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ORIGINAL ARTICLE

Cytokine responses to small sided games in young soccer players

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

Abstract

Background and Study Aim Small-sided games (SSG) are frequently used by coaches due to the effect of soccer players in improving their technical, tactical, and physical characteristics in training. When we try to improve of our players talent, we must know what kind of changes happen in blood samples. For this reason, we aimed to determine of cytokine responses to SSG in young soccer players.

Material and Methods Fourteen active male soccer players (14.5± 0.6 years) in the Under-14 and Under-15 teams voluntarily participated in the study. Soccer players are divided into 2 groups as 3x3 and 4x4 groups. 3x3 group players played 2x6x1 minutes small-sided games in 25x20 m area and 3x6x2 minutes small-sided games in 30x25 m area for 4x4 group players. Blood samples were collected at baseline pre-training and at immediately after the exercise post-training to measure interleukin 6 (IL-6), tumor necrosis factor (Tnf-α), and lactate (La) parameters. And also, heart rate (HR) and rating of perceived exertion (RPE) determined both pre-training and post-training.

Results In the study, post training levels of La, IL-6, Tnf-α, HR, and RPE both in 3x3 group and in 4x4 group were found to be significantly higher than pre-training ($p<0.05$). When the post training parameters of both groups were examined, only the Tnf-α level increased significantly in the 4x4 group ($p<0.05$), while no difference was found in the other parameters ($p>0.05$).

Conclusions Small sided games which are acutely applied in young soccer players, both 3x3 group and 4x4 group is are similar. However, with a more players can increase tnf-α released and this can effect performance as negatively in young soccer players.

Keywords: soccer, cytokine, interleukin, small-sided games

Introduction

Soccer is a sport in which anaerobic movements are practiced on an aerobic basis as a game. It is based on explosive movements such as agility, jumping, and shooting, and while players often change pace during a competition, it covers a distance of approximately 10 km. For this reason, one of the most important parts of training programs should be focused on improving the ability to use muscle strength effectively and continuously [1]. It is known that small-sided games (SSG) are frequently used by coaches due to the effect of soccer players in improving their technical, tactical, and physical characteristics in training [2].

SSG is very popular not only in adult players, but also in young soccer players, and their use begins from an early age. It is stated that it is beneficial to use small-sided games especially in young players and the reason is that it is directly related to the frequency of application of some skills [2]. It is observed that these skills are frequently repeated during small-sided games and also beneficial for the development of endurance [3]. During SSG in young players, training stimuli must be suitable for the characteristics of the individuals and therefore the rules should generally be changed to suit the physical development of young players [4]. Due to the smaller area and fewer players during the SSG, the number of situations encountered by each player on the ball and based on the game [5], as well as rating of perceived exertion (RPE), heart rate (HR) and blood lactate levels also change with the size of the playing field [6]. IL-6 manifests itself as an inflammatory response, especially following an acute exercise, with skeletal muscle contraction and subsequently IL-6 levels produced by a systemic increase in the concentration of anti-inflammatory cytokines [7]. Tumor necrosis factor-alpha (Tnf-α) and Interleukin (IL)-6 bind firmly and therefore stimulate of TNF-α to IL-6 production [8,9]. The increase in the amount of IL-6 produced by the muscle was found to be related to the duration, intensity, and muscle mass involved in the work done by the body. This increase decreases gradually after exercise [10]

Two hours after 90 minutes of soccer match, IL-6 (125%) and TNF-α (18%) levels significantly increased in children before adolescence [9]. McMurray et al. [11] reported that after 10x2 minutes of high-intensity exercise applied to adolescent children, they increased their anti-inflammatory IL-6 and TNF- α levels by 80%. In response to an acute endurance exercise, some researchers said that there were significant increases in the levels of IL-6 and TNF-α from inflammatory mediators [12], as well as in researchers who said there was

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no change [13] or even reduction [14]. As can be seen from the literature, there appears to be a contradiction concerning changes in IL-6 and TNF-α levels after an acute exercise. Also, given the physical development of young soccer players, there is a need for up-to-date information on muscle damage and muscle fatigue during athletes, which are so popular in small-sided games. In this study, it was aimed to determine the effects of 3x3 and 4x4 small-sided games applied to young players on rating of perceived exertion, heart rate, muscle fatigue, and muscle damage of players.

Material and Methods

Participants

Fourteen active male soccer players in the Under-14 and Under-15 teams voluntarily participated in the study. The median age of all players was 14 years old (min: 14 years old, max: 15 years old). There was no significant difference in age between the 3x3 and the 4x4 groups (Table 1). Subjects with any diseases (hypertension, thyroid, diabetes, cardiac, etc.) were not included in this study. We informed family of the participants in detail about the objectives of the study according to the Helsinki Declaration and obtained informed consent. This study was approved by the Ethics Committee of the Selcuk University.

Table 1 shows that descriptive statistics of participants.

Research Design

Soccer players are divided into 2 groups as 3x3 and 4x4 groups. 3x3 group players played 2x6x1 minutes small-sided games in 25x20 m area and 3x6x2 minutes small-sided games in 30x25 m area for 4x4 group players (Table 2).

Measurements

Height of all subjects was measured before the tests with a stadiometer with a sensitivity of 0.01m (m) and an electronic scale (Seca, Germany) with a bodyweight of a precision of 0.1 kilograms (kg). Heart rate (HR), rating of perceived exertion (RPE) and blood parameters were taken from the soccer players participating in pre-exercise and at immediately after the exercise. IL-6, Tnf-α and La parameters were determined from blood samples.

Heart Rate (HR): The heart rate measurements of the subjects pre-training and post training were measured with a heart rate monitor (Polar Team Pro 2, Polar Electro, Finland), which can measure within 1-second interval.

Rating of Perceived Exertion (RPE): Perceived difficulty levels of the athletes were measured with a 6-20 Borg scale. On the scale, 20 represents the highest value and 6 represents the lowest value.

Collection of Blood Samples: After taking the appropriate amount of blood samples (2.5 ml) from the athletes' cephalic vein, the serum was kept at -80°C until the analysis time after the serum was separated. Lactate (La) levels, which is one of the serum samples obtained from the subjects, was determined via Siemens Advia centavur, Tnf-α and IL-6 values were studied with the Elisa device using the micro eliza method. Blood collection procedures were performed under the supervision of a physician.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics 23 (IBM Corp). Variables were assessed using the visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk's test) for normal distribution. Descriptive analyses were presented using frequencies, medians, and minimum-maximum values since variables were not normally distributed. In the research, Mann Whitney U Test was used to evaluate the differences between the groups, and The Wilcoxon test was performed to test the significance of pairwise differences using the Bonferroni correction to adjust for multiple comparisons; 5% type-I error level was used to infer statistical significance.

Table 1. Descriptive statistics of the participants

Parameters	N	Mean	Sd
Height (cm)		170	7.8
Weight (kg)	14	68.5	4.2
Years (age)		14.5	0.6

Table 2. Dimension of Small-Sided Games

Parameters	Playing Time(min)	Rest (min)	Play-ground Size (m)	Total Size (m^2)	Per Players (m^2)
3x3 (n=6)	2x6	1	25x20	500	1: 83.33
4x4 (n=8)	3x6	2	30x25	750	1: 93.75

Results

According to Table 3, when the La, IL-6, Tnf-α, HR and RPE levels of the 3x3 and 4x4 groups included in the study were examined, the post training values for both groups were found significantly higher than before the study (p<0.05).

According to the analysis in the present study, when the La, IL-6, Tnf-α, HR and RPE levels of the 3x3 and 4x4 groups in the study were examined, the Tnf-α values at post training were significantly higher than the post training 3x3 group levels (P<0.05). When the La, IL-6, HR and RPE values at post training were analyzed, no significant difference was observed between the data of both groups (Table 4) (p<0.05).

Discussion

In this study, during the SSG, 83.3 m^2 of play area was dropped for each 3x3 group (dividing the field area by the number of players), this ratio was 93.75 m^2 for the 4x4 group. While the heart rate of the 3x3 group was 180.17± 9,54 beats/min, the heart rate of the 4x4 group, which increased the area per player, was 182.13± 11,46 beats/min. Halouani et al. [2] studied on young footballers, it is important to support our study, by reporting the heart rate of the players as 180±2.00 beats/min after 4x4 small-sided games. Also, the fact that the heart rate after the small-sided games was significantly higher than the previous heart rate in both groups shows that the small-sided games significantly affect the heart rate. Dellal et al. [15] reported that the number of heart rate increased significantly after the small-sided games applied to amateur and professional soccer players. In the study carried out, it was seen that the HR of the 3x3 and 4x4 game groups were statistically similar to each other at post training. 4x4 games have been implemented in a larger area with longer playtime compared to 3x3 games, but no significant difference has been found between the two groups in terms of HR. Kelly and Drust's study [16] reported that changes in field size in 4x4 SSG did not cause a change in the study of adult players. Unlike in another study, it has been observed that the field of soccer players decrease as the field size and the number of players increase in English professional soccer players [17]. Although these results show that there is no consensus in the literature, it can be said that the difference is due to the difference in the experimental design with the study groups.

The present study, the significant increase in the post training lactate levels of the 3x3 and 4x4 groups compared pre training shows that both the small sided games performed acutely affect the lactate levels significantly. However, when the lactate values of 3x3 and 4x4 small sided games groups were examined, there was a decrease in the 4x4 game group but it was not found statistically significant. In SSG, it has been reported that the amount of La decreases when the number of players whose field size remains the same [18]. As a matter of fact, in his study where Köklü [19] examined small-sided games, 3 sets of intermittent small-sided games and each playing time was 2 min (15x20 m playground),

Table 3. Comparison of pre training and post training La, IL-6, Tnf-α, HR and RPE levels of the participating groups

Parameters	3x3 (n=6)		4x4 (n=8)	
	Pre training	Post training	Pre training	Post training
Lactate (mmol/L)	2.66 ± 0.59	6.64 ± 2.56*	2.35 ± 0.26	4.96 ± 2.10*
IL-6 (pg/ml)	18.3 ± 4.83	29.21±9.86*	25.13±12.05	33.53±26.86*
Tnf- α (pg/ml)	0.75±0.16	1.23±0.82*	1.04±0.11	2.96±1.15*
HR (beat/min)	135.67±5.39	180.17±9.54*	95.13±15.49	182.13±11.46*
RPE	6.33±0.52	12.67±0.82*	8.63±1.69	13.63±2.07*

*: (p<0,05)

Table 4. Comparison of post training La, IL-6, Tnf-α, HR and RPE levels of the participating groups

Parameters	3x3 (n=6)	4x4 (n=8)	Sig.
Lactate(mmol/L)	6.64 ± 2.56	4.96 ± 2.10	0.228
IL-6 (pg/ml)	29.21±9.86	33.53±26.86	1.000
Tnf- α (pg/ml)	1.23±0.82	2.96±1.15*	0.001*
HR (beat/min)	180.17±9.54	182.13±11.46	0.755
RPE	12.67±0.82	13.63±2.07	0.108

*: (p<0,05)

3 min (18x24 m playground) and 4 min (24x36 m playground). The lactate levels at post training; 7.8 mmol. L-1 for 2x2 small-sided games, 6.8 mmol. L-1 for 3x3 small-sided games and 6.7 mmol. L-1 for 4x4 small-sided games setting it as supports our study. However, contrary to the studies mentioned, there is a study reporting that the lactate values increase in amateur footballers with an increase in the field size in 3x3, 4x4, 5x5, and 6x6 SSG applied as 3 sets [20]. It can be said that these contradictory results seen in the literature may be due to the duration of small-sided games, the duration of rest, and the difference in the groups of players.

Many studies show that lactate concentrations and rating of perceived exertion increase with increasing field size [5, 21]. In the study, while RPE values belonging to 3x3 group (1:83.3 m^2) were 12.67± 0.82, RPE values belonging to 4x4 group (1:93.75 m^2) where the area per player increased, was 13.63 ± 2.07 and there was no statistical difference between the groups. Fanchini et al. [22] applied the duration of the game sets as 2 minutes, 4 minutes and 6 minutes, and the rest time between sets as 4 minutes in their study on 3 to 3 small-sided games. At the post training, there was no significant difference in RPE values between sets. Also, in a study with 14 young soccer players (15.57± 0.65 years), stated that RPE values as 10.98 ± 1.43 at the end of the 4-minute game, which was played for 4 minutes, and 4 sets of 47.5x 28.5 m [23]. In the study carried out, 3x3 and 4x4 small-sided games that were acutely applied in different fields and periods did not make a significant difference in terms of RPE values. This result is similar to some of the above-mentioned literature but contradicts others.

Intermittent exercises for young athletes are reported to trigger anti-inflammatory responses to exercise within 24 hours [24]. IL-6 is produced in larger quantities than other cytokines compared to exercise. Northoff and Berg's study [25] were the first to suggest that IL-6 may play a role in the formation of an acute phase response after exercise. In this study, parallel to the first findings in the field, both post-exercise IL-6 values in the 3x3 group were 29,21± 9,86 U/ L, and post-exercise IL-6 values in the 4x4 group were 33,53± 26,86 U/ L has increased considerably according to pre-exercise values. Dring et al. [24] found a significant increase in IL-6 levels of participants after a 60-minute basketball training actively applied to 39 participants (20 men, 19 women) between the ages of 11-13. Similarly, Fanchini et al. [21] study on cytokine response after two soccer matches at 72-hour intervals, and a significant increase in IL-6 levels correspond with the findings. In a study stated that played 2 acute small-sided games to 12 young handball players in 5 days and at the end of the study, they found significant increases in IL-6 levels of handball players [26]. Exercise causes a lot of immunological changes, and it has been observed that the working muscles produce and release large amounts of IL-6 into the circulatory system. Besides, TNF-α and IL-6 are tightly bound and are thus known to stimulate of TNF-α to IL-6 production [8, 27]. When the post-exercise values of La, HR, RPE, and IL-6 parameters were compared between the 3x3 and 4x4 groups, no significant difference was observed. Only TNF-α values (2.96± 1.15 pg/ml) in the post training 4x4 group showed a significant increase compared to (1.23± 0.82 pg/ml) in the post training 3x3 group ($p<0.05$). This increase suggests that 4x 4 small-sided games causes more bilateral struggles and exercise stress both in terms of playing time and the number of players. Similarly, Dello lacono et al. [26] reported that fatigue and muscle damage may occur as a result of physical contact in team sports that require bilateral struggle. It is also stated that with the increase in exercise severity, activation of the endocrine system and emptying of muscle and liver stores may stimulate cytokine release.

Conclusions

In conclusion, many coaches continue to apply to small-sided games in young soccer player to enhance their performance and this training protocol affects their performance as positive or negative. Fatigue-related conditions and IL-6 released are similar in the 4x4 and 3x3 game form in young soccer players. When coaches apply to SSG with more player it can increase tnf-α released and this can effect performance as negatively in young soccer players. In addition to 3x3 and 4x4 SSG, other SSG protocol with more players should be investigated for future studies. Also, the chronical effects of small-sided games during long period can also be examined.

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ORIGINAL ARTICLE

The effect of 8 weeks plyometric exercise on physical and motoric features of mental disabled

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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: Physical activity for disabled people is a long-debated issue. The number of studies examining the effects of alternative exercise programs on the physical and motor outcomes of people with intellectual disabilities is limited. For this reason, the purpose of this study is to investigate the effects of 8-week plyometric exercises on some physical and motor characteristics of mentally retarded people.

Material and Methods: The method of this study is the experimental method, one of the quantitative research methods. The sample of the study consists of 24 moderately and mildly mentally retarded students aged 11-17 years old studying at a special vocational school. Participants completed a plyometric training program 3 days per week for 8 weeks. Before the training program, height, weight, BMI, vertical jump, sit and reach, standing long jump, circumference measurements, handgrip strength, shuttle test, leg strength, and back strength were compared with those after the training program. The SPSS 25 program was used for the statistical operations. The Wilcoxon test, one of the non-parametric tests, was used to compare the data.

Results: As a result of statistical analysis, significant differences were found in height, weight, vertical jump, sit and reach, handgrip strength, shuttle test, leg strength, and back strength of the participants before and after the training program ($p < 0.05$). There was no significant difference between the body circumference measurements and BMI results ($p > 0.05$).

Conclusions: When evaluating the results of the study, it was found that plyometric exercises have a positive effect on the physical and motor characteristics of the intellectually disabled people.

Keywords: physical activity, intellectual disability, plyometric exercise, motor characteristics

Introduction

Intellectual disability is one of the important issues that belong to developmental disorders and should be treated in childhood: mental retardation; the child's general intellectual functioning is significantly below average [1, 2, 3, 4]. In addition, it is defined as inadequacy in two or more adaptive behaviors such as communication, self-care, home life, social skills, academic functioning, self-direction, health, safety, leisure, and work [3, 4, 5, 6, 7].

Mental retardation affects 3% of the total pediatric population [8]. According to the results of the Disability in Turkey study, the proportion of the disabled population in the normal population is 12.29%, and 15.5% of the disabled population is mentally disabled [9].

The human body has great potential to adapt both structurally and functionally to physical exercise. Achieving this harmony with exercises aimed at improving sport-specific performance has led to the development of various training techniques [10]. The application of various training techniques and programs to the disabled has led to changes in the goals of disability sports.

One of the most important concepts in disability sports is athletic success. In order to achieve a high level of success in sports, it is necessary to work systematically and based on training principles [11, 12, 13, 14]. The idea of raising athletic performance to a higher level has appeared day by day in disability sports, and various training programs have been introduced. Training models designed to improve athletic performance often consider exercises for power, strength, and speed [12, 13, 15, 16]. Numerous training methods can be found in the literature to improve general motor characteristics and athletic performance. Plyometric training programs are just some of them.

In order to improve the athlete's speed, a system was developed to activate the explosive response during the execution of explosive movements [17, 18]. This system is plyometric training, a fairly new method that improves jumping performance and facilitates muscle response. Many researchers have noted very important physiological and physical developments as a result of plyometric training [19, 20, 21]. There is strong evidence that plyometric training improves basic motor performance [22, 23, 24].

People with intellectual disabilities have some problems performing complex exercises. However, plyometric exercises are straightforward and easy

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to perform. Reviewing the literature, one finds that the number of studies on the effect of alternative and applicable exercise programs for the mentally retarded is small. With this in mind, the aim of this study is to investigate the effects of 8 weeks plyometric exercises on the physical and motor characteristics of people with intellectual disabilities.

Material and Methods

Participants

The method of this research is the experimental method, one of the quantitative research methods [4, 14, 25]. The universe of this study consists of students with moderate and mild intellectual disabilities. WSSPAS: Web-Based Sample Size & Power Analysis Software [26], developed by İnönü University Faculty of Medicine, Department of Biostatistics and Medical Informatics, was used to determine the number of participants to be included in the study. After power analysis, it was determined that at least 20 participants should participate in the study. In this regard, the sample of our study consists of 24 (19 men, 5 women) students who aged 11-17 years, with moderate and mild intellectual disabilities. All participants were informed by the researcher about the possible risks and details of the study. Since the participants were under the age of majority, 'Voluntary Consent Form' was obtained from their parents. The study was approved by the Istanbul Esenyurt University Health Sciences Institute Ethics Committee. The research was conducted in accordance with the criteria of the Declaration of Helsinki.

Research Design

Anthropometric measurements and test batteries were performed on the volunteers who participated in the study. In this context, the height, weight, and BMI values of the participants were determined. Vertical jump test, sit and reach test, standing long jump test, handgrip strength, shuttle test, and back strength and leg strength test were also performed. Body circumference was measured and recorded on the right side of the participants using a tape measure. The participants were given the necessary information about the test, the test equipment was presented, and the necessary motivation was provided during the test. Information about the general health of the participants was obtained. Before starting the test, participants were given a trial to understand the tests. To evaluate the tests, each application was performed 2 times after the trial and the best score was noted.

Statistical Analysis

The SPSS 25 program was used for the statistical analysis in this study. The mean (X) and standard deviation (sd) of all subjects were calculated. In the analysis of normality between groups, the values of kurtosis and skewness (between +1.5 and -1.5) were checked. The study found that the data had a normal distribution. To compare the groups, the 'Paired-Samples T Test', one of the parametric tests, was performed. The study set a significance level of $p < 0.05$.

Results

When Table 1 is examined, a significant difference was found in the height and weight of the participants ($p<0.05$), but no significant difference was found in BMI ($p>0.05$).

When Table 2 is examined, a significant difference was found in the vertical jump, sit and

Table 1. Comparison of Wilcoxon test results for anthropometric characteristics

Parameters	Pre-Study $\bar{X} \pm SS$	Post-Study $\bar{X} \pm SS$	Z	p
Weight (kg)	60.43 ± 17.71	61.29 ± 17.18	-2.701	.007*
Height (cm)	165.12 ± 16.46	166.83 ± 16.44	-3.646	.000*
BMI (kg/m^2)	28.39 ± 29.73	22.03 ± 5.39	-3.646	.377

*Significance level was determined as $p<0.05$.

Table 2. Comparison of Wilcoxon test results of participants' motoric characteristics

Parameters	Pre-Study $\bar{X} \pm SS$	Post-Study $\bar{X} \pm SS$	Z	p
Vertical Jump (cm)	11.70 ± 7.41	15.91 ± 8.41	-4.223	.000*
Sit and Reach (cm)	13.37 ± 6.98	115.45 ± 7.04	-4.367	.000*
Standing Long Jump (cm)	90.20 ± 33.50	100.20 ± 34.37	-3.919	.000*
Handgrip (kg)	23.99 ± 11.01	25.76 ± 10.82	-3.302	.001*
Shuttle Test (no)	10.20 ± 4.42	13.16 ± 4.46	-4.233	.000*
Back Strenght (kg)	50.37 ± 29.16	53.91 ± 29.10	-4.322	.000*
Leg Strenght (kg)	43.50 ± 21.41	47.70 ± 22.50	-4.305	.000*

*Significance level was determined as $p<0.05$.

Table 3. Comparison of Wilcoxon test results of participants' body circumference

Parameters	Pre-Study $\bar{X} \pm SS$	Post-Study $\bar{X} \pm SS$	Z	p
Shoulder Circumference (cm)	97.87 ± 12.79	98.54 ± 12.60	-1.492	.136
Chest Circumference (cm)	84.00 ± 10.57	83.91 ± 10.32	-.154	.878
Abdominal Circumference (cm)	78.37 ± 14.82	78.16 ± 15.36	-.211	.833
Hip Circumference (cm)	89.83 ± 14.76	89.54 ± 14.17	-.847	397
Upper Leg Circumference (cm)	42.91 ± 5.62	42.54 ± 5.74	-.545	.586
Lower Leg Circumference (cm)	32.70 ± 4.63	33.37 ± 4.86	-1.948	.051

*Significance level was determined as $p<0.05$.

reach, standing long jump, hand grip, shuttle test, back and leg strength of the participants ($p<0.05$).

When Table 3 was examined, it was found that the body circumference measurements of the participants did not change significantly after the training program ($p>0.05$).

Discussion

The purpose and type of exercise training for people with disabilities has long been a debated topic. There are shortcomings in the literature regarding which exercises provide the most benefit for different disability groups. The motor and physical development deficits caused by the disability should be well known, and care should be taken to select exercises that are not too difficult for the disabled person to use. Reviewing the literature, it was found that plyometric exercises have positive effects on physiological and motor characteristics [27, 28, 29].

In the literature, it has been determined that the motoric development of the mentally handicapped is not sufficient, and it has been observed that the strength training applied to these individuals produces positive developments in their motoric properties [1, 2, 12, 13, 15]. When examined in this context, in the study conducted by Ates [30], in addition to the football training, there were significant differences in the results of vertical jump, leg and back strength, right hand grip strength, and sit-up test results in the football players who underwent plyometric training 2 days per week compared to the control group. Bavlı [31] concluded that plyometric training in combination with basketball training has a positive effect on motor characteristics. In the study conducted by Palandino and Barriuso [32], it was found that plyometric exercises and eccentric exercises had a positive effect on the jumping and balance performance of football players. Bedoya et al. [33] concluded in the literature review that football-specific skills such as jumping and agility improved significantly.

Kurt et al. [34], which examined the effects of speed training and plyometric training on speed, jumping, and anaerobic performance in hearing-impaired individuals, found that these training methods had a positive effect. In his study, Elnaggar [19], found that plyometric training has a positive effect on balance performance in children with cerebral palsy (CP). He concluded that plyometric training promotes physical rehabilitation and muscle activation in CP. Hammami et al [35] concluded that plyometric exercises increase the level of physical fitness in junior male handball players. In studies conducted with different sample groups, plyometric exercise has been shown to cause physiological changes as well as physical and motoric effects [19, 30, 31, 35, 36].

This study showed similar results with studies in the literature. It is thought that well-planned plyometric training programs will also show positive results in individuals with other disabilities.

Whether for rehabilitation or performance improvement, plyometric training is a training method that should be included in training programs.

Study Limitations

This study was planned for more participants, but the number of participants was limited due to the pandemic. The study can be repeated by increasing the number of participants.

Conclusions

The result of this study: since plyometric exercises do not involve complex exercises, physical and motor characteristics were found to improve when applied to individuals with moderate and mild mental disabilities. The results of our study will provide guidance to trainer, teachers and families working with individuals with intellectual disabilities. It is thought that plyometric exercises can be applied to the mentally handicapped in physical education and sports activities. The effect on mentally disabled people can be studied by using easy to perform exercises, such as Calisthenic Exercise, Functional Exercise or Core Exercise.

Conflict of interest

The authors claim that there is no conflict of interest.

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ORIGINAL ARTICLE

Optimization of body balance indices according to Body Mass Index categories during physical education lessons for university students

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Abstract

Background and Study Aim: Body stability is an important factor in the manifestation of human motor skills. The purpose of the research is to evaluate the efficiency of balance exercises, applied for 28 weeks, with a frequency of one activity / week, on a group of undergraduate students of the "Dunărea de Jos" University of Galați.

Material and Methods: 195 subjects participated (99 males and 96 females), divided for analysis into 3 groups (underweight, N = 21, age = 20.16 ± .38, BMI = 17.46 ± .20); (normal weight, N = 111, age = 20.30 ± .21, BMI = 21.70 ± .17); (overweight / obese, N = 63, age = 19.90 ± .18, BMI = 30.69 ± .61). The tests were applied at 3 distinct times: initial T1 at the beginning of the academic year, intermediate T2 towards the end of semester 1 and final T3 at the end of semester 2. 3 static balance assessment tests were used (One leg standing test with closed eyes, Stork test and Flamingo test), respectively 4 tests to evaluate the dynamic balance (Bass test, Functional reach test, Walk and turn field sobriety test and Fukuda test).

Results: ANOVA with repeated measurements and the differences between the test moments highlight in most cases values of F associated with significant thresholds ($p < 0.05$), so there is an improvement in results for all 3 groups. The differences between T1 and T2 tests are larger than those between T2 and T3, so for almost all tests the progress is higher in the first semester, and in semester 2 there is a slight reduction, as a result of adapting to the proposed exercises. Even if they progress significantly, the group of overweight people has obviously weaker average results than normal weight and underweight people, signaling numerous individual cases that have problems in maintaining static balance and commit errors in dynamic balance tests. The better performances of the underweight in 3 cases (One leg standing test, Flamingo test Fukuda test and Walk and turn field sobriety test) cannot be generalized due to their small number compared to the other 2 groups, and this aspect can be considered as a new direction of investigation.

Conclusions: There are premises for a favorable evolution of the balance indices for the group tested in this age group, but it must be taken into account that the low initial fitness level (generated by the lack of concerns for a lifestyle based on physical activities) is a factor that facilitated these less spectacular advances, but still statistically significant.

Keywords: students, static and dynamic balance, assessment, BMI stages, physical activity

Introduction

The balance of the body is important in maintaining different positions and the correct execution of movements, and along with increasing postural muscle strength has a decisive role in the stability of the body of obese people, who have high risks of falling [1, 2, 3]. The sense of balance is fundamental in ensuring the technical correctness of the procedures in sports activities and reducing the risks of injury [4, 5, 6]. The importance of dynamic balance training for young athletes in Malaysia as a factor in injury prevention is highlighted by Lee et al. [7]. The use of balance assessment tests (as elements of the functional fitness battery) may signal possible postural control deficits, induced by the occurrence of muscle fatigue and affecting the efficiency of motor activities [8]. Poor balance values are often correlated with problems and risks of ligament and muscle injuries, requiring actions to improve coordination, which also has beneficial effects on the results of balance tests [9].

The optimal interaction between the vestibular, proprioceptive and visual systems conditions the performance associated with balance, which may be affected by aging [5, 10, 11, 12]. The values of the balance evaluated with the eyes open are higher than the ones evaluated with the eyes closed, aspect confirmed by the testing of the Polish ballerinas, at which better performances are signalled with increasing age, those aged 18 years old having higher results than puberty 14 years old [13]. Postural stability also depends on the information provided

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by the cervical proprioceptors, whose feedback improves the balance on the non-dominant leg of Taekwondo fighters, compared to untrained people [14]. Ways to optimize body stability for different age groups are frequently sought.

The introduction of additional actions with the additional demand for attention can affect the balance. Frequent use of mobile phones for Taiwanese students (texting while walking) affects dynamic balance performance and reduces postural stability, but it has been found that younger subjects can easily prevent falls and adapt more quickly to such tasks, according by Nurwulan et al. [15].

For children and adolescents (9-18 years) there is an improvement in postural balance with increasing age, for groups of athletes aged 9-12 years are found better values for girls, but this difference between genders is no longer reported for the group 13-18 years [16]. The use of hover-boards has beneficial effects on the static balance (One leg standing test and Stork test), respectively dynamic (Balance beam walking test) at the level of young Italian football players, being indicated the use of these devices also in other sports [17]. Playing handball as a recreational sport for postmenopausal women (49-79 years old) facilitates the improvement of postural balance and bone health, reducing the risk of falls and injuries for this category of population [18].

The comparison of performances between athletes (football players) and groups of sedentary students of the same age confirms the significantly better values of athletes, so the involvement in physical activities improves balance [19]. The associations between balance issues and the low level of fitness of African children is highlighted by Verbecque et al. [20]. The authors indicate that there is a high chance of impaired balance with increasing BMI values, so the preventive role of physical activity in maintaining and reducing body weight is vital. The decrease in leg muscle strength and antero-posterior balance performance for pubertal children (overweight and obese classes) is highlighted by Alhusaini et al. [21]. The application of the Bruininks-Oseretsky test battery on young people (10-21 years old) highlighted the difficulties related to balance for the overweight, compared to the normal-weight one [22]. For adults, there are difficulties in maintaining balance for the inactive and obese, so physical activity has the role of improving these problems [2, 3, 23]. For the obese, a greater balance is identified compared to the normal weight, and the reduction of body weight in these cases (through physical exercise) is a solution that ensures an improvement of the postural control [24]. The idea is supported by another study, where increasing muscle strength for obese people does not necessarily bring an improvement in balance, the weight loss being more important [25].

A comparison between obese young Japanese girls (9 years old) and adult men showed poor results of girls in static and dynamic balance tests, with high chances of injury and reduced control of movements during motor activities [26]. In obese and overweight young adults, poor results are confirmed in dynamic balance tests, with obvious mid-lateral displacement of the center of gravity, major risks of falling and higher time required for performing various motor tasks, aspects to which are added postural problems at the level of the spine [27].

Purpose of the Study. The study purpose was to evaluate the efficiency of balance exercises, applied for 28 weeks, with a frequency of one activity / week, on a group of undergraduate students of the "Dunărea de Jos" University of Galați, divided into 3 BMI categories (underweight, normal weight and overweight).

Materials and Methods

Participants.

The studied group consists of 195 students from "Dunărea de Jos" University of Galați (99 males and 96 females included in the undergraduate study programs of years 1 and 2 of the Faculty of Automation, Computers, Electrical and Electronic Engineering, respectively Medicine and Pharmacy), made up by random selection to ensure numerical balance by gender and divided for data analysis into 3 categories: underweight (N = 21, age = 20.16 ± .38, BMI = 17.46 ± .20), normal weight (N = 111, age = 20.30 ± .21, BMI = 21.70 ± .17), overweight / obese (N = 63, age = 19.90 ± .18, BMI = 30.69 ± .61). Participants do not have constant concerns about performance physical activities, so the influence of this factor on results cannot be taken into account. The study group was informed about the duration, purpose and balance tests applied, ensuring the confidentiality and protection of personal data, in accordance with the Helsinki Declaration [28, 29].

Research Design.

The research took place at the level of the Research Center for Human Performance within the Faculty of Physical Education and Sports in Galați (Romania), respecting the design of longitudinal investigations. The applied tests evaluate the dynamics of static balance indicators (One leg standing test with eyes closed / s, Stork test / s, Flamingo test / number of falls), respectively the evolution of performance at dynamic balance (Bass test / points, Functional reach test / cm, Walk and turn field sobriety test / errors and Fukuda test / degrees of rotation), the application and quantification of the results being exemplified by Walden, Zhang et al. [30, 31, 32, 33]. The batch testing was performed during the academic year 2018-2019, in 3 distinct stages (T1-initial testing, at the beginning of the academic year; T2-intermediate testing, in the 12th week

/ December, before the winter holidays; T3-final testing, at the end of the academic year). Students who were absent from physical education lessons were not included in the statistical calculation, in order to highlight the efficiency of the motor structures proposed for the development of balance. Participants were advised not to engage in stress-based efforts prior to testing, so that muscle and nerve fatigue does not affect the value of the results.

Training program. The exercise program was implemented over a period of 28 weeks, with a frequency of one activity per week, the structures oriented towards the development of balance being explained and practiced for 15-25 minutes in each lesson, with variable and individualized dosage, according to the effort potential of each participant. Table 1 selectively presents proposed exercises to optimize the level of static and dynamic balance, with the mention that they have been alternated and changed during the activities, in order to avoid capping the results, by adapting the participants to the proposed stimuli.

Statistical Analysis.

The statistical calculation was based on the use of Anova parametric techniques with repeated measurements, separately for each subgroup analyzed (underweight, normal weight and overweight / obese). We preferred to include the overweight and obese in a single category, in order to simplify the statistical analysis and reduce the resulting data volume. Data on: Maucly's Test of Sphericity were synthesized, with the application of the Greenhouse-Geisser correction factors (for $\varepsilon < 0.75$) and Huynh-Feldt (for $\varepsilon > 0.75$) when the sphericity could not be assumed, the values of F and associated significance thresholds (sig.), size effect expressed by Partial eta squared ($\eta^2 p$), the differences between the average values between the test moments and their significance, using the Bonferroni correction factor [34, 35]. The confidence interval was set at 5% ($p < 0.05$), according by Murariu, Opariuc [36, 37, 38].

Table 1. Selection from the variants proposed and applied for the development of balance

Motor structures proposed for the development of static balance
• From standing, lunging by making a step back with your palms on your hips and holding the position with your arms up. • From sitting with the palms on the hips, raising the right knee and thigh parallel to the ground, maintaining the position for 5-30 seconds, then the action is repeated for the left leg. Same with lifting a leg outstretched forward / sagittal plane, with the heel at a distance of 10-30 cm above the ground. • From standing on one leg, throwing a tennis ball vertically and holding the arm on the side of the support leg. The same goes for holding the raised leg with the arm. Same with throwing the ball from one hand to the other. • Maintaining balance by flexing and extending the knees from sitting on the platform or balance ball / bosu balance trainer. • From standing on one leg, bending the torso forward and touching the tip of the supporting leg with the opposite arm, the free leg is bent / flexed from the knee and oriented / lifted back. • From standing on one leg, slight half-flexion with return and arms outstretched sideways, vertically or in other planes. • From standing facing the wall, lifting on tiptoes with a slight bend of the torso forward to the limit of imbalance, then balancing by pushing with the palms towards the wall.
Motor structures proposed for the development of dynamic balance
• Moving on various hardness surfaces (soft, semi-hard or hard mattresses), jumping from one foot to the other while maintaining balance. • Successive jumps on one leg, over a drawn line or a cord stretched on the ground, maintaining the position 2-3 sec before the next jump. On return, the detachment leg changes. The same with alternate jumps, from one foot to the other. • From standing sideways to a column of 5-6 bottles, spaced 50 cm apart, jump on one leg next to each bottle, maintaining balance and placing a glass on it. The same with zigzag / snake jumps between bottles. The same jumping back to each bottle. • Running bypassing milestones at 360^0 alternating the direction of rotation: left / right. • Walking on the narrow side of the gym bench with variable speed, with jumps over various objects and turning at 90, 180. 360^0. The same by moving backwards on the gym bench. • Jumps on one leg or from one leg on the other, on different signs / markings drawn on the ground, maintaining the unipodal balance for 1-5 sec. The same with jumps on one leg, in circles arranged under different variants / arrangements on the ground.

Results

The values of the Anova parametric test with repeated measurements (table 2) indicate significant progress at the level of the 3 groups for most tests (F values correspond to thresholds p <.05), except for the group of underweight in Walk and turn field sobriety test, where p = .329, statistically insignificant value. Partial eta squared scores indicate a strong influence of the applied balance exercise program on the results, with the highest values for all 3 groups in the Bass test and Functional reach test (for underweight, in the Bass test, 81.5% of the variance is explained by the intervention of the proposed program, and for overweight, at the Functional reach test, 81% of the variance is attributed as an effect of the applied program). It should be noted that for the rest of the tests, at the level of the group of normal weight, stronger influences of the program are registered (through the values of (η^2p) than at the level of the groups of underweight and overweight. The weakest effects of balance exercises are found in the Walk and turn field sobriety test and Fukuda test for underweight and normal weight, but with strong effects on overweight.

Comparison and analysis of average differences in pairs at the level of the underweight (Table 3) indicates in most cases significant progress (p <.05), except for the Walk and turn field sobriety test (where errors are missing in the intermediate and final tests), respectively in the Fukuda test (where no significant progress is found between intermediate and final testing). With the exception of One leg standing test, where slightly higher progresses are found between intermediate and final tests, for the other data pairs there are larger differences between initial and intermediate tests compared to those between intermediate and final tests, which confirms the higher progress in the first stage of preparation / semester 1, the adaptation to the stimuli / exercises in the program generating a lower improvement of the results in semester 2.

The situation is similar for the group of normal weight (table 4) with larger differences for the first semester of preparation and smaller for the second, but significant for most data pairs. In the case of the Walk and turn field sobriety test, only for the initial test-final test pair there is significant progress (so at

Table 2. ANOVA results with repeated measurements on BMI steps (1 = underweight, 2 = normal weight, 3 = overweight)

Test	Lot	Maucly's Test of Sphericity		Correction factor	df	Error df	F	Sig.	Partial eta squared (η^2_p)
		Sig.	ε						
One leg standing	1	0.000	0.595	Greenhouse-Geisser	1.191	23.811	22.371	0.000	0.528
	2	0.000	0.656	Greenhouse-Geisser	1.312	144.367	173.947	0.000	0.613
	3	0.000	0.658	Greenhouse-Geisser	1.317	81.630	35.441	0.000	0.364
Stork	1	0.000	0.532	Greenhouse-Geisser	1.063	21.266	19.095	0.000	0.488
	2	0.000	0.734	Greenhouse-Geisser	1.469	161.587	229.964	0.000	0.676
	3	0.000	0.688	Greenhouse-Geisser	1.376	85.289	86.992	0.000	0.584
Flamingo	1	0.000	0.633	Greenhouse-Geisser	1.267	17.683	13.178	0.001	0.397
	2	0.000	0.742	Greenhouse-Geisser	1.485	163.345	137.359	0.000	0.555
	3	0.000	0.769	Huynh-Feldt	1.538	95.363	57.571	0.000	0.481
Bass	1	0.005	0.702	Greenhouse-Geisser	1.403	28.063	88.068	0.000	0.815
	2	0.002	0.919	Huynh-Feldt	1.809	198.952	410.853	0.000	0.789
	3	0.000	0.779	Huynh-Feldt	1.558	96.586	193.259	0.000	0.757
Functional reach	1	0.001	0.669	Greenhouse-Geisser	1.337	26.740	45.000	0.000	0.692
	2	0.000	0.719	Greenhouse-Geisser	1.438	158.150	213.035	0.000	0.659
	3	0.051	0.941	Sphericity Assumed	2	124	264.773	0.000	0.810
Walk and turn	1	-	0.500	Greenhouse-Geisser	1.000	20.000	1.000	0.329	0.048
	2	0.000	0.797	Huynh-Feldt	1.576	173.349	6.424	0.004	0.055
	3	0.035	0.932	Huynh-Feldt	1.863	115.529	33.036	0.000	0.348
Fukuda	1	0.768	1.000	Sphericity Assumed	2	40	8.138	0.001	0.289
	2	0.000	0.536	Greenhouse-Geisser	1.072	117.948	5.201	0.022	0.045
	3	0.000	0.836	Huynh-Feldt	1.671	103.633	29.853	0.000	0.325

Table 3. The results for differences of underweight average values (N=21)

Test	Mean	Std. deviation	Std. error	T1-T2	Sig.b	T1-T3	Sig.b	T2-T3	Sig.b
One leg standing T1	11.013	9.912	2.163						
One leg standing T2	11.275	9.954	2.172	-0.262*	0.001	-0.544*	0.000	-0.282*	0.001
One leg standing T3	11.556	9.936	2.168						
Stork T1	3.957	4.335	0.946						
Stork T2	4.140	4.345	0.948	-0.183*	0.004	-0.257*	0.000	-0.073*	0.000
Stork T3	4.213	4.347	0.949						
Flamingo T1	5.095	4.288	0.936						
Flamingo T2	4.476	3.855	0.841	0.619*	0.006	1.048*	0.003	0.429*	0.026
Flamingo T3	4.047	3.556	0.776						
Bass T1	61.952	13.573	2.962						
Bass T2	64.095	14.390	3.140	-2.143*	0.000	-4.048*	0.000	-1.905*	0.000
Bass T3	66.000	14.679	3.203						
Functional reach T1	40.142	4.980	1.087						
Functional reach T2	41.214	4.779	1.043	-1.071*	0.000	-1.714*	0.000	-0.643*	0.000
Functional reach T3	41.857	4.855	1.060						
Walk and turn T1	0.004	0.218	0.048						
Walk and turn T2	0.000	0.000	0.000	0.048	0.988	0.048	0.988	0.000	-
Walk and turn T3	0.000	0.000	0.000						
Fukuda T1	18.476	21.864	4.771						
Fukuda T2	17.571	22.048	4.811	0.905*	0.018	1.286*	0.001	0.381	0.225
Fukuda T3	17.190	21.671	4.729						

*. The mean difference is significant at the .05 level; b. Adjustment for multiple comparisons: Bonferroni.

the level of the entire study stage / academic year), but without significant accumulations per semester ($p > 0.05$). A particular situation is encountered at the Fukuda test level, where there is a slight decrease in performance for intermediate testing (several degrees of rotation), but without the difference between the initial and intermediate testing being significant. The situation is remedied by the better performance from the final testing, which generates significant progress between the level of semester 2 and the entire stage of implementation of the proposed program ($p < 0.05$).

The overweight group made significant progress on almost all data pairs associated with the tests (Table 5), with the exception of the Walk and turn field sobriety test, between intermediate and final testing. For One leg standing test and Stork test, however, greater progress is found for semester 2, so adapting overweight and improving performance in these 2 tests are slower, but this is not confirmed for other situations, where the biggest differences are still between initial and intermediate tests. For the Fukuda test, the average performance is poor (around 30 degrees), which is the threshold for the manifestation of vestibular disorders on the side of body rotation.

Graph 1 shows the average performance values of the 3 batches at the final tests. Overweight people have the weakest results in tests to assess static and dynamic balance, but their progress (statistically confirmed) does not allow the approach to the values of normal weight and underweight. They have the shortest holding times at static balance, the lowest score on the Bass test, they make the most errors on the Flamingo test and the Walk and turn field sobriety test, and they have the highest rotation scores around the body axis on the Fukuda test. It is interesting that the underweight group has results close in value to that of the normal weight in most tests and even slightly better than them in One leg standing test, Flamingo Fukuda test and Walk and turn field sobriety test, which requires checks by studies on larger groups in this category, in order to generalize these results.

Discussion

Our study identifies the effectiveness of the diversified exercises proposed to optimize the level of balance, an aspect confirmed by other similar research.

Applying core training on unstable surfaces for 18–25-year-olds in Turkey generates gender

Table 4. The results for differences of normal weight average values (N=111)

Test	Mean	Std. deviation	Std. error	T1-T2	Sig.b	T1-T3	Sig.b	T2-T3	Sig.b
One leg standing T1	6.320	6.098	0.579						
One leg standing T2	6.480	6.106	0.580	-0.160*	0.000	-0.291*	0.000	-0.131*	0.000
One leg standing T3	6.610	6.135	0.582						
Stork T1	4.298	3.855	0.366						
Stork T2	4.419	3.837	0.364	-0.121*	0.000	-0.200*	0.000	-0.079*	0.000
Stork T3	4.498	3.838	0.364						
Flamingo T1	6.378	3.482	0.331						
Flamingo T2	5.603	3.151	0.299	0.775*	0.000	1.279*	0.000	0.505*	0.000
Flamingo T3	5.099	2.954	0.280						
Bass T1	69.360	12.137	1.152						
Bass T2	71.549	12.380	1.175	-2.189*	0.000	-4.279*	0.000	-2.090*	0.000
Bass T3	73.639	12.584	1.194						
Functional reach T1	40.076	6.035	0.573						
Functional reach T2	41.247	5.785	0.549	-1.171*	0.000	-1.874*	0.000	-0.703*	0.000
Functional reach T3	41.9505	5.630	0.534						
Walk and turn T1	0.234	0.485	0.046						
Walk and turn T2	0.189	0.457	0.043	0.045	0.074	0.072*	0.013	0.027	.250
Walk and turn T3	0.162	0.437	0.042						
Fukuda T1	20.891	24.770	2.351						
Fukuda T2	21.477	26.628	2.527	-0.586	1.000	1.964*	0.000	2.550*	0.040
Fukuda T3	18.927	23.760	2.255						

*. The mean difference is significant at the .05 level; b. Adjustment for multiple comparisons: Bonferroni.

differences for dynamic balance (Y test), but not for the rest of the fitness components [39]. In order to reduce the risk of injury, for American football players are recommended exercises for vestibular, proprioceptive, neuromuscular, with eyes closed and open, respectively on various surfaces - stable and unstable [40]. The use of unstable surfaces improves the values of dynamic balance and reduces the static postural balance for 7-year-old gymnasts [41]. Exercises performed on stable ground are less effective than the variant of unstable surfaces, for women of the 3rd age (60-80 years), by applying a program of this type (12 weeks, with 2 workouts of 45 min./week and 25 minutes oriented to equilibrium structures) progress is achieved, according by Matla et al. [42]. Our program also included this kind of exercises, and the significant progress at the level of the 3 categories confirms their viability.

The variants proposed by specialized studies for balance optimization are extremely varied. An improvement of the results by applying a Tabata training program (for young football players / ages = 23 years) is obtained for the Flamingo test, but without statistical significance, according by Ceylan et al. [43]. Other research highlights the role of various physical activity programs (combat sports, pilates) on increasing balance values and reducing the risk of falls in different categories of the population [2, 3, 6, 44, 45]. The type of sport practiced influences the values of balance. Higher values in the balance tests of young Turkish athletes who are involved in individual sports (karate, gymnastics, judo, table tennis) compared to those involved in team games (basketball, volleyball, handball), as well as the increase the performance of the dynamic balance as age increases are identified by Turkeri et al. [46]. A program of balance exercises applied to children (10-12 years), for 8 weeks x 3 sessions per week generated superior performance in the Flamingo test, but also the speed and agility tests [47]. For teenagers in Kosovo, in the Flamingo test, girls perform better only for the 14-15 years old age group, then boys get superior performance [48]. Balanced values between Montenegrin and Kosovo teenagers in the Flamingo test are obtained by Morina et al. [49]. Long-term application of fitness programs (3 years x 3 sessions / week x 90 min) and their combination with diet positively influences the performance of fitness tests, including the Flamingo test, for boys aged 8-11 years [50]. We obtained in this test the best results for underweight, followed by normal weight, overweight having the lowest performances.

Table 5. The results for differences of overweight average values (N=63)

Test	Mean	Std. deviation	Std. error	T1-T2	Sig.b	T1-T3	Sig.b	T2-T3	Sig.b
One leg standing T1	4.959	2.907	0.366						
One leg standing T2	5.116	2.935	0.370	-0.157*	0.000	-0.353*	0.000	-0.196*	0.000
One leg standing T3	5.312	2.990	0.377						
Stork T1	2.695	1.220	0.154						
Stork T2	2.777	1.256	0.158	-0.082*	0.000	-0.177*	0.000	-0.094*	0.000
Stork T3	2.871	1.245	0.157						
Flamingo T1	10.571	4.599	0.579						
Flamingo T2	10.047	4.681	0.590	0.524*	0.000	0.905*	0.000	0.381*	0.000
Flamingo T3	9.666	4.700	0.592						
Bass T1	58.523	13.023	1.641						
Bass T2	60.571	12.630	1.591	-2.048*	0.000	-3.714*	0.000	-1.667*	0.000
Bass T3	62.238	12.708	1.601						
Functional reach T1	38.941	8.292	1.045						
Functional reach T2	40.238	8.129	1.024	-1.297*	0.000	-2.107*	0.000	-0.810*	0.000
Functional reach T3	41.047	7.778	0.980						
Walk and turn T1	1.000	0.879	0.111						
Walk and turn T2	0.619	0.658	0.083	0.381*	0.000	0.429*	0.000	0.048	0.964
Walk and turn T3	0.571	0.734	0.093						
Fukuda T1	31.952	30.571	3.852						
Fukuda T2	31.000	30.526	3.846	0.952*	0.000	1.714*	0.000	0.762*	0.000
Fukuda T3	30.238	29.899	3.767						

*. The mean difference is significant at the .05 level; b. Adjustment for multiple comparisons: Bonferroni.

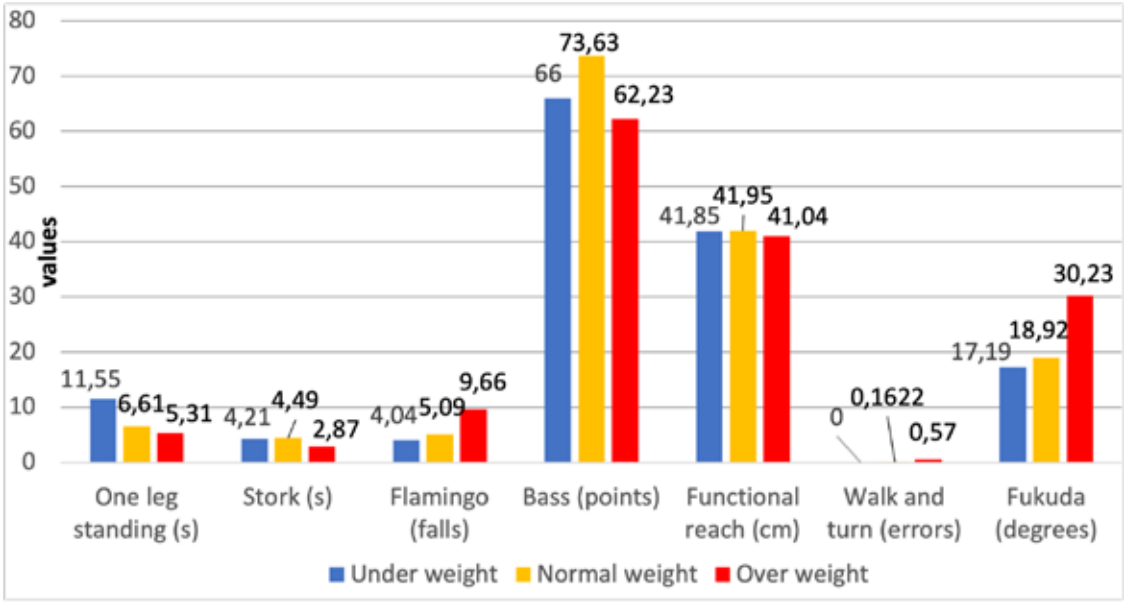

Figure 1. Presentation of the average values of the performances of the 3 lots at the final tests

A decrease in performance in balance tests is reported after the age of 50, and for the interval 20-49 years similar results are recorded, overweight women obtaining lower scores than normal weight [51]. The differences between obese and normal weight for One leg standing test and dynamic balance assessment tests are also reported among Chinese children aged 8-10 years [52]. Young obese

people (21.7 years) have the poorest results in bipodal and unipodal balance tests, compared to normal weight and underweight, according by Ku et al. [53], aspect similar to our research. Young people (ages = 21 years) with concerns related to physical activities (moderate to vigorous intensity) have a lower balance area and implicitly a better balance, with higher values for testing with eyes open [54].

Comparisons between static balance values between female dancers with at least 7 years of activity and sedentary ones (18-23 years) indicate higher balance values for dancers and superior postural control [55]. An exercise program applied 5 weeks, to influence the dynamic balance in elderly and overweight women is proposed by Bellafiore et al. [56]. In this case, performance improvements are obtained for most of the people involved, as a result of the efficiency of the muscular structures and the visual system, which ensures the postural balance. The use of DCE / dynamic core exercise in the warm-up part of physical education lessons for children at the beginning of puberty (10-11 years), for 6 weeks has favorable effects on balance and flexibility [57]. Other authors propose exercises with elastic cord at the level of elite gymnasts' girls (14 years), through an applied program 12 weeks x 18 hours per week + 2 hours dedicated to exercises with elastic cord, which generate favorable effects on body balance [58]. There are also researches that demonstrate the effectiveness of applying oriental techniques (Yoga asanas) for obese young people (21-25 years), for a period of 4 weeks x 3 sessions per week x 45 min / session. Significant improvements are found in the Functional reach test and One leg standing balance test [59]. Our study confirms the effectiveness of programs based on balance exercises for the age category investigated, even if it was applied with a frequency of one session / week, being in accordance with the other research previously analyzed, through the beneficial effects found.

Conclusions

The application of balance exercises generates performance optimization in the tests applied to all groups investigated, so they are prerequisites for increasing body stability in static and dynamic actions for university students. The progress made is not spectacular, but the fact that they are statistically significant is still a positive aspect. It should be noted that for most tests there is more progress between the initial and intermediate tests, and slightly less between the intermediate and final tests, as a result of a possible adaptation to the exercises proposed in the second part of the program implementation. Even if the group of overweight progresses significantly, its results are weaker than those of normal weight and underweight; this category having the biggest problems in maintaining the body in different positions, but commits most errors and has poor scores in dynamic balance tests. The fact that underweight people get results close to those of normal weight and for 3 even better tests (One leg standing test, Flamingo test Fukuda test and Walk and turn field sobriety test) must be interpreted with some reservations, their weight / representation in the study group requiring the repetition of the research on a much larger sample at the level of underweight. Favorable results can also be explained by the low initial fitness level of the group (without concerns about sports activities), which facilitated the progress made.

The limits of the study and new research directions. The high volume of data did not allow the presentation of differences in gender and between gender tests, or the analysis of the significance of differences between BMI classes / (independent samples), which are the subject of another scientific paper. It would be interesting to analyze the results of the battery of tests for students of the Faculty of Physical Education and Sports and whether reading the practical contents of the curricula generates significant improvements in performance related to balance (these data are already collected and will be statistically processed). The use of modern equipment and technologies (which investigate static and dynamic balance using sensors and baropodometric platforms) would facilitate a more nuanced investigation of the mechanisms that condition body stability and identify factors that reduce the value of performance in balance tests.

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Conflict of interest

No potential conflict of interest that is of any relevance to this study was reported by the authors.

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REVIEW ARTICLE

Main research areas in kickboxing investigations: an analysis of the scientific articles of the Web of Science Core Collection

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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: Combat sports are among the most popular sports nowadays. Scientific support of combat sports is one of the urgent tasks of modern sports science. The purpose of this article is an analytical analysis of studies devoted to kickboxing.

Material and Methods: The bibliometric database Web of Science Core Collection (WoS) is analyzed. 194 articles that met the search criteria were selected for the primary analysis. We used bibliometric methods for processing the information received in the context of kickboxing. The VOSviewer 1.6.18 software was used: keyword analysis method and direct citation analysis with the construction of bibliometric maps, visualization of cluster density, and citation weights.

Results: The constructed bibliometric maps made it possible to identify the leading thematic areas of research, the most popular areas of research in this area. They can be divided into sports and rehabilitation and recreational areas. In a sports context, these include the performance of technical and tactical elements of kickboxing, the study of the physiological characteristics of combat sports athletes; assessment of the main physical qualities and analysis of the adaptive potential of athletes; the study of biochemical and features of homeostasis, the state of the cardiorespiratory system; highlighting factors important for winning competitions. In the rehabilitation context, kickboxing is used to optimize the functional state, recover from injuries, and improve the quality of life of patients with chronic diseases. The use of the VOSviewer software, version 1.6.18, made it possible to conduct a comprehensive analysis of the problem, to determine the priority scientific directions in this area. In sports, this is an analysis of the technical and tactical indicators of athletes, the time spent on their implementation, the study of the metabolic characteristics of combat sports athletes, and the assessment of their physical qualities.

Conclusions: The conducted bibliometric analysis of publications on the problem of kickboxing confirms the relevance of this area of sports science. There is a lack of research on a comprehensive study of success, monitoring the state of kickboxing athletes. These directions should be recognized as the most relevant in this area.

Keywords: kickboxing, combat sports, bibliometric mapping, VOSviewer

Introduction

Modern sports activities significantly demand the level of functional fitness of combat sports athletes. For a qualitative assessment of the state of combatants, it is necessary to use informative and objective methods. No unified position on determining the most effective methods for monitoring the state of combat sports athletes has yet been developed. An analysis of scientific research in this area was carried out in the study [1]. Domestic and foreign experts widely use biochemical, physiological methods, and special fitness tests to control the functional state of combatants. The limitations of some biochemical methods, and indicators of the reaction of the body of athletes to the load, were revealed. Relevant is the analysis of data that evaluates the response of athletes to stress. A lack of research on certain groups of athletes has been revealed. These include young athletes, athletes over 30 years old, and girls and women involved in combat sports.

The most relevant in the scientific support of sports should be the justification for monitoring the health of athletes, the study of the effects of sports stress and adaptation, the identification of selection criteria, and the establishment of integral indicators of training. A complex of works [2, 3] was devoted to this. Informative coefficients of statokinetic stability, resistance to hypoxia, and an integral rating indicator of the success of the competitive activity were obtained. An analysis of effective adaptation, readiness variability, normal limits, stable and premorbid health conditions,

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overtraining, and overwork are proposed. The search and substantiation of evaluation and diagnostic technologies in the monitoring of physical fitness and the development of training programs were carried out. The functional and metabolic stability of a single special functional system of motor activity was confirmed during long-term adaptation.

Several factors determine success in sports. These include specific sports skills, the level of development of physical qualities, features of the functional state of the central body systems, and anthropometric characteristics. It has been repeatedly pointed out that athletes have different physical characteristics depending on the sport. The study of these features is an important task in sports science. The development of an anthropometric profile for a particular sport is important for optimizing training and identifying specific markers. Such a profile can serve as a diagnostic criterion for predicting the results of an athlete [4].

The problem of factors determining success in combat sports has not yet been resolved [5]. There is no consensus on a fully comprehensive assessment of these factors. The specificity of most combat sports makes it difficult to single out one or more factors leading to victory. Strength has been identified as a predictor of success in mixed martial arts (MMA), wrestling, and Brazilian jiu-jitsu. The aerobic and anaerobic potential has been studied in Brazilian Jiu-Jitsu, Judo, Boxing, Kickboxing (KB), and MMA. Its various contributions to success at various levels are confirmed. Endurance, flexibility, and body composition have also been investigated, but this issue has not been finally resolved. The authors conclude that it is necessary to comprehensively study the physical and physiological characteristics of kickboxing athletes.

Kickboxing is one of the most popular modern combat sports. This is a complex type of combat sports in terms of technique, tactics, and structure of movements. It requires an adequate level of motor skills as the basis for successful competitive activity [6, 7].

Combat sports training is complex in terms of the intensity of training, the development of various physical qualities, and the study of many technical skills. This is due to the specific of combat sports. The effects of kickboxing training on cardiorespiratory endurance, muscular endurance, single leg balance, trunk flexibility, trunk strength, static arm strength, speed agility, and explosive leg strength have been studied [8]. A positive effect on improving well-being, balance, aerobic endurance, flexibility, static arm strength, and the development of speed and agility has been confirmed.

One of the important areas of sports science is the directed influence on the functional state of athletes. A promising method of its implementation is the use of the alimentary factor. The importance of informing kickboxers about food ergogenic products and the level of special training of athletes on these issues has been confirmed [9].

In the context under consideration, it was of interest to conduct a bibliometric analysis of scientific publications devoted to kickboxing in the journals of the international database Web of Science Core Collection.

The purpose of the study is an analytical analysis of publications devoted to kickboxing and the establishment of priority scientific directions in this area.

Methodology

Data sources

The Web of Science Core Collection (WoS) bibliometric database has been selected for the research sampling process as at 06/01/2022.

The quality of the information sources was the main criterion for choosing the databases. The sample is 194 records (Web of Science Core Collection). The articles matched the search term "kickbox*" in the topic. This made it possible to combine publications according to the criteria "kickboxing", "kickboxer", etc. The search period was 1970–2022. The period of actual publications was 1991–2022. Most publications – 165 (85.05%) – appeared in the period 2008–2022. 83 articles (42.78%) were published in the period 2018–2022.

Table 1 presents TOP-10 different categories. These WoS subject areas are of the greatest interest in the context of the topic of the article: Sport Science, Physiology, Rehabilitation, Anthropology.

TOP-10 journals which contain articles on the research topic are the following: Journal of Strength and Conditioning Research -10, Medicine and Science in Sports and Exercise – 8, Archives of Budo – 6, International Journal of Environmental Research and Public Health – 6, Archives of Budo Science of Martial Arts and Extreme Sports – 5, Human Sport Medicine – 4, Ido Movement for Culture. Journal of Martial Arts Anthropology – 4, International Journal of Performance Analysis in Sport – 4, Journal of Sport Medicine and Physical Fitness – 4, Physical education of students – 4.

Method of Study

The Web of Science Core Collection database was used to clarify world trends in kickboxing research: the publication period 1991–2022 was considered. The search results are presented in Table 1. According to the information on the most significant categories (table 1, 100 sources), we analyzed the most priority scientific studies in the field of kickboxing.

Data analysis

We used bibliometric methods [10, 11] to identify the leading researchers on the problems of our

Table 1. Results analysis table for web of science categories field (Web of Science Core Collection)

Category	Items (N; %)
	All subject areas, n=194
Subject area (top 10 items)	Sport Science (85; (43.81 %), Education Educational Research (11; (5.57 %), Hospitality Leisure Tourism (10; (5.15 %), Medicine General Internal (9; (4.63 %), Public Environmental Occupational Health (8; (4.12 %), Clinical Neurology (7; (3.61 %), Endocrinology Metabolism (6; (3.09 %), Environmental Science (6; (3.09 %), Orthopedics (6; (3.09 %), Physiology (6; (3.09 %).
	Subject areas, in the context of the topic of the article, n=100
Subject area	Sport Science (85; (43.81 %), Physiology (6; (3.09 %), Rehabilitation (5; (2.58 %), Anthropology (4; (2.06 %).

NOTE: the source of information is the authors' own research (06/01/2022).

study in processing the information received in the context of kickboxing. To do this, we used VOSviewer 1.6.18, a software tool for creating and visualizing bibliometric networks [12]. The most important for the study was the implementation of the keyword analysis method [10] and direct citation analysis [11]. The methodology for calculating the main indicators for the analysis and identification of the most significant research categories is described in detail in the work of van Eck and Waltman [13]. Based on the most cited references, we identified promising areas of research in this category. Distance-based bibliometric maps have been used – these are maps where the distance between two elements reflects the strength of the connection between the elements. A smaller distance usually means a stronger connection.

Results

The analysis carried out made it possible to create the corresponding visualization maps.

Network visualization is presented in Figure 1.

The network is created based on 24 elements – keywords. They are grouped into 5 clusters. The size of the keywords corresponds to the number of links received, and the spatial proximity reflects the strength of the connection between subjects. Fig. 1 allows highlights the most popular research. They are focused on the keywords "combat sports", "performance", "sport", "kickboxing", "exercise".

The first cluster includes 6 keywords. It is marked red on the map. The cluster received the code title «Rehabilitation». The most significant keyword is "exercise". This keyword is characterized by having 18 links to other map keywords. Keywords and publications of the cluster confirm the possibility of using kickboxing for rehabilitation and recreational purposes. It has been proven to optimize health, improve the quality of life, and recovery from traumatic brain injuries.

The second cluster is marked green on the map. It received the title "Combat sports". This keyword is part of it. It was characterized by the presence of 21 links. The keywords of this cluster are as follows In descending order of the number of connections: "performance" – 20, "time-motion analysis" – 14, "physiological-responses" – 13, "adolescents" – 8, "taekwondo" – 6. Keywords of this cluster determine the focus of publications on the assessment of the time spent on the implementation of technical and tactical elements of kickboxing, the study of the physiological characteristics of athletes, and the study of the connection between them and performance.

The third cluster is marked blue on the map. It received the code title "Sport". This is the most significant of the five words in this cluster. It has 20 links. The keywords of this cluster are arranged as follows in decreasing order of the number of links: "kickboxing" – 18, "power" – 16, "strength" – 11, and "reliability" – 8. The keywords reflect the focus of research on the assessment of basic physical qualities, such as strength and endurance, and analysis of the adaptive potential of athletes.

The fourth cluster is marked yellow on the map. It includes four keywords: "lactate" – 15 links, "health rate" – 13, "recovery" – 12, "time" – 12. We titled it "Recovery". The keywords illustrate the study of the recovery features of athletes, the study of the biochemical features of homeostasis, and the state of the cardiorespiratory system.

The fifth cluster is marked in purple on the map. It consists of three keywords: "competition" – 15 links, "profile" – 13, "velocity" – 10. We titled it "Success". This research is focused on studying the important factors for winning competitions.

The results of the overlay visualization are shown in Figure 2.

Keywords are analyzed by frequency of citation and differ in color. Blue corresponds to the lowest average number of citations, yellow corresponds to the highest.

In the first cluster, this indicator is the highest for "quality-of-life" – 30.20. In the second cluster for

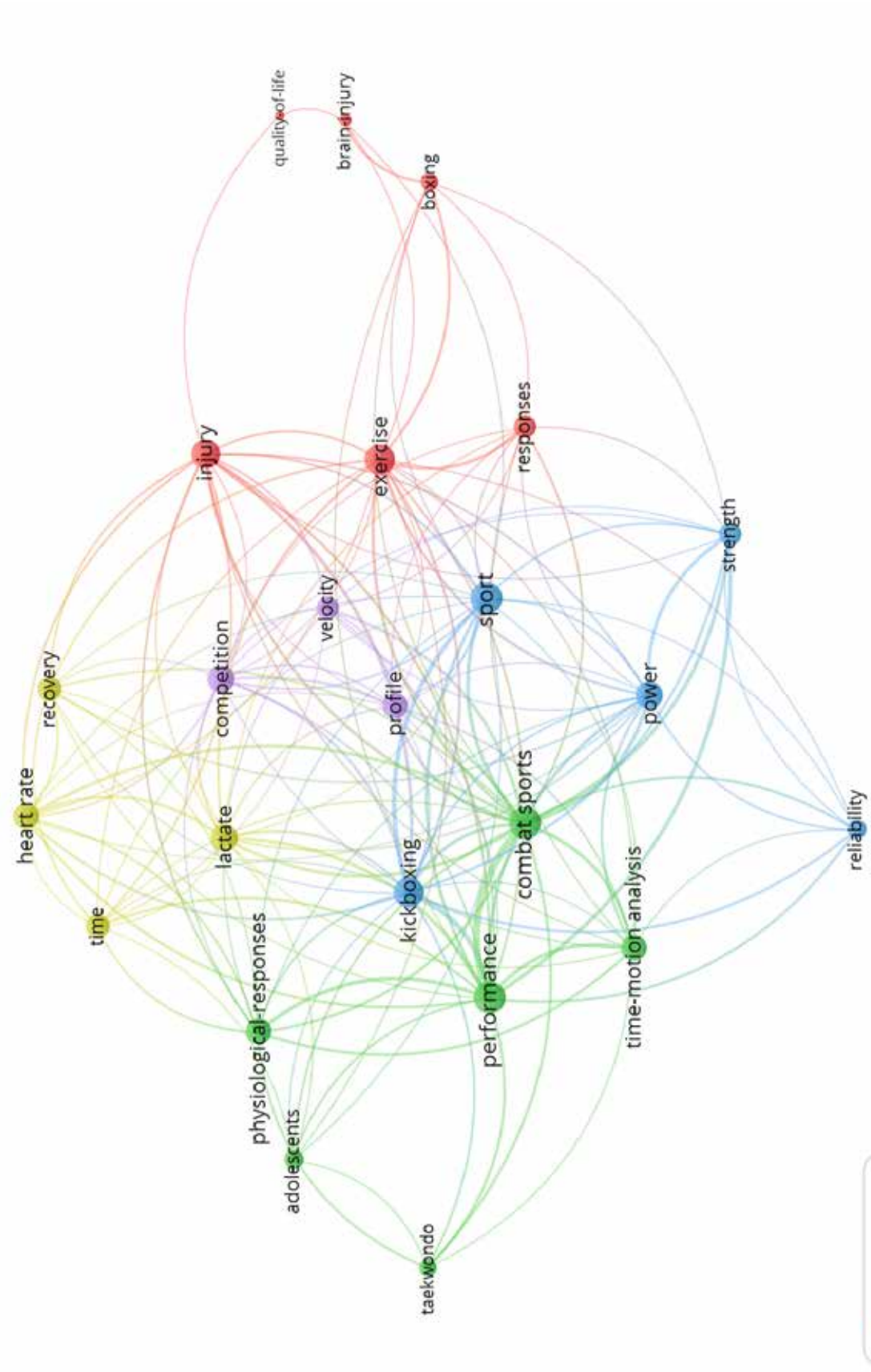

Figure 1. The main keywords in kickboxing publications, network visualization. Source: Own research based on data sourced from WoS and analyzed with VOSviewer (06/01/2022).

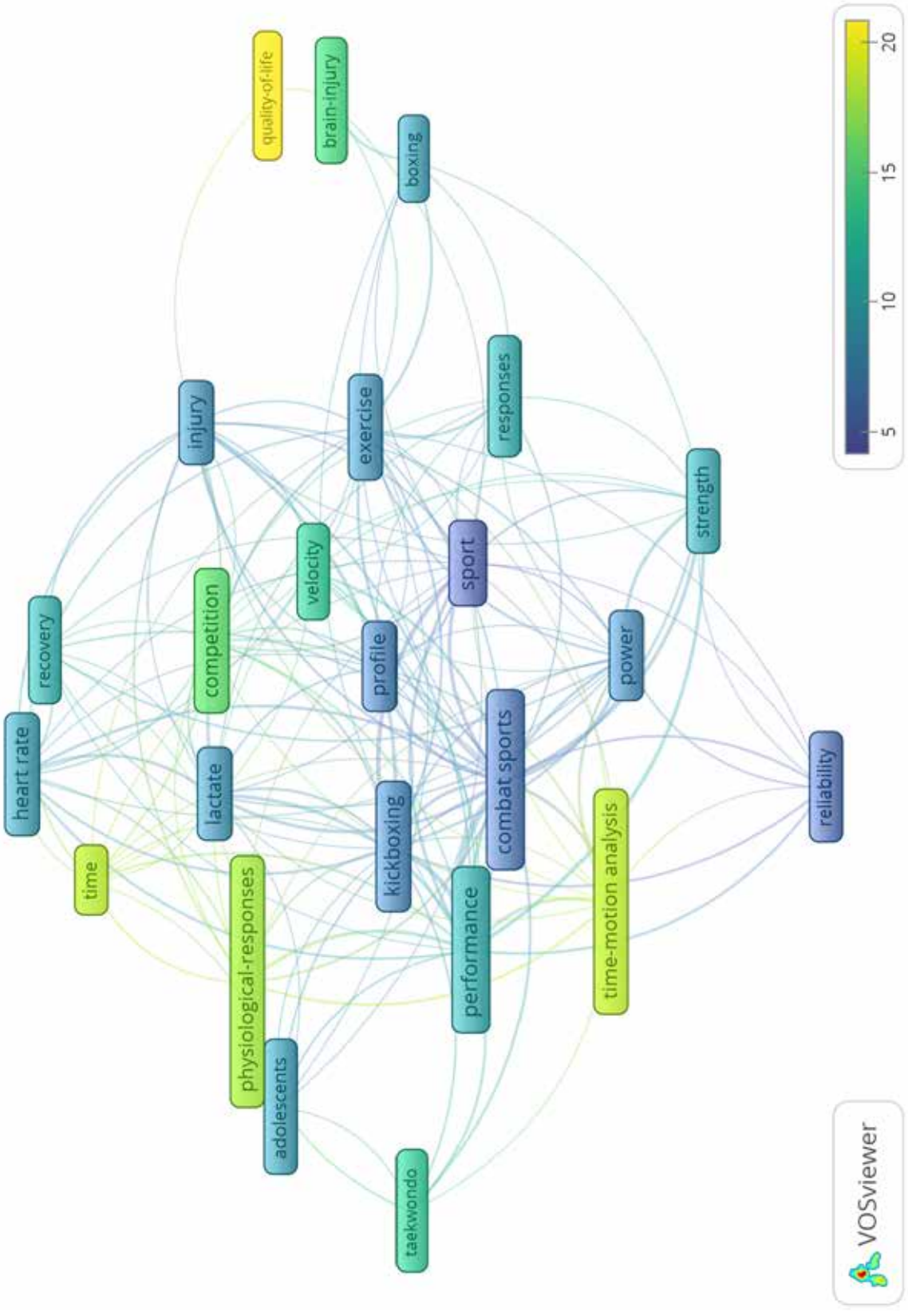

Figure 2. Average number of keyword citations in kickboxing publications, overlay visualization. Source: Own research based on data sourced from WoS and analyzed with VOSviewer (06/01/2022).

"time-motion analysis" – 17.89 and "physiological-responses" – 17.25. In the third cluster for "strength" – 10.09. In the fourth cluster for "time" – 17.80. In the fifth cluster for "competition" –15.14.

The results of density visualization are shown in Fig.3. Data interpretation on Fig. 3 is similar to Fig. 1: the more important the subject is, the larger is its circle and font size. Fig. 3 allows identifying the studies that can be categorized as the most popular. These include studies on the topic (in order of importance): "combat sports", "performance", "kickboxing".

The total strength of the simultaneous connection with other keywords was determined for each of the 24 keywords

The maximum value of the strength of the simultaneous connection with other keywords is set for "combat sports" – 94. In decreasing order, they are as follows: "performance" – 89, "kickboxing" – 58, "sport" – 41, "power" – 40, "exercise" – 35, "lactate" – 33, "injury" – 33, "strength" – 28, "heart rate" – 27, "physiological-responses" – 27, "time-motion analysis" – 27, "competition" – 24 , "profile" – 20, "recovery" – 18, "time" – 17, "velocity" – 16, "reliability" – 15, "responses" – 15, "taekwondo" – 12, "boxing" – 11, " adolescents" – 10, "brain-injury" – 6, "quality-of-life" – 2.

A bibliometric citation map (Fig. 4) was created based on the sample (n=146). To determine the main references, the sample was limited to the following indicators: the maximum number of co-authors – 25, the minimum number of author's documents – 2; the minimum number of author citations is 0. Out of 486 authors, 65 reached the indicated limits. 21 authors with the highest total link strength were selected among them. Analysis of Fig. 4 illustrates the work fields of these authors. Most authors belonged to the green and red clusters. The blue cluster is represented by only two authors. The authors of the yellow and purple clusters are absent from the map. The results allow us to conclude about the most popular authors focused on the problems of kickboxing. Among them are the follows: Francini Emerson, Ouergui Ibrahim, Ambrozy Tadeusz, Rydzik Łukasz.

Discussion

The analysis made it possible to identify the most priority areas in the scientific support of kickboxing. They can be divided into sports and rehabilitation and recreational areas.

In a sports context, priority is given to the implementation of technical and tactical elements of kickboxing, the study of the physiological characteristics of combat sports athletes; assessment of the main physical qualities and analysis of the adaptive potential of athletes; the study of biochemicals and features of homeostasis, the state of the cardiorespiratory system; highlighting factors important for winning competitions.

Kickboxing training is used in rehabilitation and recreation to optimize the functional state, recovery from injuries, and improve the quality of life of patients with chronic diseases. In the context under consideration, we were interested in the first direction.

An analysis of network visualization (see Fig. 1) allows us to draw the following conclusions. The study of combat sports is the most sought-after. It is interesting to highlight the general term "combat sports" and the separate term "kickboxing". This reflects the studies in which these sports were compared. Such a comparison allows us to highlight the specific features of kickboxing, and to assess the impact of the sport on the body of athletes. The overwhelming majority of works are aimed at studying sports kickboxing. This explains the widespread use of this keyword. The keyword "exercise" implies an analysis of the characteristics of the training. Simultaneously, this word is common to both selected areas. Exercises are used in both sports for rehabilitation and recreation. This issue was confirmed in the analysis of the first cluster.

Overlay visualization analysis data illustrate the relevance of kickboxing to improve the quality of life of various ages' people and health conditions. In the sports context, the significance of the study of technical and tactical actions in kickboxing, psychophysiological, physical, and physiological characteristics of athletes has been confirmed. A sufficiently high citation level confirms the relevance of research on the functional state in various stages of preparation and competition periods. The importance of studying competitive features in kickboxing is also confirmed.

The density visualization analysis also makes it possible to highlight the most important directions in the studied problem. These include general problems of combat sports, comparison of kickboxing with other types of combat sports, and analysis of the athletes' potential. The analysis of Fig. 3 confirms the conclusions made in the analysis of Figs. 1. Density imaging analysis data confirm that publications are predominantly devoted to sport. Studies devoted to the recreational and rehabilitation issues are practically unconnected with other publications.

Performing technical and tactical elements of kickboxing, studying the physiological characteristics of combat sports athletes.

The most sought-after authors in the field of kickboxing work in this direction. The results of the study [14] confirmed the effectiveness of using video recordings of fights with special software for calculating and analyzing special indicators of technical and tactical training.

The analysis of video recordings in combat

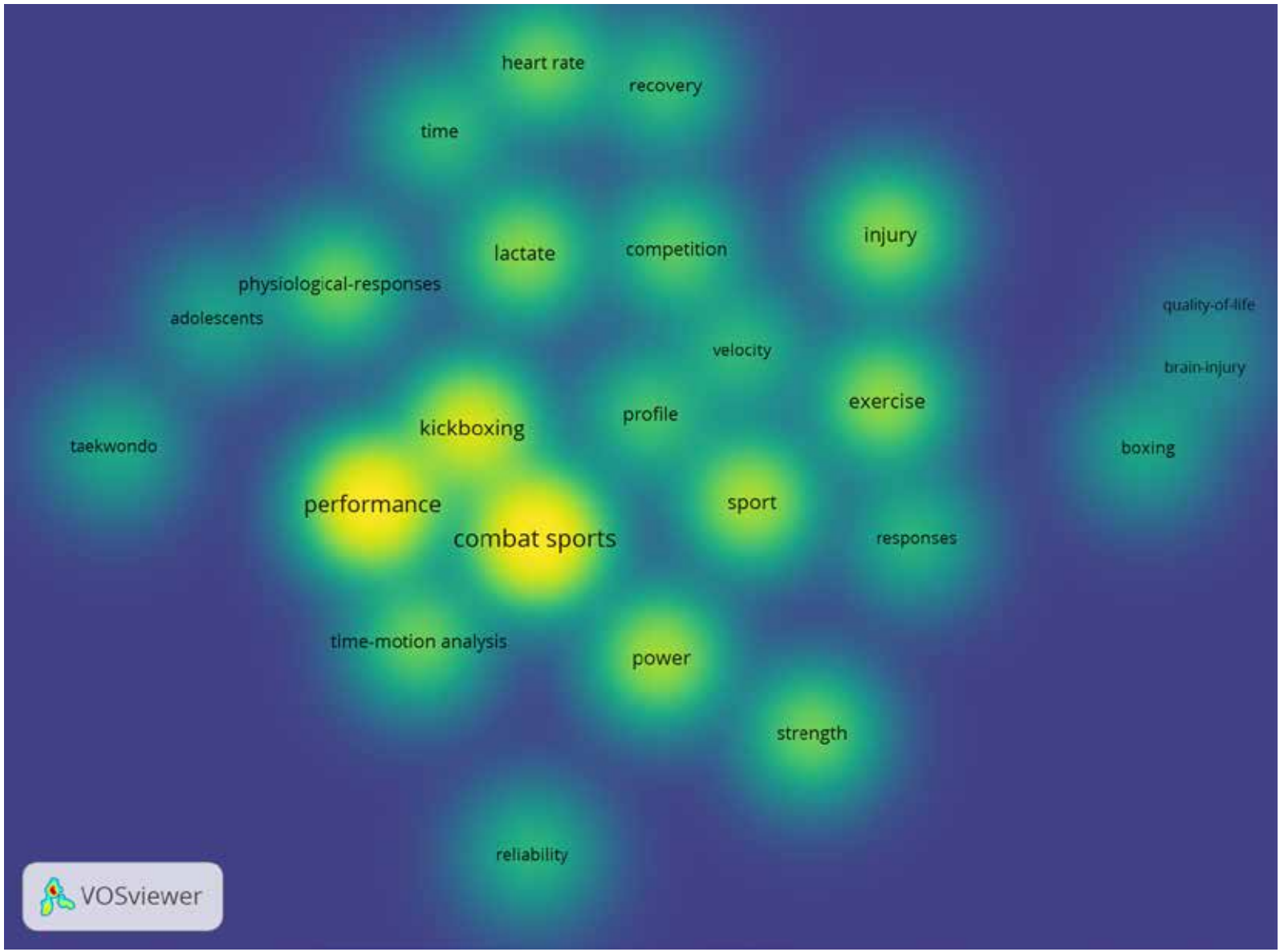

Figure 3. Directions of research in publications devoted to kickboxing (direct citation analysis, visualization of cluster density, weights - citations). Source: Own research based on data sourced from WoS and analyzed with VOSviewer (06/01/2022).

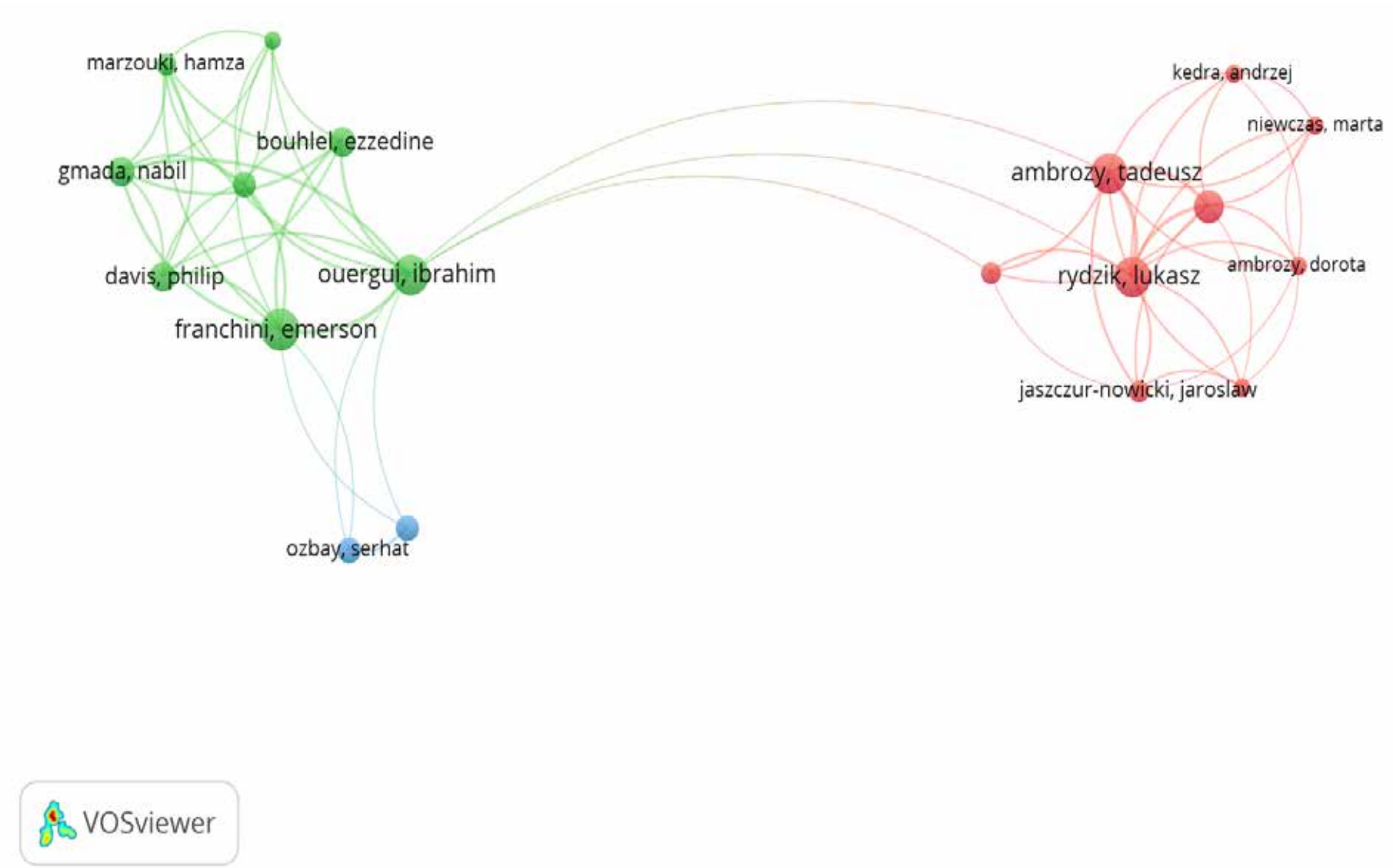

Figure 4. Main authors studied kickboxing problems, direct citation analysis, element density visualization, weights – citations): Source: own study based on data from WoS and analyzed using VOSviewer (06/01/2022).

sports is a simple and effective method of research. It was used to assess the frequency of rule violations and the possible impact on performance [15]. Performance indicators were calculated: activity, overall performance, and attack performance. The connection between the number of rule violations and indicators of technical and tactical training was determined. It was found that the calculated indicators had no connection with the number of rule violations.

Using the most effective techniques in kickboxing allows increases the likelihood of success. Ambrozy et al. [16] analyzed the connection between wins and the use of various techniques. The head hook and roundhouse kick were the most effective kickboxing techniques to win by knockout. Particular attention to the fighters during training should be given to the combinations of punches and kicks using these techniques.

Belosevic et al. [17] identified the most significant technical indicators for achieving success in kickboxing. An analysis was made of a sample of 8 final matches of the K1 tournament and the frequency of components of 280 matches. Reducing the distance is an important condition for a successful attack. The front hook can be used to thwart an opponent's attack and successfully defend.

An analysis of the time spent on the implementation of various technical and tactical elements for elite kickboxing athletes was carried out [18]. Male athletes performed more jab crosses and fewer low kicks than females. They punched more often than kicked, to the head more often than to the body and legs. It is concluded that the training programs must be adapted to the specific requirements of the weight categories and gender of kickboxing athletes to develop technical and tactical abilities that increase the chances of athletes to win.

Another popular trick in kickboxing is the double side kick. The determination of the main parameters of this kick was the purpose of this study [19]. Analysis of video recordings of kicks by elite athletes made it possible to identify the elements most important for the successful implementation of this technique.

The series of studies by Ouergui et al. [14,20,21] was devoted to the analysis of the time structure of fights in kickboxing. The results confirm the intermittent nature of kickboxing competition. This information is important for planning training sessions, simulating physical activity at competitions, and maintaining a high level of technique during a fight. An analysis of video recordings of fights showed that kickboxing athletes were more engaged in offensive actions than defensive ones. The most commonly used moves were straight punches, roundhouse kicks, blocking/parrying, and kicking. The winners used more attacking (i.e., hook strikes), defensive techniques (i.e., kicking and clinching), and punch combinations than the losers. To win, athletes must develop the most commonly used offensive techniques.

Mala et al. [22] studied the features of body composition and the asymmetry in combat sports athletes. It was determined the differences in body composition between groups in terms of the absolute values of free fat mass (FFM), bone mass, protein mass, basal metabolic rate, absolute value of total body water (TBW). A significantly larger volume of water was found in the dominant hand compared with the non-dominant hand in karate and fencing athletes.

Similar results were obtained when studying the body composition of elite combat sports athletes [23]. Judo and sambo athletes have a larger relative amount of fat tissue (about 12%). The values of fat tissue for kickboxing and taekwondo athletes were in the range of 7%-9%. The resulting models of body composition of wrestlers, kickboxing and taekwondo athletes make it possible to individualize the training process and predict sports results.

The availability and information content of heart rate predetermined the interest in using this indicator in the state monitoring of kickboxing athletes. The review summarizes the data devoted to heart rate (HR) to combat sports matches and determines the load on the cardiovascular system and the intensity of combat sports matches [24]. Optimal HR intensity as a percentage of HRmax ranged from 90-94% in judo, 86–100% in taekwondo, 83–94% in karate, and approximately 95% during Muay Thai matches. It is recommended to use HR to assess the potential of the cardiovascular system and control the intensity of exercises during combat sports competitions.

Gavrlilovic et al. [25] studied the dynamics of heart rate in kickboxing athletes during various training and competitive loads. During a match, kickboxing athletes achieve higher peak heart rates compared to punching and kicking the punch bag and sparring.

Another review was devoted to the analysis of data on methods for rating of perceived exertion (RPE) during competition and training in combat arts [26]. The rating of perceived exertion is a powerful tool for assessing training and competitive loads in beginner and elite combat athletes. RPE methods make it possible to assess the activation of the anaerobic and aerobic systems.

Evaluation of the main physical qualities and analysis of the adaptive potential of athletes.

The conducted bibliographic analysis confirmed that Ambrozy Tadeusz, Rydzik Łukasz are among the most effective authors in the field of kickboxing. In the article [27], they studied the effect of modified training based on the principles of crossfit on the

development of general physical fitness in a group of kickboxing athletes compared to the control group. An experimental training program based on the principles of crossfit training demonstrated a positive effect on the general and special physical fitness of kickboxing athletes.

Ambrozy et al. [28] confirmed that individuals with higher physical fitness were more active and effective in attack. Indicators of special effectiveness correlated significantly with technical and tactical parameters. Improvements in performance depended on punching speed, kicking distance, and special fitness test scores.

Strength, power and flexibility are some characteristics that give kickboxing athletes an edge over their opponents [29]. Increasing the level of these qualities with the help of special exercises allows increase the success of athletes. The importance of increasing flexibility in the preparation of kickboxing athletes has been confirmed. Simultaneously, the strength of compression is recognized as an uninformative quality for this sport.

Catikkas et al. [30] assessed the anthropometric characteristics of combat sports athletes such as karate, taekwondo, judo, and kickboxing. It was established that the mesomorphic somatotype dominates. Although the BMI was considered normal, the percentage of body fat was low. The athletes had broad shoulders, narrow hips and average body sizes.

The state monitoring of kickboxing athletes requires informative, valid and accessible and functional tests. The urgency of monitoring especially increases when regular observations by the coach are impossible. The physical fitness of athletes was studied during the SARS-CoV-2 pandemic [31]. A test developed by the International Committee for the Standardization of Physical Fitness Tests (ICSPFT) was used. The Tanita BC601 Body Constitution Monitor assessed the body constitution. The effectiveness of these methods has been confirmed. An increase in the body weight of athletes and deterioration in their physical fitness have been determined.

An important aspect of monitoring is the substantiation and development of screening tests to predict the growth of athletes' sportsmanship. It is proposed to use for the ratio of the second and fourth fingers of the hand (2D:4D) [32]. In judoists, wrestlers and kickboxing athletes, the 2D:4D ratio was significantly lower (on average by 0.035) than in other athletes, and in karate and taekwondo athletes it was significantly higher (on average by 0.014) than in other athletes. This index can be a useful criterion in the selection of athletes. The definition of 2D:4D reference values for specific sports is recommended.

The tensiomiography method can be used as a screening test for the kickboxing athletes' state [33]. This method allows determining local muscle fatigue, assessing the marker level of exercise-induced muscle damage (EIMD).

The specific kickboxing circuit training protocol (SKCTP) can be used for a similar purpose [7]. The effectiveness of SKCTP as a special tool for quantitative assessment of the level of physical fitness of kickboxers has been confirmed. This is because SKCTP adequately reproduces the hormonal, physiological and physical aspects of competition.

Combat sports can lead to specific morphofunctional changes in the body. Domaradzki et al. [34] conducted a comparative analysis of the posture of kickboxing and crossfit athletes. The presence of specific postural disorders in kickboxing athletes has been confirmed. It is concluded that it is necessary to include special corrective exercises in training. Postural indicators should be used for monitoring the condition of kickboxing athletes.

A comparative analysis of the strength of the leg muscles of elite kickboxing athletes was carried out in this study [35]. The presence of pronounced asymmetry was confirmed. The non-dominant leg had lower strength indicators. It is proposed to consider the results in athletes training organization.

The actual scientific direction in kickboxing is the search for adequate methods for analyzing the state of athletes. The specificity of this sport determines the interest in the study of maintaining balance. Korobeynikov et al. [36] studied the correlation between neurodynamic function and postural stability in highly skilled kickboxing athletes. Kickboxing athletes with a higher level of stability have a smaller area of fluctuations in the total center of body mass during visual deprivation. Such a higher level of resistance in kickboxing athletes is associated with an increase in accuracy and attention under conditions of differentiated information processing, while reducing muscle strength and reducing the speed of the sensory-motor response to a complex stimulus.

Similar results were obtained in a study [37]. The authors note that it is difficult for athletes to maintain balance in the third phase of the strike when performing strikes. Special balance exercises were used to improve balance, and their effectiveness was confirmed.

Flexibility refers to the physical qualities important for striking. An analysis of the goniometric parameters of the joints of the extremities of combat sports athletes was carried out in this study [38]. The influence of the level of skill on the amplitude of movements in kickboxing athletes was confirmed. The established differences reflect the specifics of the sports. The wrestlers had a higher range of motion of the wrist joint. This determines the quality of the grip in the fight. The amplitude of flexion of the right elbow joint and movements

in the shoulder joints in kickboxing athletes were increased. This allows for achieving a high-quality and strong strike. The constancy of maintaining the combat stance decreases the amplitude of adduction in the right wrist joint and abduction in the left shoulder joint in experienced athletes. An increase in training experience leads to the development of working asymmetry of movements in the joints.

Biochemical, physiological, and psychophysiological indicators of athletes reflect their functional state. Heart rate, lactate level, the speed of perceived reaction to load, the number of attacks, and leg strength in kickboxing competitions were determined in the study [39]. The metabolic requirements of athletes gradually increase from the first to the third round. This is manifested by cardiovascular responses, lactate levels, and the level of perceived load. The strength of the leg muscles and the number of punches and kicks decreased significantly during the fight. Thus, physiological stress increased, and technical and tactical indicators decreased during the three rounds.

The analysis of the adaptive potential of kickboxing athletes is one of the priority areas of research. Podrigalo et al. [40] studied the adaptive capabilities of the cardiovascular system of kickboxing athletes during standard physical activity and the recovery period. Sufficient adaptive potential of athletes, high power of the myocardium, and the possibility of more economical adaptation to the loads performed have been confirmed. The peculiarities of the reaction of participants to the loads performed reflect the specifics of combat sports.

The specificity of combat sports necessitates the control of body weight and its changes. The aim of this study [41] was to determine the rapid weight loss (RWL) in elite kickboxing athletes. Most athletes typically lose 2–5% of their body weight, while 30% lose 6–8%. It is alarming that almost 30% reported a 10% or more weight loss during sports performance. Almost half of the athletes always practice a gradual diet and increase physical activity to reduce body weight. Kickboxing athletes typically lose weight three to four times a year, usually 7–15 days before a competition. The practice of RWL in kickboxing athletes is somewhat specific and different from those of other combat sports. This can be explained by a large number of weight categories and a specific weighing protocol.

Choosing the optimal nutrition strategy is essential for success in sports. The popularity of the Mediterranean diet and the pronounced health character determined the interest in its use in sports. The influence of the Mediterranean diet on the physical performance of kickboxing athletes and runners was studied in this study [42]. Maintaining this diet for three months, along with training, improved functional test scores and reduced body fat percentage.

Analysis of the physical development of combat sports athletes is an important element in predicting the growth of sportsmanship. The physique features of elite combat sports athletes were studied using special indices [43]. A higher body mass index in wrestlers reflects the predominance of the muscular component of the somatotype. The Erisman and Pignier indices, the shoulder width index illustrate better muscle development in wrestlers and kickboxing athletes compared to karate and taekwondo athletes. The increase in the relative body surface of wrestlers reflects the growth of their aerobic capacity. An increase in the strength index confirms the importance of grip strength for success in wrestling. Limb segment ratio indices reflect the peculiarities of combat sports techniques. The conclusion is made about the presence of features due to the specifics of the types of combat sports. The validity of the use of special indices, especially those illustrating the ratio of limb segments, in monitoring the functional state of athletes, has been proven.

Slimani et al. [44] studied the effect of mental training on the development of muscle strength, hormonal changes, and physiological adaptation in trained male kickboxing athletes. The inclusion of mental training in the training of athletes contributed to the reduction of stress levels. The athletes' characterized features were the following: a decrease in the concentration cortisol, normalization of the parameters of the cardiovascular system, and improvement in strength indicators.

The study of the biochemical features of homeostasis, the state of the cardiorespiratory system

Kickboxing fights are performed under conditions of anaerobic metabolism. Athletes must have a good tolerance for metabolic acidosis and the ability to fight effectively despite acid imbalances. Indicators of homeostasis determine the possibility of success. An analysis of the level of acid balance and technical and tactical indicators of kickboxing athletes in the dynamics of the fight was carried out in the study [45]. Elite athletes demonstrated a change in blood oxygen and carbon dioxide saturation immediately after the fight. 20 min after the fight, all indicators tended to normalize and did not differ significantly from the initial values. It is concluded that anaerobic training should be included in the training programs for kickboxing athletes. This will prepare the athletes for the stress during a fight.

Kickboxing is a type of combat sports that requires high physical fitness and coordination of movements. A kickboxing fight causes significant physiological stress. Therefore, it is important to determine the body composition of athletes before the competition and analyze their skin temperature

and skin pH during the fight [46]. Changes in skin temperature and pH were demonstrated after each round of the fight. The level of fat and muscle tissue significantly correlates with the technical and tactical skills of the K1 athletes under study.

The high loads in kickboxing require athletes to achieve high results in various aspects of fitness. This review was devoted to the analysis of the anthropometric, physiological, physical, and psychological characteristics of kickboxing athletes, considering their activity profile [6]. Male kickboxing athletes, both amateur and elite, demonstrated a higher proportion of mesomorphy with well-developed muscle mass and a low percentage of body fat. The potential of the cardiorespiratory system in these athletes varies from moderate to high. Regardless of the level of kickboxing athletes, high peak and average anaerobic power outputs have been reported. High-level kickboxing also requires sufficient limb muscle strength. Confirmed characteristics affect success and should be considered in training.

The presence of different styles in kickboxing determines the specifics of the physiological reactions of athletes and the peculiarities of conducting fights. Ouergui et al. [47] studied these indicators in full contact, light contact, and point fighting. The results are the basis for improving training. Trainers should pay special attention to the development of anaerobic and muscular strength in all disciplines, especially for full contact, light contact, and maximizing aerobic power. The training regimen may include high-intensity interval training to mimic the specifics of these sports.

Monitoring the functional state of athletes is one of the leading problems in sports science. The biochemical and physiological reactions of kickboxing athletes during fights have been studied [48]. Blood lactate level and heart rate were used as monitoring indicators. It has been determined that a fight in kickboxing causes severe physiological stress in participants. The load in the fight was close to the maximum, and anaerobic metabolism played an important role in ensuring performance.

An adequate tool for monitoring the state of athletes is to control the reaction to training loads. Biochemical methods are adequate tools for monitoring the state of athletes [49]. The stress of adaptive mechanisms leads to an imbalance in the POL system – antioxidant defense. Information on the assessment of the activity of POL processes and the state of the antioxidant system and the degree of balance shift between prooxidants and antioxidants are indicators of the general state of the body, the activity, and perfection of the functioning of regulation systems, and the maintenance of a stable state of homeostasis. The informational significance of indices reflecting the ratio of various biochemical indicators, as well as the study of the dynamics of correlation structures for assessing the sufficiency of loads, was confirmed. The painlessness and information content of saliva studies is the basis for the use of such studies in monitoring the functional state of athletes.

The possibility of using psychophysiological and functional tests, biochemical analysis, and technical and tactical indicators in monitoring was studied in this study [50]. The informativeness of the study of blood lactate was confirmed. It was concluded that it is necessary to increase tolerance to lactate accumulation to perform more strokes.

Analysis and prediction of success in kickboxing.

This direction should be recognized as the most relevant in the context under consideration. The issues of predicting success, improving performance, and increasing sportsmanship are most often indicated in publications when substantiating the relevance of research. The solution to this problem requires the selection and application of adequate tools.

The importance of using informative tests to assess the state of kickboxing athletes is emphasized in the study [51]. The authors examined the validity and reliability of the Kickboxing Anaerobic Speed Test (KAST) and compared it with the Maximum Cyclic Sprint Test (MCST). The first test involved performing various striking techniques with the arms and legs. The second test was performed on a bicycle ergometer with repeated cyclic efforts of 5 x 6 sec with 10-sec rest intervals. The reliability and validity of the tests used were confirmed. The use of these tests allows for dividing athletes into elite and sub-elite.

Study [52] has a similar focus. The authors used the 10-second frequency speed of kick test (FSKT) and counter movement jump (CMJ) test to differentiate the skill level of kickboxing athletes. It has been shown that FSKT can be used to identify successful and unsuccessful kickboxing athletes, as it is more effective in distinguishing groups than the CMJ test.

Olmez et al. [53] studied the effect of sprint and calisthenics training methods on improving athletic performance in kickboxing. Anthropometric indicators (body length and weight, body composition) and functional indicators (aerobic endurance VO(2)max), peak anaerobic power, and isometric leg strength) were used to evaluate the effectiveness. Repetitive sprint training and calisthenics methods are effective in regulating athletes' body composition and accelerating the development of aerobic endurance, power, and strength.

The prediction of sportsmanship's growth can be based on the study of the connection between the technical-tactical and physical training of athletes.

Rydzik et al. [54] determined a significant correlation between the indicators of technical and tactical training and the results of fitness tests. There is a connection between the effectiveness, activity, and effectiveness of attacks and upper limb movement speed, explosive strength, static hand strength, agility, VO(2)max, and abdominal muscle strength.

An important point in the prediction of combat sports is the determination of the sportsmanship level of athletes. Various indicators and criteria can be used for this. The review [55] is devoted to determining the optimal physiological profile for differentiating combat sports athletes of different levels. Wrestling is characterized by the development of maximum strength and a lower level of speed qualities. Combat sports require the predominant development of speed. The sportsmanship level directly depends on the anaerobic capabilities of the athletes. The ability to maintain long-term anaerobic efforts determines success in wrestling, and short-term – in combat sports.

The success of athletes is determined by the level of general and special performance. Romanov et al. [56] studied these indicators at the stages of pre-competitive training. An assessment of the overall performance of kickboxing athletes revealed significant reserves of the anaerobic threshold, lung volume, respiratory rate, and pulmonary ventilation. The values of systolic pressure testified to the high cardiovascular potential of the athletes during the functional test. A higher rate of lactic acid neutralization in working muscles was observed, which indicated a higher rate of adaptation to the applied loads.

A promising method for predicting success in kickboxing is the development of special prognostic methods. The use of sequential analysis according to Wald made it possible to develop such a technique [57]. The prognostic table includes morphofunctional, physiological, biomechanical, and psychophysiological indicators, the information content of which varied within 115.45 – 2.23. The content of the prediction consists of evaluating the results, determining the appropriate predictive coefficient, and summing these coefficients to achieve one of the prognostic thresholds. Following generally accepted approaches, the threshold value was set at ± 13, which corresponds to a probability of 95% ($p<0.05$). Exceeding the positive threshold means a high level of success for the athlete. When the negative threshold is reached, the probability of success is low.

Conclusions

The conducted bibliometric analysis of publications devoted to kickboxing in the WoS database confirms the relevance of this area of sports science. The use of the VOSviewer program, version 1.6.18, made it possible to conduct a comprehensive analysis of the problem, to determine the priority scientific directions in this area. Publications belong to two main areas: sports and rehabilitation and recreation. These areas are practically unrelated.

In sports, the most popular direction is the analysis of the technical and tactical indicators of athletes, and the time spent on their implementation. Research has a pronounced practical orientation. The study of the metabolic characteristics of combat sports athletes and the assessment of their physical qualities are quite relevant. There is a lack of research on the comprehensive study of success. This direction is declared in many works but is practically unimplemented. The situation is similar in studies of monitoring the condition of kickboxing athletes. These areas should be recognized as the most relevant in this area.

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ORIGINAL ARTICLE

The effect of physical exertion on the concentration of copper and blood pressure in 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: Several mineral elements are necessary for the athlete's body, which significantly impact the development of sports achievements because of their active role in bringing internal balance to the athlete's body. The study aims to determine the concentration of copper in the blood before and after the implementation of physical exertion at a level of 180 pulse/min on middle-distance runners.

Material and Methods: Twelve athletes who are team members at Egyptian clubs were chosen deliberately as a research sample. The study participants were at the end of their special preparation. The experiment was conducted between July 12, 2021, and July 14, 2021, on the research sample, resting after exerting physical effort by running on a treadmill at a speed of 10 km / h. The runner continued at this speed for 3 minutes, after which the device's speed increased by 2 km / h every minute until reaching a heart rate of 180 pulse/ min.

Results: The mineral differences in the copper element are attributed to the immediate induced by physical exertion by increasing the copper element in the blood within the normal level. This causes many changes and responses within the body cells. The copper element plays a significant role in oxidation and reduction processes via enzymes that require the copper element to produce energy in the cells and tissues due to the body's exposure to physical exertion. Athletes' exposure to physical exertion causes copper-dependent enzymes to produce energy in cells and tissues due to the element's requirement.

Conclusions: Copper affected the physical effort of middle-distance runners at a heart rate of 180 pulse/min. In addition, Middle-distance runners' blood pressure (systolic and diastolic) was affected by the physical exertion at a heart rate of 180 rpm.

Keywords: copper, blood pressure, athletes, physical exertion

Introduction

Mineral elements are essential for an athlete's body because they are vital in bringing internal balance to the athlete's body, significantly affecting athletic achievements [1]. Therefore, modern techniques are used to measure and determine the proportions of mineral elements to support the movement of progress, and the events of a state of development increase the level of responses of the cells in athletes [2]. Reaching high athletic levels requires consistent training over a long period to any of the body's responses [2, 3, 4, 5]. Copper is a component of many proteins and enzymes that perform critical biological functions in the cells and contribute to maintaining their homeostasis [2]. It is a necessary metal for living things, but it is also potentially toxic to cells due to its ease of oxidation as a free ion [6]. Therefore, to perform their essential functions, copper-dependent metalloproteins, such as antioxidants, the copper ion must be compartmentalized and present in appropriate intracellular and extracellular concentrations [7].

This mineral's deficiency and excess can both harm cellular integrity and functionality. A sufficient copper intake is required to ensure athletes perform well [8]. Other nutrients, such as iron and zinc, may adversely affect copper homeostasis and harm the antioxidant function when consumed in excess [9]. Athletes frequently use nutritional supplements that do not adequately consider copper supply, which may jeopardize copper's essential role during physical activity [10]. Intense physical exercise increases the release of reactive oxygen species and may affect copper homeostasis. Several factors influence the levels of metalloproteins, serum copper, and physical activity [11].

Trace minerals (TMs) are necessary for the human body due to several biological functions that could be directly or indirectly involved during different physiological processes that can be altered as adaptation mechanisms to endurance exercise

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[12, 13, 14, 15]. Changes in blood pressure during any athletic event are one of the physiological mechanisms by which the cardiovascular system provides oxygen to the exercising muscles. Blood pressure in healthy normotensive men never exceeds safe levels during strenuous exercise [16]. However, the evidence for a correlation between serum copper and blood pressure (BP) has been inconsistent or contradictory, and most studies have been conducted in adult populations [17]. Therefore, the subjects with high blood pressure who wishes to participate in competitive athletics should proceed with caution. Although this problem has recently received much attention, information on the effects of muscular exercise on human blood pressure is primarily limited to laboratory tests.

Purpose of the Study.

• To evaluate the concentration of copper in the blood before and after the implementation of physical exertion at a level of 180 pulse/min on middle-distance runners.

• To determine the blood pressure before and after the implementation of the physical effort at a level of 180 pulse/min on middle-distance runners.

Materials and Methods

Participants

Temporal domain: From July 1, 2021, to July 29, 2021.

The research sample was chosen deliberately, as it included 12 athletes who are members of Egyptian club teams.

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Suez Canal University (approval number 121/2021). All participants provided written informed consent.

Research Design

The researchers used the descriptive approach using the survey method.

Devices and tools used in the research

The following devices and tools were used:

1- Atomic absorption spectrometry
2- The treadmill device
3- Blood pressure measuring device
4- Medical scale for measuring weight and height
5- Cooling case
6- Plastic tubes, medical syringes, cotton, and sterile material
7- stethoscope

Body Measurements

The subjects' height and weight were measured using a medical scale, and their height and weight were recorded

Functional measurements

1- *Copper element measurement*

Blood samples were collected from subjects before and after exerting physical effort at a rate of 180 pulse/min, then the samples were chemically digested and prepared for measurement in the atomic absorption spectrometer. Afterward, the results were compared with the calibration curve to measure the concentration of copper in the blood.

2- *Heart rate measurement*

The heart rate of the research subjects was measured only at rest and for 30 seconds x 2.

3- *Arterial blood pressure measurement*

Blood pressure was measured before and after physical exertion at a rate of 180 p/min directly on the research sample.

4- *Conducting the experiment*

The main experiment was conducted between July 12, 2021, and July 14, 2021, on the research subjects in a resting position and after exerting physical effort by ascending the athletes on the treadmill.

Moving at a speed of 10 km / h, where the jogger continues at this speed for 3 minutes, and then the speed of the device increases every one minute 2 km / h until it reaches a heart rate of 180 pulse/ min, after which the assistant staff was prepared.

Statistical Analysis.

Data were fed into the computer and analyzed using IBM SPSS software version 20.0. (Armonk, NY: IBM Corp). The Kolmogorov-Smirnov was used to verify the normality of the distribution of variables. Paired t-test was used to compare two periods for normally distributed quantitative variables. The significance of the obtained results was determined at 5% level.

Results

The variables heart rate, height, weight, and age at rest are represented by the mean, standard deviation, and coefficient of variation. The researchers tested the homogeneity of the research sample, as shown in (Table 1), where the coefficient of variation for the variables is less than (25 %), indicating the homogeneity of the research sample. The results of copper and blood pressure before and after implementing physical effort are displayed in (Table.2).

Table 1 displays the arithmetic mean, standard deviation, and the calculated and tabulated T value for the copper, systolic, and diastolic pressure variables before and after implementing the physical effort.

The calculated (T) values for copper metal, systolic pressure, and diastolic pressure were (6.72) (11.98) (3.394), which is greater than the tabular (T) value (2.015) below the level, as depicted in (Table 2). (0.05). When the heart rate reaches 180 rbm, there are significant differences between the dimensional effort of each copper element and the systolic and diastolic pressures.

Table 1. Demographic data for the study sample

Variables	Arithmetic medium	Standard deviation	Variation coefficient
Heart rate/min	55.12	3.76	6.21%
Length/cm	169.01	4.31	3.01%
Weight/kg	58.22	5.52	9.22%
Age/year	23.14	1.75	6.29%

Table 2. Relationship between elements before and after physical effort

Variables	Physical effort		The standard deviation of differences	Standard error	T Value	P-value	Statistically significant
	Before	After					
Copper element µ/100ml	85.2	99.33	4.11	1.28	6.72	0.038	Sig.
Systolic pressure mm Hg	118	177	12.06	4.03	11.98	0.0102	Sig.
Diastolic pressure mm Hg	65	78	5.14	2.01	3.394	<0.0001	Sig.

The statistical test used: Two sample T-test; p-value≤0.05 considered statistically significant (95% confidence interval).

Discussion

The mineral differences in the copper element are attributed to the immediate induced by physical exertion by increasing the copper element in the blood within the normal level. This causes many exchanges and responses within the body cells. The copper element plays a significant role in oxidation and reduction processes via enzymes that require the copper element to produce energy in the cells and tissues due to the body's exposure to physical exertion.

Furthermore, the copper element accelerates the absorption of iron by hemoglobin, which plays a vital role in the process of oxygen transport, which combines with iron to provide oxygen to the working muscles and produce the energy during the physical effort in the research sample. Copper-binding enzymes influence the process of energy production within cells. Copper is released from its storage site into the bloodstream in significant amounts due to muscular effort. Increase iron absorption to compensate for the deficiency and increase the rate of oxygen transport by increasing iron absorption.

Based on the research findings, hemoglobin in the blood works to deliver oxygen in combination with iron to the working muscles through the arteries and blood vessels. Consequently, it was necessary to have a metal that works to regulate the balance in the internal environment through which some related interactions are controlled in energy production during continuous training for middle-distance runners [13, 14, 15]. The mineral differences are attributed to the physical effort at a rate of 180 pulse/min, which imposes a burden on the members of the research sample by increasing the blood concentration [18]. This causes a long-lasting blood viscosity in sports, which is reflected in the increased resistance to blood flow in the blood vessels, including an elevation in blood pressure [systolic and diastolic). This is reflected in the increase in the effects and responses made by the heart muscle to ensure the muscles' need for oxygenated blood and to produce the energy required for these muscles to continue working during physical exertion.

These findings are consistent with the findings of the Lamberts study in that the long-distance athlete had elevated blood pressure after exerting an effort for a period of [10 minutes) on a moving treadmill [19, 20]. Due to the significant correlation between blood concentration and blood viscosity, blood concentration is one of the most important physiological factors in exercising [21, 22]. Sporting activity increases the density and turbulent blood flow in the blood vessels due to the increased speed of the general flow throughout the circulatory system [23, 24].

Conclusions

1- The study aimed to determine the concentration of copper in the blood of middle-distance athletes before and after the implementation of physical activity at a pulse rate of 180 per minute. The average increased from 85.2/100ml before the effort to 99.33/100ml after the effort, according to the results. In addition, copper levels in the blood rose but remained within normal parameters. Due to the increased exposure of athletes to physical exertion, the body undergoes numerous exchanges and responses, including copper, which plays a significant role in oxidation and reduction processes via enzymes that require copper to produce energy in cells and tissues.

2- Blood pressure before and after the implementation of physical effort at a rate of

180 beats per minute in athletes leads to an increase in the effects and responses made by the heart muscle to meet the oxygenation needs of the muscles to continue functioning.

3- Our study found a positive and nonlinear association between serum copper and elevated blood pressure in athletes.

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The authors of this original article. Collected, organized, and analyzed all of the data utilized in this article and concluded from the results of the data analysis.

Conflict of interest

The authors declare no conflicts of interest.

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The effects of deep breathing on the mental toughness of athletes in Puchong Fuerza football club

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Abstract

Background and Study Aim: A group of psychological traits that are essential to achieving peak performance are referred to collectively as mental toughness. One of the most significant psychological traits linked to sports success, according to athletes, coaches, and sport psychologists, is mental toughness. This study aims to identify the effects of deep breathing on the mental toughness of athletes in Puchong Fuerza Football Club who played in M3 Football League, the Malaysia's third-tier football league.

Material and Methods: The research was conducted experimentally with two sessions which include pre-test and post-test. Mental Toughness Questionnaire 48 (MTQ48) and deep breathing techniques were used in this research. Data findings were analyzed to answer the research questions and null hypothesis. Hypothesis testing was used, and inferential statistics analyzed the data. Paired sample t-test was used to identify the effects of deep breathing techniques on mental toughness scores in pre-test and post-test.

Results: The analysis results showed that data on mental toughness was negative. It proved by the mean score difference of the pre-test and post-test, in which there were increments of mental toughness score after applying deep breathing technique. Meanwhile, there was a significant difference in mean scores between players toward their mental toughness based on pre-test and post-test results.

Conclusions: Therefore, the deep breathing technique has relations with performance and psychological outcomes and can be use as a pre-match mental preparation. It is suggested that coaches and athletes may include the deep breathing technique in training program. The players need to undergo psychological skill training such as deep breathing technique to improve their mental toughness and to ensure that anxiety is at an optimal level in order to achieve excellent performance in competitions.

Keywords: mental toughness, deep breathing, football athletes, mental toughness questionnaire

Introduction

Performance in football is not only based on physical fitness, technique, tactics, endurance, agility, and coordination, but psychological factors such as motivation, psychological skills (PS), and mental toughness have been considered essential for football performance [1, 2, 3]. According to Weinberg et al., athletes with strong appear to prevail more often compared to athletes with weak mental toughness as physical, technical, and tactical skills are as important as mental fitness [4].

In sports, mental toughness is as important as physical fitness for players. Stress and pressure are often experienced by athletes, both amateur and elite sports athletes [5]. Hence, mental or psychological training is very crucial for them [6].

Sports psychologists explained that mental toughness is the ability to consistently perform toward the upper range of your talent and skill regardless of competitive circumstances, as well as s the most critical psychological attribute in determining success [3, 7, 8, 9]. Mahoney et al. states mental toughness is a term often used to describe a collection of psychological characteristics thought to be central to high performance [10]. Athletes, coaches, and sports psychologists have consistently implicated mental toughness as one of the most important psychological characteristics related to success in sports [7]. Most athletes and coaches believe that psychological factors are equally important as physical and skills attributions to be the winner. Cowden argued that at least 88% of relevant studies found athletes with higher levels of mental toughness tend to achieve more or perform better [11]. With very upper-range skills and psychology, they have excellent skills in controlling their mind to achieve victory. Mental toughness will not compensate for lack of talent, but it can differentiate between winning and losing in close contests. Mentally tough athlete has a high sense of self-belief and an unshakable faith that they can control their destiny. These individuals can remain relatively unaffected by competition

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and adversity [12].

Researchers nowadays are tended to focus on defining and describing mental toughness without exploring the relationship between mental toughness and variables such as achievement level, gender, age, sporting experience, or type of sports. The importance of this study was to investigate the effects of deep breathing on mental toughness. The study of Nirmalasari et al. recommended that the combination of the deep breathing exercise with active range of motion decreases the systole in Congestive Heart Failure (CHF) patients [13]. In line with Greiwe et al. study, proper breathing is inextricably interwoven with well-coordinated movement and mental skills in sports [14]. It also served to figure if all the athletes can dominate the deep breathing technique and apply it in any situation, especially in tournament seasons. Through the interventions, athletes can feel stress reduction before or during the tournament. Therefore, the study is crucial to help the coaches apply and develop the psychological skills of athletes, especially in mental toughness through deep breathing, to help the team attain success.

This research focused on investigating the effects of deep breathing on the mental toughness of Puchong Fuerza athletes. This research was carried out in two sessions, i.e., pre and post-sessions. Deep breathing and mental toughness literature review were studied in depth to construct the main research question in this study. This study focused on football athletes who played in Malaysia's third-tier division.

Materials and Methods

Participants.

The athletes involved in this research are 24 footballers of the M3 football league from Puchong Fuerza Football Club. The criteria include the athlete must actively compete within 1 to 2 years, have a good health condition, and will be able to commit to this research. All procedure performed in this study were in accordance with ethical standard of the institutional Research Ethics Committee. Informed consent was obtained from all participants involved in this study.

Research Design.

This research is a quantitative experimental study. Athletes were requested to take pre-test and post-test to measure the effects of deep breathing on mental toughness. The Mental Toughness Questionnaire-48 (MTQ48) as conducted in previous study was administered to collect scores [13]. The previous study by Dahlan and Muhamad [15] as well as Lamat et al. [16] also used MTQ48 as an instrument. A quantitative approach focused on research, whereas the data analysis process focused on numerical data using statistical counting. The results from this study were explained in terms of calculation and numbers.

This study used two main research instruments, i.e., the deep breathing technique and MTQ48. There were a lot of suitable ways for athletes to practice the deep breathing technique. They could sit straight up or even lie down while putting the hands-on top of their stomach and chest. In this study, the researcher used 343 breathing methods: inhale in the count of 3, then holding the breath in the count of 4, and exhaling in the last count of 3. The researcher's rationale chooses the minimal count of seconds because this technique could be done anytime without consuming much time. For example, if the athletes feel stressed during the tournament, they can do deep breathing techniques to relieve their stress. Meanwhile, there were 48 questions to be answered using 5 points Likert scale in the Mental Toughness Questionnaire 48-Items (MTQ48). The respondents were required to answer all the questions by circling the correct choices.

Statistical Analysis.

The data were obtained from the questionnaire. The researchers recorded all the data and analyzed them using IBM SPSS Version 23.0. The significant statistic was set at $p \leq 0.05$. Paired sample t-test was used to analyze the score differences of mental toughness in pre-test and post-test.

This study aims to identify the effects of deep breathing techniques on the mental toughness of football athletes from the third-tier Malaysia football league club, Puchong Fuerza FC. The data obtained from the pre and post-tests of the questionnaires were analyzed using paired sample t-test inference statistics and were processed using SPSS software version 23.0. The researcher reviewed the sample answers in the pre-test and post-test questionnaires to ensure that the respondents answered according to the instructions. The process of analyzing the data divided into two parts, i.e. Part A and Part B. Part A contained the demographics of the respondents. At the same time, Part B analyzed the scale values of pre-test and post-test questionnaires for the respondent groups by comparing mean and paired sample t-tests in Statistical Package For The Social Sciences (SPSS) version 23.0. Two null hypotheses were presented to answer the two research questions of this study. Paired sample t-tests were used to determine if there were any significant differences in the effects of deep breathing technique between pre-test and post-test mental toughness scores and to determine if there were any mean differences between players towards their mental toughness score.

Results

Analysis of the significant difference on the effects of deep breathing technique.

The paired sample t-test was used to identify the effects of deep breathing techniques on the pre-test and post-test on mental toughness scores. The test determined any significant differences in the effects of deep breathing techniques between pre-test and post-test mental toughness scores. The increment of mean scores could determine how far deep breathing techniques affect the mental toughness scores. Table 1 shows the differences in mean scores for the pre and post-groups.

Table 1 illustrates the paired sample t-test and the differences between the mean score from pre-test and means score from post-test. Paired sample t-test analysis showed that the p-value was 0.024, which was significant at the level $p<0.05$. Thus, this finding rejects the first null hypothesis which is there are no significant differences between the effects of deep breathing technique between the mental toughness score of pre-test and post-test.

Analysis means differences between players towards their mental toughness

The paired sample t-test was also used to identify the different effects on the feeling of players after doing the deep breathing technique using mental toughness score. The test determined any mean differences between players towards their mental toughness score. The increment on these two mean scores indicates how far the deep breathing technique affects the mental toughness score of players. Table 2 shows the paired sample statistics for the mean score for the pre and post-group.

Based on Table 2, the mean score for pre-test was 3.6163, while the mean score for post-test was 3.8017. The data indicate that the mean score value for the post-test was higher than the mean score value for the pre-test. Thus, this finding rejects the second null hypothesis: there were no mean differences between players towards their mental toughness score.

Discussion

The results of this study including the difference between mental toughness scores in pre-test and post-test after applying deep breathing techniques, is discussed. The analysis results showed that data on mental toughness was negative. It proved by the mean score difference of the pre-test and post-test, in which there were increments of mental toughness score after applying deep breathing technique. The previous study by Perciavalle et al. proved that the use of deep breathing techniques has a significant improvement between the beginning and the end of the training and also lead to an effective improvement of management stress in everyday life [17].

During the testing of the first and second null hypotheses, the paired sample t-test was used. It shows a significant value of deep breathing technique between pre-test and post-test of mental toughness scores (0.024). Meanwhile, there was a significant difference in mean scores between players toward their mental toughness based on pre-test and post-test results. The athletes showed an increasing reaction towards their mental toughness. Based on table 1, the mean score difference between pre-test and post-test was -0.18535. These finding agreed with Cowden who indicated that mental toughness is one of the most crucial psychological factors impacting athletic success [11]. The link between mental toughness and sporting achievement can be observed not just when performance is measured objectively, but also when the athlete evaluates their own performance subjectively [8, 9, 18, 19, 20].

Hence, the hypotheses null was rejected. Paired sample t-test was used to test the null hypothesis to answer null hypotheses 1 and 2. The data analysis showed that both null hypotheses were rejected successfully due to the significant means score difference in the first and second objectives.

Table 1. The differences in mean scores for the pre and post-groups.

	Paired Samples Test							
	Paired Differences							
TEST	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pair 1 PRE TEST-POST TEST	-18535	.37530	.07661	-.34382	-.02687	-2.419	23	.024

Table 2. The paired sample statistics for the mean score for the pre and post-group.

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE-TEST	3.6163	24	.19241	.03928
	POST-TEST	3.8017	24	.33606	.06860

Based on the results, deep breathing was proven to positively impact [21] athletes' mental toughness, especially before or during a tournament [22].

Conclusions

In conclusion, this deep breathing technique can positively affect athletes' mental and psychological development. Besides performing deep breathing techniques during tournaments, athletes can apply them daily. In addition, deep breathing exercises can improve pulmonary function [23], motor abilities [10]. Having a good mind is as essential as having a healthy body.

The researchers carried out this study to expand more literature about the importance and relation of psychological skills to sports [24], profound breathing, and mental toughness. There are so many benefits to be harnessed in applying this skill or technique. This study can open the athletes' eyes by doing the right thing in managing their emotions and making sure that they are always positive.

Recommendation for Future Research

A strong mentality is vital, especially for medium or high-intensity sports. The previous research by Bell et al. also focused on the importance of mental toughness in sports [25]. From the benefits of the study, athletes will know the importance of having mental toughness and can keep it up by just using simple methods such as deep breathing.

For future research, the researchers hope there would be more studies about a psychological technique [26] that could help improve the mental toughness of athletes. The researchers could expand and increase the respondents to get a better validity about this concept of study.

Finally, future researchers also can study athlete perceptions of the effects of deep breathing towards mental toughness, especially for high profile athletes. Clear studies also must be done to spread more knowledge between athletes and non-athletes.

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ORIGINAL ARTICLE

The effects of small-sided games versus traditional training on physical fitness and skills among Under-12 hockey players

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

Abstract

Background and Study Aim: Despite many evidences showed the effectiveness of small sided games (SSG) to be included in sport training programs, majority of the study was done in soccer, while is very limited in hockey. The purpose of this study was to determine and compare the effects of small sided games and traditional training on physical fitness components (cardiovascular endurance, power, speed) and skills (dribbling, hitting, passing) among Under-12 hockey players.

Material and Methods: A total of 36 primary schools' male students aged below 12 that represent their district were randomly divided into three groups; i) 3x3, ii) 4x4 and iii) traditional training (TT). The yo-yo test (cardiovascular endurance), standing long jump test (power) and 30m sprint test (speed) were conducted to measure level of physical fitness performance while the skills of the players was tested based on the skills of dribbling, hitting and passing. Pre- and post-tests were conducted on all fitness and skill level before and after 8 week intervention period. Mixed between within analysis of variances (ANOVA) was used to analyze the differences in physical fitness and skills performance between and within the three groups.

Results: The results of this study showed all groups managed to improve their physical fitness and skills in the post test. However, the 3x3 and 4x4 SSG have better improvement compared to TT in physical fitness while no significant differences were found in skills tests.

Conclusions: In conclusion, SSG interventions were found to be more effective in improving physical fitness but not in terms of skills. Coaches are encouraging to implement SSG in their training program in order to improve both physical and skills among hockey players.

Keywords: physical conditioning, training program, sport-specific training, youth sport, performance

Introduction

Small sided games (SSG) are a training method that modifies playing area size dimensions, rules and players formations to compete like a real situation (actual match) [1, 2, 3, 4]. Years by years, study on the effectiveness of SSG keep getting attention because it was shown to improve athletes' physical fitness, technical and tactical skills simultaneously to meet the demands of the game [3, 4, 5, 6]. In order to investigate the effectiveness of SSG training, numerous comparison studies have been conducted between SSG training with other training methods. It was also found in study by Pekas et al. [7] which showed SSG training significantly improved power and passing skill accuracy among volleyball player compared to the instructional training (traditional) method. Other than that, study by Amani-Shalamzari [6] showed both SSG and Generic Fitness Training (GFT) increase physical fitness and only SSG increase technical performance. The most frequent training method that have been compared with SSG was high intensity interval training (HIIT), which usually showed similar effect on the improvement in cardiovascular endurance performance by both type of training [8, 9, 10, 11].

SSG is one of the training methods that often being practiced in team sport such as soccer and has proven its effectiveness in various aspects of physical fitness and technical performance [12, 13, 14]. Hockey is a team sport involves tactical skills such as attacking and defending. In addition, there are various type of technical skills in hockey such as dribbling, hitting, and passing skills. This game situation requires the player to have not only good technical skills but also having optimum physical fitness level such as cardiovascular endurance, speed, agility and power to meet the competition demands [15]. However, lack of studies related to SSG training conducted in hockey especially among children, thus little evidence was available regarding

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appropriate SSG training format for young hockey player to ensure it can reach the usual desired match intensity.

However, conducting SSG training program should have several aspects to be considered. Among them is the size or format of the SSG. In hockey, the SSG can be played by having at least 2x2 to promote skills improvement such as passing. The more number of players would promote coordination and teamwork. However, previous studies in soccer have shown that 3x3 formation is better to enhance cardiovascular endurance. Thus, a coach should consider how the SSG training can be used to promote both skills and physical fitness in order to save time while optimizing the benefit. The effects of the formation of SSG in hockey is rare, thus, a study is needed as a reference to the coaches.

Therefore, the purpose of this study was to determine the effect of 8 weeks 3x3 and 4x4 small sided games training on physical fitness and specific hockey skill performance among male hockey player under 12 years old.

Materials and Methods

Participants

A total of 36 male hockey players under 12 years old was involved in this study. All participants were divided into three groups, which consisted of 3vs3, 4vs4 and traditional training (TT) groups. Both the 3vs3 and 4vs4 intervention groups received small sided games (SSG) training for eight weeks, while the control group underwent normal training as usual. Pre- and post-tests of physical fitness and skills were performed on all three groups. Participants were free from any injuries and participation consent has been signed by their parents. This research has been approved by the Sultan Idris Education University Research Ethical Committee.

Research Design

Physical fitness measured in this study consisted of cardiovascular endurance, power and speed. Yo-yo test was performed to measure cardiovascular endurance. Cones were used to mark out two lines 20m apart. To start the test, participants were instructed to place their foot behind one of the lines and begin running to another line when the beep sound start. The "beeps" tempo quickens after every minute. Participants must continuously run between the two lines following "beeps" tempo and they will be stopped if did not arrive at the lines two times in a row.

Standing long jump test was performed to measure power. For this test, participant was asked to stand and place their feet behind the line marked. Participant then ready by swinging the arms and bending the knees to jump horizontally as far as their can and landing with two foot. Each participant was given three attempts, the furthest distance counted as performance.

Lastly, 30m sprint test was performed to measure speed. For this test, cones were placed between the starting and finishing line 30 m apart. Participant then sprint as fast as possible from starting line to finishing line. The stopwatch started when the participant starts the run and stopped when the participant finished the run. Each participant was given three attempts, the fastest time being recorded as performance.

Beside physical fitness test, this study also measured specific hockey skill consisting of dribbling, hitting and passing. For dribbling test, the cones were placed in a straight line of 10 meters apart. Participant were instructed to dribble the ball by using hockey stick through the cone slalom. Time was taken from start of dribbling to the end when the ball crosses the last cone.

To perform hitting skill test, participant stand behind the line marked, then hit the ball by using hockey stick to the goal. Performance was counted based on the number of balls successfully put into the goal.

Lastly, for passing skill test, participant required to pass the ball by using hockey stick into several target that have been set around them.

Statistical analysis

Descriptive statistic was used to obtain mean and standard deviation. A 3x2 mixed design ANOVA was used to determine the effect of small sided game training between intervention groups (3vs3, 4vs4) and control group during pre and post-test on physical fitness and skills performance. P-value of 0.05 was set as significant value. All statistical analysis was performed using Statistical Package for Social Science (SPSS) Version 23.

Results

Participants characteristics

Table 1 showed the mean and standard deviation of participant physical characteristics consisting age, height and body mass.

Table 1. Mean and standard deviation of participant physical characteristics.

Hockey player (N=36)	Mean± Standard Deviation
Age (years)	11.12 ± 0.72
Height (cm)	155.58 ± 2.68
Body mass (kg)	45.25 ± 2.59

Result of the mixed between within ANOVA indicated that there was significant interaction ($p<0.05$) for cardiovascular endurance $F(2,33)=7.836$, $p=.002$, $\eta_p^2=.322$ between test and group. Table 2 showed the mean and standard deviation for physical fitness component during pre and post-test between group. As showed in table 2, no significant

difference during pre-test for all group. However, yo-yo test performance that was converted to vo2max value in group 3vs3 (p=.013) and 4vs4 (p=.022) were significantly better compared to traditional training (TT) in post-test. No significant difference was showed between group 3vs3 and 4vs4.

There was significant interaction for power F(2,33)=10.176, p=.000, η_p^2=.381 between test and group. No significant difference during pre-test for all group. However, as showed in table 2, standing long jump performance on group 3vs3 (p=.033) and 4vs4 (p=.014) were significantly greater compared to traditional training (TT) in post-test. No significant difference was showed between group 3vs3 and 4vs4.

As the other 2 parameters, there was significant interaction for speed F(2,33)=4.092, p=.026, η_p^2=.199 between test and group. No significant difference during pre-test for all group. However, 30m shuttle run test performance on group 3vs3 (p=.022) and 4vs4 (p=.009) were significantly greater compared to control group in post-test. No significant difference was showed between group 3vs3 and 4vs4 (table 2).

Table 3 showed the mean and standard deviation for skills performance during pre and post-test between group. Result of the mixed between within ANOVA in table 3 indicated there was significant differences of pre- and post-test in each groups (p<0.05). However, no significant differences were found between all the groups in the pre- and post-tests (p>0.05).

Discussion

The results of this study indicated that all kind of training whether adopting SSG or traditional methods successfully improved the physical fitness and hockey specific skill performance of under 12 hockey players. However, using SSG methods were found to be more effective on the physical fitness components.

Previously, Asci [12] have compared various player formations in soccer (3vs3, 4vs4, 5vs5, 7vs7 and 9vs9) and have found 3vs3 formations significantly increase heart rate result (HR and % Hr_{max}) compared to other formation which indicates the occurrence of an increase in intensity. According to Asci [12], reducing number of player gave opportunity for players to play at sufficient high intensity zones during SSG training, thus allows players to meet the demands of the actual match. This cardiovascular endurance performance enhancement may also be associated with an increase in maximum oxygen uptake as found in study by Delextrat and Martinez [16] that showed 6 week of SSG training significantly improve Vo^2max capacity. While, Delextrat et al. [17] explained that adaptation results from high intensity training such as SSG with 3vs3 formation and 4vs4 was capable to speed up the recovery of PCr storage associated with the process of reoxygenation. A faster rate of muscle reoxygenation in recovery from exercise can result better muscle aerobic function due to the increasing of muscle oxidation capacity and increasing of blood

Table 2. Mean and standard deviation for physical fitness component during pre and post-test between group.

Physical fitness component	Test	3vs3	4vs4	TT
Cardiovascular: vo2max (mL/kg/min)	Pre	39.08±2.42	38.83±2.20	38.75±2.36
	Post	42.15±1.00[c]	42.33±1.96[c]	40.08±2.50[a,b]
Power:	Pre	31.40±2.16	32.08 ±1.16	31.98±2.67
vertical jump (cm)	Post	36.55±0.16[c]	36.77±0.19[c]	33.55±0.15[a,b]
Speed (s):	Pre	5.93±4.92	5.88±.515	5.99±.515
30 m sprint (s)	Post	5.45±.622[c]	5.40±.652[c]	5.72±.515[a,b]

Note: a= significantly difference from 3vs3 group, p < 0.05; b= significantly difference from 4vs4 group, p < 0.05; c= significantly difference from TT, p < 0.05

Table 3. Mean and standard deviation for skills performance during pre and post-test between group.

Skills	Test	3vs3	4vs4	TT
Dribbling (s)	Pre	15.42±1.44	15.17±1.44	15.58± 1.88
	Post	14.37±1.30	14.25±1.12	14.23±1.19
Hitting (n)	Pre	6.25±.965	6.08±1.08	6.33±1.07
	Post	7.38±1.21	7.25±0.96	7.40±0.90
Passing (n)	Pre	15.01±2.74	15.08±2.78	15.21±2.72
	Post	16.43±1.31	16.50±1.24	16.75±2.08

flow to the muscles simultaneously that allows player to play longer in the game.

Other than that, power performance also improved in this study. This result was in line with the studies by Karahan [18] and Iacono et al. [19] that have compared the effect of SSG training with skill based training (SBT) and repeated shuffle sprint (RSS) on power performance. According to Karahan [18], SSG training was relevant and can be used to improved power performance due to the reduction of players in the SSG game formation causes players have to do acceleration more often, on a regular basis indirectly builds up explosive of leg strength. In addition, result of 8 week SSG training in this study sufficient to improve power performance, in contrast to the study by Rodríguez-Fernández et al. [20], and Paul et al. [21] which showed that SSG training for 4 and 5 weeks was not sufficient to improve power performance. It proved that power development can be influenced by duration of intervention training.

Moreover, speed performance enhancement in this study was similar to the previous studies that were conducted on the comparison between SSG training with RSS and HIIT [8, 19] which showed improvement in performance in the SSG group was similar to RSS and HIIT training. Successful speed performance improvement through SSG training can be caused by repetitive sprint movement performed by players due to the small number of players in training and increasing in the explosive force of the leg muscles, thus increase motor movement unit such as efficiency of lengthening and shortening muscle cycle.

Despite the success of SSG training in improving physical fitness greater than TT, skill performances were shown not to be differences between groups. Timmerman et al. [15] found SGG formation 3vs3 significantly increase dribbling skills compare to 6vs6 and control group among hockey players. Clemente and Rocha [22] in their study conducted effects of SSG formation 2vs2, 3vs3 and 4vs4 on handball players showed increase in dribbling performance. They argued the improvement is contributed by repetitive movement performed which is, the less number of players the larger playing area and the more dribbling movements need to be performed by players to attack and defence.

No significant differences between groups were also shown in hitting skill. Study by Nathan [23] compared the effects of SSG on high skilled and low skilled players and the results showed hitting score among high skill player was higher compared to low skill player. Thus, it can be concluded that, the magnitude of improvement is affected by maturity and level of performance, in which this study only employed Under-12 years old hockey players.

Lastly, no significant differences between all groups were also found in passing skill. All groups were shown to have significant improvement in the passing skill in the post-test, in line with Eniseler et al. [13] that conducted the effects of SSG on passing skill among soccer players. The non-significant differences suggested that in terms of skill performance, any kind of training should be effective as this is the stage of learning and improving the skills among the Under-12 years old participants.

Conclusions

In conclusion, 8 weeks SSG training was found to be more effective in improving physical fitness compared to TT. The reduction in the number of players by using SSG formations 3vs3 and 4vs4 in this study compared to normal training resulted in increasing the game intensity allowing for the adaptation of aerobic capacity among players, thus enhance cardiovascular endurance performance. Other than that, this 3vs3 and 4vs4 SSG formation also causes players have to do repetitive high-intensity runs movement more frequently, indirectly develop their explosive of the leg muscle production that can improve power performance as well as speed performance. Despite the skill performance were shown to be significantly improved in all groups, there were no significant differences found when comparing between groups. This condition can be contributed by the complexity of skill as participants of this study consisted of male hockey players under 12 years old who were still in the developmental stage and still did not reach the level of cognitive and physical maturity to have greater magnitude of improvement.

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