of three, six, nine, and twelve classes depends on the modes of strength exercises and has different focuses. The CTE3 – speed and strength focus; CTE6, 9 – comprehensive focus; CTE12 – explosive-strength focus. The obtained values of centroids for the CTE of 3, 6, 9, 12 classes enable the management of schoolchildren's strength training.

Conflict of interest

The authors state no conflict of interest.

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ORIGINAL ARTICLE

Correlation of maximal respiratory exchange ratio with anaerobic power and maximal oxygen uptake in anaerobic trained athletes

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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 respiratory exchange ratio (RER) is the ratio of the amount of carbon dioxide produced (VCO2) to the amount of oxygen uptake (VO2) is important. It indirectly informs about the predominant metabolic pathway to provide the energy needed during exercise. The relationship of maximal RER with aerobic and anaerobic capacity in athletes remains unclear. The purpose of this study was to investigate the relationship between maximal RER and anaerobic power and maximal oxygen uptake (VO_{2max}) in anaerobic trained athletes.

Material and Methods Thirteen male alpine skiers (age 18.1 ± 3.1 years) competing in national and international competitions participated in the study. Athletes first performed an incremental treadmill run test to determine their VO_{2max} (ml/kg/min), maximal RER (VCO_2 / VO_2) and maximal running speed (km/h). After 48 hours, the athletes performed the Wingate anaerobic test to determine peak power, mean power, minimum power, and fatigue index. Pearson correlation coefficients were used to examine the relations between variables.

Results Maximal RER was positively correlated with peak power ($r = 0.587$, $p < 0.035$), mean power ($r = 0.656$, $p < 0.015$) and minimum power ($r = 0.674$, $p < 0.012$). Maximal RER did not significantly correlate with fatigue index ($p > 0.05$). Maximal RER was negatively correlated with the VO_{2max} ($r = – 0.705$, $p < 0.007$) and maximal running speed ($r = – 0.687$, $p < 0.01$).

Conclusions Maximal RER may be useful for evaluating anaerobic capacity in anaerobic-trained athletes. Measuring the maximal RER values of athletes during incremental exercise may provide information about physiological adaptations in response to physical training.

Keywords: anaerobic capacity, aerobic capacity, wingate test, incremental exercise

Introduction

The ratio of carbon dioxide produced (VCO_2) to the amount of oxygen (VO_2) used is known as the respiratory exchange ratio (RER). In addition to blood lactic acid, the RER is widely used to assess physiological metabolism in athletes [1]. The RER indirectly informs about the predominant metabolic pathway to provide the energy needed during exercise [2].

The RER changes depending on whether the exercise intensity is above or below the anaerobic threshold and increases with exercise intensity [3, 4]. RER values less than 1.00 mean that energy requirement meets predominantly by aerobic metabolism during exercise. Steady-state RER values measured at rest and exercise intensities below the anaerobic threshold typically range from 0.7 to 1.0, depending on the ratio of substrate utilization to obtain energy [3, 5]. A high RER value indicates predominantly carbohydrate utilization, while a low RER value indicates lipid oxidation [3, 6].

A RER value of about 1.00 represents the highest exercise intensity at which the respiratory system maintains a physiological steady state [7]. Lactic acid produced as a result of the anaerobic glycolysis during exercise disassociates into lactate and hydrogen ions (H^+), and H^+ is buffered by both bicarbonate and non-bicarbonate buffers [8]. The relationship between VCO_2 and VO_2 during an incremental exercise is characterized by a relatively linear relationship up to a certain intensity of exercise [9, 10]. When anaerobic glycolysis begins to predominate energy production, VCO_2 increases faster than VO_2, resulting in an increase in RER [10, 11]. The RER value rises above 1.00 due to non-metabolic CO_2 production from buffering of excess H^+ with bicarbonate in addition to the CO_2 produced by aerobic metabolism [11, 12]. At exercise intensities above the anaerobic threshold (RER > 1.00), hyperventilation occurs so that additional CO_2 produced by buffering excess H^+ can be removed from the body [10, 11]. Therefore, a RER value above 1.00 during exercise indicates predominantly anaerobic metabolism is utilized [11, 12].

RER is used as one of the simplest non-invasive methods to determine the anaerobic threshold [13]. The RER method used to assess the anaerobic threshold is based on the observation that a part of the expired CO_2 is derived from the body bicarbonate pool because of lactic acid accumulation during exercise [10]. Anaerobic threshold values based on RER have been shown to be associated with athletic performance [14, 15]. RER has been shown to provide information about physical fitness at exercise intensity above the anaerobic threshold in trained and untrained healthy men [3]. RER values are also used to provide an index of whether the exercise intensity is too high to be sustained throughout the exercise [16]. A RER value above 1.10 is considered a

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good indicator of achieving maximum effort in healthy individuals [16-18]. During incremental exercise, RER can provide a prediction of maximal oxygen uptake (VO_{2max}) in untrained and trained individual [19]. The peak RER can also be used to assess exercise capacity and metabolic responses in individuals with reduced exercise tolerance [20].

Considering that the RER exceeds 1.0 at exercise intensities above the anaerobic threshold, it has been interpreted that high RER values may be important in high-intensity short-distance efforts [9, 15]. During high-intensity exercise, blood lactate concentration has been shown to be the most important determinant of RER in athletes [21]. Blood lactate concentration can be used to estimate aerobic and anaerobic capacity as it reflects the balance between lactate production and removal [8]. It has been shown that there is a significant relationship between anaerobic performance and post-exercise lactate concentration [22, 23]. The increase in CO_2 and thus the RER has been found to be quantitatively related to the magnitude of the increase in lactic acid [12]. Therefore, the maximal RER measured during incremental exercise may be related to anaerobic capacity in athletes.

The association of the maximal RER with aerobic and anaerobic capacity has not been clearly established. The purpose of this study was to investigate the relationship between maximal RER measured during incremental exercise and anaerobic power and VO_{2max} in anaerobic-trained athletes.

Material and Methods

Participants

Thirteen male alpine skiers (mean ± SD; age 18.1 ± 3.1 years, height 174 ± 3.6 cm, body mass 67 ± 9.5 kg) competing in national and international competitions volunteered to participate in the study. Measurements were performed following the approval of the Ethics Committee and carried out in accordance with the Declaration of Helsinki. All testing and training procedures were fully explained, and written informed consent was obtained for each participant. All athletes performed two tests 48 hours apart, consisting of the incremental treadmill test and the Wingate test. To avoid unnecessary fatigue accumulation, the athletes were not allowed to perform any training the day before each test.

Incremental Treadmill Test

Incremental running test was performed on a motorized treadmill (h/p/Cosmos Quasar med, Nussdorf-Traunstein, Germany). Throughout all tests, breath-by-breath gas measurements were taken using an indirect calorimetric system (Quark PFT Ergo, Cosmed Srl, Rome, Italy) which was calibrated before each session to the manufacturer's instructions. The heart rate was recorded continuously using a wireless HR monitor (S610i, Polar, Finland). Breath-by-breath data were smoothed using a five-step average filter and then reduced to 15 s stationary averages. Maximal oxygen uptake (VO_{2max}), maximal respiratory exchange ratio (RER) and maximal running speed were determined during the incremental treadmill test.

Each athletes performed a standardized warm-up consisting of a 5-min run at their own pace followed by about 3-min stretching. Following the warm-up period, athletes performed a progressive protocol with an initial speed of 7 km/h with speed increments of 1 km/h at a constant 5% incline every minute until they could no longer keep the running pace. The athletes were instructed to run until voluntary exhaustion and given strong verbal encouragement throughout the test to elicit their best performance. Achievement of VO_{2max} was considered as the attainment of at least two of the following criteria: 1) a plateau in oxygen uptake (VO_2) despite increasing speed, 2) an HR within ten beats per minute of age-predicted maximum HR (220 – age), and 3) a respiratory exchange ratio (RER) above 1.10. The VO_{2max} was defined as the highest 15-s VO_2 value reached during the test.

Wingate Anaerobic Test

The Wingate anaerobic test was performed on a computerized cycle ergometer (Monark 824E, Monark, Sweden) in standard version [24]. The athletes completed a warming up of 5 minutes cycling at a pedaling rate of 60–70 rpm including two unloaded maximal sprints of 5 seconds each, performed at the end of the 3rd and the 5th minutes. Following the initial warm-up period, the athletes performed about 3-min stretching. The athletes were instructed to pedal as fast as possible. Following the warm-up period, the athletes pedaled at maximal (all-out) effort for 30s on a cycle ergometer against resistance corresponding to 7.5% of their body mass. Athletes were verbally encouraged to maintain a pedaling rate as high as possible for 30 seconds. Peak power (watts), mean power (watts), minimum power (watts) and fatigue index (percent) were calculated with Monark Anaerobic test computer software program.

Statistical Analysis:

Data are reported as the means ± standard deviation (SD). Statistical significance was accepted at $p < 0.05$. The assumption of normality was assessed through the Shapiro-Wilk test. Pearson correlation coefficients were used to examine the relations between variables. Almost perfect ($r = >0.9$), very large ($r = 0.7$-0.9), large ($r = 0.5$-0.7), moderate ($r = 0.3$-0.5), small ($r = 0.1$-0.3) or trivial ($r = <0.1$) of association were defined [25]. Simple linear regression analysis was used to determine the success of prediction (Sigma Plot 12.0, Systat Software Inc., Chicago, USA). IBM SPSS 21 software (IBM SPSS Statistics 21 Inc., Chicago, IL) was used for the statistical analyses.

Results

The results obtained during incremental treadmill test and Wingate anaerobic test are shown in Table 1. Linear regression analyses of the relationship between maximal RER and Wingate anaerobic test variables are given in figure 1.A, B and C. Maximal RER was largely positively correlated with peak power ($r = 0.587$, $p < 0.035$), mean power ($r = 0.656$, $p < 0.015$) and minimum power ($r = 0.674$, $p < 0.012$). Maximal RER did not significantly correlate with fatigue index ($r = – 0.074$, $p > 0.05$).

Figure 1.D shows the linear regression analysis of the relationship between maximal RER and VO_{2max}. Maximal RER was very largely and largely negatively correlated with the VO_{2max} ($r = -0.705$, $p < 0.007$), and maximal running speed ($r = -0.687$, $p < 0.01$), respectively.

Table 1. Mean values for variables determined from incremental treadmill test and Wingate anaerobic test. Mean ± SD

Variables	Mean ± SD
VO_{2max} (ml/kg/min)	54.2 ± 6
Maximal running speed (km/h)	14.3 ± 0.6
Maximal RER (CO_2/O_2)	1.19 ± 0.03
Peak power (Watts)	601.6 ± 123.6
Mean power (Watts)	454.9 ± 80.1
Minimum power (Watts)	266.8 ± 49.9
Fatigue index (%)	55.3 ± 3.4

Discussion

We examined whether maximal RER measured during incremental exercise was related to anaerobic power and VO_{2max} in anaerobic-trained athletes. The main results of this study indicated that maximal RER was positively correlated with the peak power, mean power and minimum power. This finding suggests that the higher the maximal RER, the better the anaerobic capacity in anaerobic-trained athletes. In addition, higher maximal RER was associated with lower VO_{2max} and maximal running speed during the incremental exercise. Maximal RER may be useful for estimating anaerobic capacity in anaerobic-trained athletes.

Above the anaerobic threshold, RER kinetics reflect additional CO_2 production as a result of H^+ buffering associated with lactic acid increase and compensatory hyperventilation for metabolic acidosis [9, 11]. The association between increased blood lactate concentration and decrease in intracellular pH [26] has been documented to occur with a decrease in power [27]. A peak RER value between 1.10 and 1.20 is considered a good indicator of achieving maximum effort in healthy individuals during incremental exercise [17]. In the present study, the maximal RER measured during incremental exercise was related to the peak power, mean power and minimum power of the Wingate anaerobic test. Anaerobic power and capacity are the best indicator of athletic performance in alpine skiing, which race duration varies between 45 seconds and 3 minutes [28]. Anaerobic capacity in alpine skiing is commonly evaluate using the Wingate

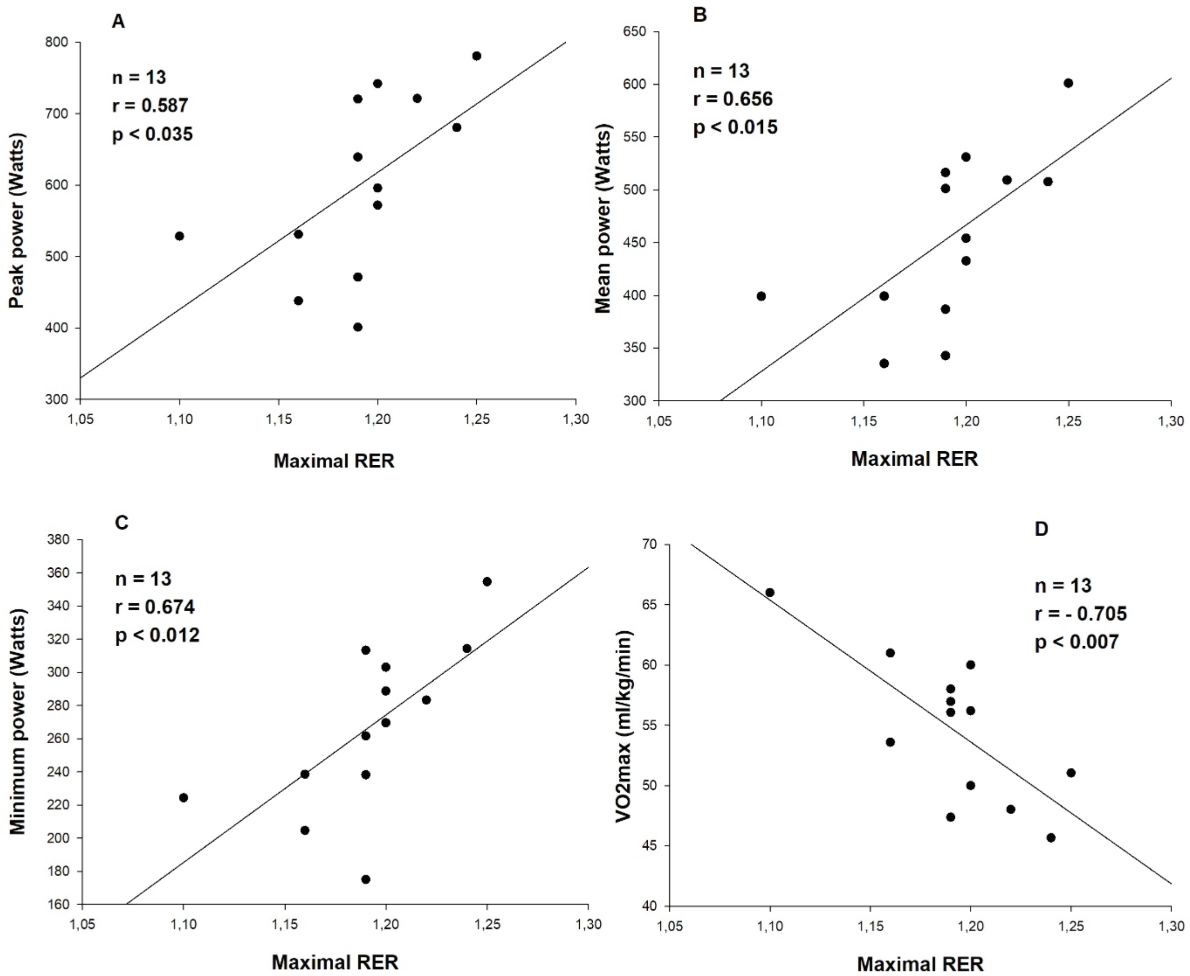

Figure 1. Correlation between A) peak power and maximal RER, B) mean power and maximal RER, C) minimum power and maximal RER, and D) VO_{2max} and maximal RER in all subjects.

anaerobic test [29, 30]. The Wingate anaerobic test, consisting of 30 seconds of maximum cycle exercise, is performed to determine the athletes' ability to maintain their maximal anaerobic power and high-power output [31]. It has been shown that 80% of the energy turnover during Wingate anaerobic test is derived from anaerobic metabolism dominated by glycolysis [33]. Maximal RER may be useful for determining the glycolytic capacity in anaerobic trained athletes. We did not directly measure blood lactate levels in our study. On the other hand, the maximal RER is likely to reflect the rate of lactic acid accumulation [12]. During high-intensity exercise at 70% of peak power output (80% VO_{2peak}), plasma lactate concentration has been shown to be the most important determinant of RER in trained cyclists [21]. The higher RER value may be explained by the higher demand of anaerobic glycolysis during the incremental exercise test and thus the higher lactic acid concentration. It has been shown that the subjects who achieved the best performance in the repeated sprint test were achieved higher lactate concentrations [22]. A close correlation has been found to be between the post-competition blood lactate concentration and the velocity maintained over 400-m and 800-m top-level competitions [23]. Besides the post-exercise blood lactate concentration [23], maximal RER values may also be used to evaluate the anaerobic capacity of athletes.

A RER value above 1.10 has been proposed as evidence of attainment of VO_{2max}, which is known as an indicator of aerobic capacity [17, 18]. In the current study, maximal RER was statistically negatively related to VO_{2max} and maximal running speed measured during the incremental exercise. Similar to our results, Ramos-Jiménez et al. showed that VO_{2max} was negatively correlated with RER measured during three different exercises at below, within, or above the lactate threshold [3]. A negative correlation between relative blood lactate change and VO_{2max} during incremental exercise has been reported [8]. RER response during maximal incremental exercise may be affected by different types of physical training [19]. In our study, the subject profile consists of alpine skiers. In alpine skiing, the physical capacity of the athlete is closely related to the ability to perform high-intensity exercise and develop high power output [30]. For this reason, the traditional training of alpine skiers includes anaerobic exercises such as plyometric training, speed, change of direction and resistance training [33]. During incremental exercise, anaerobic-trained athletes have been shown to have a greater lactate increase after the anaerobic threshold than endurance-trained athletes, despite having lower VO_{2max} [8]. In our previous study, we observed higher maximal RER values in alpine skiers compared to endurance athletes, despite a lower VO_{2max} and shorter running time to exhaustion during incremental exercise [34]. Higher RER values may mean that anaerobic-trained athletes utilized a greater proportion of anaerobic metabolism at higher intensity during exercise than aerobic-trained athletes. Anaerobic training increases intracellular and extracellular buffer capacity [35], which may contribute to a higher increase in RER values [36].

Maximal RER values may also be related to the genetic makeup of the athlete. Fast-twitch fiber-dominant muscle has a higher buffering capacity of H^+ than slow-twitch fiber-dominant muscle [37]. RER has been shown to be inversely related to the proportion of slow-twitch muscle fibers during exercise [38]. A high RER reflects a direct respiratory response to arterial acidosis as well as an indirect stimulation of chemosensitive fibers by local metabolic changes [16]. When the buffering systems are saturated, H^+ can no longer be compensated by the circulation, causing a drop in blood pH and, as a result, the accumulation of H^+ stimulates hyperventilation [8, 11]. A high muscle buffer capacity may allow anaerobic glycolysis to be longer utilization before the performance-limiting pH level is reached [37].

After the anaerobic training period, blood lactate concentrations may increase more than before the training period during exhaustive exercise due to increased muscle buffer capacity and glycolytic enzymes [39]. It has been shown that athletes who regularly perform anaerobic training have a greater muscle buffering capacity than endurance athletes or untrained subjects [8]. During anaerobic exercise training, large accumulation of lactic acid may improve buffer capacity [35, 39], providing a stimulus for the adaptation of muscle pH regulatory systems [31]. Reducing the inhibitory effects of H^+ in muscle cells by anaerobic training may lead to the improvement of the athlete's ability to perform high-intensity exercise for a longer period [31]. The magnitude of the RER increase at heavy exercise intensities is likely to depend on the rate of buffering [12]. After a period of anaerobic training, the H^+ release and buffering capacity of the muscles has been shown to be increases [40]. In our previous study, after a 6-week period of anaerobic training, maximal RER values during incremental exercise increased by 5.6 % compared to the pre-training period, which may be due to enhanced buffering capacity [36]. On the other hand, endurance training to improve aerobic capacity increases oxidative enzyme activity while decreasing RER values [41]. Presumably, the anaerobic training stimulus may increase glycolytic and buffering capacity as contributing factor to anaerobic capacity. Therefore, it is likely that RER during incremental exercise may increase in relation to anaerobic capacity in anaerobic-trained athletes.

Conclusions

The results of the present study indicated that higher maximal RER was associated with higher anaerobic power, while lower aerobic capacity in anaerobic-trained athletes. Maximal RER may be important for determining anaerobic capacity in anaerobic-trained athletes. Measuring the maximal RER values of athletes during incremental exercise may help evaluate their physiological characteristics and physiological adaptations in response to physical training. Further research is necessary to determine the relationship between anaerobic capacity and maximal RER and lactate concentration in athletes.

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Conflict of interest
Authors declare no conflict of interest.

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Results

Discussion

Conclusions

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