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ORIGINAL RESEARCH

Improvement of the motor and functional capacity of post-cerebrovascular accident hemiplegics by exercise retraining combined with a varied exercises program

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Received: January 21, 2023
Accepted: April 08, 2023
Online Published: June 30, 2023

Abstract

The study aimed to investigate the effect of exercise retraining combined with a program of varied physical exercises on heart rate, training intensity, aerobic capacity, lower limb strength, and body composition of hemiplegic patient's post-cerebrovascular accident. This was a 12-week follow-up study, of 30 post-stroke hemiplegic patients aged 18 years and over, who were subjected to an effort retraining program, consisting of walking on a treadmill at a progressive speed of 2.7 to 6 km per hour and a slope of 5 to 12% combined with various transfer exercises, going up and down stairs, on an ergometric bike, balance and limb strengthening thighs, Abdo and Buttocks, lasting 60 minutes per session, 3 times a week and from 40 to 75% progressive of the Maximum Heart Rate. We used the paired Student's t-test to compare continuous variables before and after the programs. A significant increase was obtained in 12 weeks of intervention for most of the parameters: +12 (37 vs 49); $p < 0.001$ for balance, +1.4 meters per second (1.39 vs 2.79). $p < 0.001$ for walking speed, +4 degrees (11 vs 15); $p < 0.001$ for step angle, +32 steps per minute (37 vs 69); $p < 0.001$ for walking cadence; +213 meters (143 vs. 356); $p < 0.001$ for the distance covered in six minutes, +3 ml/min/Kg (29 vs 32); $p < 0.001$ for maximum oxygen consumption and +12% (22 vs 34); $p < 0.001$ for lean body mass. On the other hand, the time of the Time up and go test, of the walk on the descent and ascent, and the fat mass, was significantly reduced: -14 seconds (55 vs 41), $p < 0.003$; -16 minutes (67 vs. 51); $p < 0.001$ and -16 minutes (59 vs 43); $p < 0.001$ and - 5% (41 vs 36); $p<0.001$. The exercise training program combined with various physical exercises improves the maximum oxygen consumption of post-stroke hemiplegic patients. The combination of an exercise training approach based on functional and motor improvement should make it possible to optimize post-stroke rehabilitation strategies.

Keywords: Exercise retraining, hemiplegia, motor and functional capacity, varied physical exercises.

Introduction

Cerebrovascular accident is the second leading cause of death and the leading cause of acquired disability in the world. It is defined as a neurological deficit of localized and diffuse vascular origin, the crisis of which lasts more than 24 hours (Kusuayi et al., 2018a; Monod-Broca, 2001). Stroke victims present with somatic limitations, conditions that will alter motor and functional capacity, the performance of activities of

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To Cite: Kusuayi, G., Nduakulu, C. B., Tshiyamba, S. N., & Ekisawa, C. N. (2023). Improvement of the motor and functional capacity of post-cerebrovascular accident hemiplegics by exercise retraining combined with a varied exercises program. *Turk J Kinesiol*, 9(2), 85-90. **DOI:** 10.31459/turkjkin.1240330

daily living, and quality of life (Adoukonou et al., 2010). Motor and functional impairments generate significant deconditioning and a state of fatigue in post-stroke patients. In the subacute post-stroke phase, this deconditioning will reduce the capacity for effort, muscle strength, and walking ability. Changes in walking in stroke survivors are the result of biomechanical dysfunctions that reduce performance (Walker et al., 2012; Kim & Johnston, 2011). To restore these motor and functional deficiencies, exercise retraining strongly depends on the level of functional impairment, balance, muscle strength, endurance, and spasticity, but also on the environment and aids. Stroke has many risk factors. Among them are found: arterial hypertension, atherosclerosis, arteriovenous malformations, excess cholesterol, diabetes, obesity, sedentary lifestyle and risky behaviors such as smoking or excessive alcohol consumption (O'Donnell et al., 2016; Bohannon, 1987).

Vascular Hemiplegia is one of the direct consequences of a stroke which is characterized by the obstruction or rupture of a vessel carrying blood to the brain. This results in a lack of oxygen supply endangering the functioning of one or more areas of the brain (Sibley et al., 2009). This leads to the deconditioning of patients with the effort generating cardiovascular and respiratory disorders which is a process involving the interaction of many components, the disturbance of one of which can lead to lameness, a modification of the functional parameters and a loss of autonomy of post-cerebrovascular accident patients. To overcome the latter, the current trend in rehabilitation is exercise training where many studies have shown these favorable effects (Courbon et al., 2006; Donovan et al., 2008; Johnston et al., 2009). The non-existence of this approach to the care of post-cerebrovascular accident hemiplegic patients in rehabilitation centers in the Democratic Republic of Congo motivated us to undertake this study in the Physiology Lab of the effort of the Faculty of Medicine and Medical Fitness and Functional Exercises of University Clinics of Kinshasa to research the effect of exercise retraining combined with a program of varied physical exercises. The study aimed to investigate the effect of exercise retraining combined with a program of varied physical exercises on heart rate, training intensity, aerobic capacity, lower limb strength, and body composition of hemiplegic patient's post-cerebrovascular accident.

Methods

Participants

This is a follow-up study of 30 post-cerebrovascular accident hemiplegic patients, including 21(70%) mean 9(30%) women, with an average age of 40±10 years.

Procedure

These patients were subjected to an effort retraining program, consisting of walking on a treadmill at a progressive speed of 2.7 km to 6 km per hour, a slope of 5 to 12% combined with various physical exercises of transfer, climbing, and descending stairs, on an ergometric bike, balance and strengthening of the upper limbs, lower limbs, Abdo and buttocks, lasting 60 minutes per session from 40 to 75% progressive of the maximum heart rate, with a frequency of 3 times a week for 12 weeks, developed by a team of experts in clinical kinesiology from the Republic Democratic of Congo. The primary judgment criterion is suffering from hemiplegia following an ischemic or hemorrhagic stroke of fewer than 6 months, capable of carrying out a transfer and a displacement alone. All these post-stroke hemiplegic patients benefited from an evaluation before and after the programs. The study was conducted in accordance with the Helsinki Declaration and approved by the Institutional Review Board of Kinshasa University Clinic prior to the registration of participants. The following parameters were evaluated:

Parameters, Tests, and Measurements

Timed Up and Go Test

The walking balance of the hemiplegic subject was measured using a timed test, Timed Up and Go which consists of starting from a seated position, getting up, walking 3 meters facing you, doing a half -turn and coming back to sit, for the person who realizes it. The subjective balance of the patients was measured by the Berg balance scale, which is a self-administered questionnaire of 14 questions with a maximum total score of 56 points.

Six-Minute Walk Test (TDM6)

The six-minute walk test is an objective measure of functional ability in people with significant disabilities (Donovan et al., 2008), performed on a 20-meter flat track, free of obstacles and marked at all 5 meters. The examiner present acted as a timekeeper and could make a chair available if the patient requested it or if it seemed necessary. At the end of the test, the test score corresponded to the distance traveled in 6 minutes and the fatigue perception scale was used to quantify the difficulty felt during the test. Walking speed in seconds, the normal reference value of which is 5.98 km/h or 1.7 meters per second (Donovan et al., 2008).

Temporo-spatial gait test

The length of the step measured by a new tape measure when walking between the distance between the toe of one foot on the ground and the heel of the contralateral foot which lands on the ground, the normal reference value of which is 45 cm, 15 degrees for the step angle made by a goniometer on the line of the step during a half step. 67.4 steps per minute for the walking rate recorded using an Omron brand pedometer measured by the number of heel contacts on the ground of each foot in one minute and 5.98 km / h or 1.7 meters per second for walking speed.

Aerobic capacity test and training load

Aerobic capacity assessed by the method of calculating VO_2 max expressed by the following formula: [VO_2max (ml/kg/min) = 26.9 + (0.014 * Dist. (m) TDM6) – 0.38* BMI (kg/m^2)] (Kusuayi et al., 2018b). The intensity of the training was evaluated by the percentage of the maximum heart rate, expressed by the following equation: % HR max = (HR of exercise - HR of rest / HR max - HR of rest) x 100 (formula from Karvonen, 1957). Patients worked between 60-80% progressive workload. This method is based on HR reserve = [(% desired exercise intensity * (HR max - HR rest) + HR rest] (Heyward, 2010) whose HR max in beats per minute (bpm) was evaluated using the formula (Tanaka, 2001): HR max= 208- (0.7x age). During this test, the patient's tolerance to effort manifested by perceived exaggerated fatigue, dyspnea, vertigo, profuse sweating at least and the evolution of heart rates was monitored by a heart rate monitor, a pulse oximeter and by kinesiologists.

Lower limb strength test

The strength of the lower limbs on the hemiplegic and non-hemiplegic side was measured isometric ally using a Takei A5401 Digital Hand Grip Dynamometer® brand dynamometer. The patient was seated on a chair with the knee flexed at 90°. The dynamometer was attached with a strap to the person's ankle and to the "top" of the evaluator, the patient had to try to develop maximum force forward; with the idea of regaining the 0° position at the knee. Three trials were performed for each limb and the best score was retained.

Body composition test

Total body fat in %, visceral fat in %, and muscle mass in % were measured by the Omron BF-511 Healthcare Netherlands brand weight scale.

Data Collection and Analysis

The data collected was entered and processed using SPSS 21.0 software. Quantitative variables were expressed as means ± standard deviation. The comparison of the means of the continuous variables before and after the program was carried out by the paired Student's t test. A value of $p \leq 0.05$ was considered as statistical significance.

Results

The comparison of motor and functional parameters of post-stroke hemiplegic patients before and after combined exercise training programs is presented in Table 1.

The results of the present study indicated that there was a significant increase was observed: +12 (37 vs 49); $p < 0.001$ for balance, +1.4 meters per second (1.39 vs 2.79). $p < 0.001$ for walking speed, +4 degrees (11 vs 15); $p < 0.001$ for step angle, +32 steps per minute (37 vs 69); $p < 0.001$ for walking cadence; +213 meters (143 vs. 356); $p < 0.001$ for the distance covered in six minutes; +25Kg (20..vs 45); $p < 0.001$ for lower limb muscle strength on the hemiplegic side, + 26 bpm (61vs 87); $p < 0.001$ for heart rate reserve; +15% (35 vs. 50); $p < 0.001$ for workload, +3 ml/min/kg (29 vs 32); $p < 0.001$ for maximum oxygen consumption and +12% (22 vs 34); $p < 0.001$ for lean body mass. On the other hand, the walking balance achieved by the Time up and go test, the walking time on the descent and on the ascent, the heart rate at rest and one minute after the effort, the intensity of the effort and fat mass significantly reduced: -14 seconds (55 vs 41), $p < 0.05$; -16 minutes (67 vs. 51); $p < 0.05$ and -16 minutes (59 vs 43); $p < 0.05$, -6 Bpm (88 vs 82); $p < 0.05$ and -18 Bpm (99 vs 81); $p<0.05$, -9 (16 vs. 7); $p < 0.05$ and - 5% (41 vs 36); $p < 0.05$.

Discussion

Significant improvement in balance, speed, cadence, walking distance, endurance, lower limb muscle strength, cardiovascular capacity, adaptation and exercise tolerance in post-stroke hemiplegics subjected to exercise retraining on a treadmill combined with a varied physical exercise program was revealed.

Table 1
Comparison of motor and functional parameters of post-stroke hemiplegic patients before and after combined exercise training programs.

Variables	Before	After	t	p
Time up and go (sec)	55.00 ± 13.01	41.00 ± 18.04	3.27	0.003*
Berg Balance Scale (points)	37.00 ± 8.03	49.00 ± 14.12	6.96	0.001*
Walking speed (m/sec)	1.39 ± 0.45	2.76 ± 9.80	10.68	0.001*
Step length (m)	1.10 ± 9,00	1.45 ± 10.20	3.75	0.004*
Pitch angle (degree)	11.00 ± 0.70	15.00 ± 0.91	4.38	0.001*
Walking cadence (steps/min)	37.32 ± 20.85	69.02 ± 22.00	8.53	0.001*
TDM6, distance traveled (m)	143 ± 24.25	356 ± 12.51	10.49	0.001*
Walk downhill (min)	67.01 ± 6.79	51.45 ± 10.23	9.77	0.001*
Limb muscle strength (kg)	59.00 ± 0.94	43.00 ± 4.08	9.18	0.001*
Limb muscle strength (kg)	20.00 ± 10.37	45.00±8.60	10.68	0.001*
Resting HR (bpm)	88.00 ± 1.59	82.00 ± 2.50	6.96	0.001*
HR after exercise (bpm)	99.00 ± 1.72	81.00 ± 1.94	10.52	0.001*
Reserve HR (bpm)	61.00 ± 1.23	87.00 ± 1.55	8.53	0.001*
% of Heart Rate max (%)	35.00 ± 9.86	50.00 ± 1.71	7.59	0.001*
Borg scale (point)	16.00 ± 1.92	7.00 ± 2.30	3.34	0.002*
VO_2max (ml/min/kg)	29.45 ± 1.60	32.00 ± 2.50	9.96	0.001*
Lean mass (%)	22.00 ± 2.36	34.00 ± 11.00	3.75	0.001*
Fat mass (%)	41.00 ± 12.11	36.00 ± 9.03	4.62	0.001*

*TDM6: Six-Minute Walk Test; HR: Heart rate. * p<0.05*

Our results correspond to the study by Harari et al. (2004), who observed a significant decrease in the time to achieve the Time up and go test at the end of the exercise training program (Harari et al., 2004) and an increase in Berg Balance Scale score after the program (Chaudhuri & Behan, 2004; Bourgeais et al., 2009). In addition, Barbeau et al. showed that gait training on a treadmill between 0 and 40 percent of body weight facilitates the transfer of gait to the ground in post-stroke patients (Barbeau et al., 2006). One study reported a significant decrease in the energy cost of walking with exercise retraining programs. The latter used different means to evaluate the Six-Minute Walk Test (Adoukonou et al., 2010). The studies used high-intensity exercise training programs of 70% to 80% of max Heart Rate respectively and a score of 13 to 16 out of 20 on the fatigue perception scale, found that training on a treadmill allowed an increase in VO_2 max after 6 months of an intervention program (Johnston et al., 2009; Truelsen, 2010). Thus, if these programs are of low intensity with the Borg scale of 11 to 13, the distance achieved in the minute walk test can also be increased by around 26.6%. Exercise training programs focusing on walking ability in post-stroke patients vary from study to study. This observation could explain the differences between the results obtained in the literature concerning the effects of the latter on endurance and walking speed. Indeed, studies show that there are significant differences from one exercise training program to another in terms of program duration, number of sessions per week and work intensity (Klit et al., 2009; Kessomtini, 2015). The frequency and duration of exercise training sessions improve functional parameters when patients practice exercise training 3 to 4 days per week and the duration of sessions exceeds one hour per day (Toledano et al., 1999). One study reports a significant increase in Heart Rate max of over 4 beats per minute. The cardiovascular capacity of post-stroke patients is therefore more improved with mixed effort training protocols than those centered on walking, cycling, treadmill and walking platform carried out independently (Petrilli et al., 2022; Gallien et al., 2005). Bourgeais et al. proposed a structured exercise training program focusing on muscle strength with elastic bands (2 sets of 10 repetitions). Moreover, it seems that 12 weeks of retraining with mixed effort combined with strength exercises or with spontaneous activities are sufficient to significantly increase the VO_2 max of post-stroke patients (Bourgeais et al., 2009). The frequency and duration of exercise training sessions improve functional parameters when patients practice exercise training 3 to 4 days per week and the duration of sessions exceeds one hour per day (Toledano et al., 1999). One study reports a significant increase in Heart Rate max of over 4 beats per minute. The cardiovascular capacity of post-stroke patients is therefore more improved with mixed effort training protocols than those centered on walking, cycling, treadmill and walking platform carried out independently (Petrilli et al., 2022; Gallien et al., 2005). Bourgeais et al. proposed a structured exercise training program focusing on muscle strength with elastic bands (2 sets of 10 repetitions). Moreover, it seems that 12 weeks of retraining with mixed effort combined with strength exercises or with spontaneous activities are sufficient to significantly increase the VO_2 max of post-stroke patients (Bourgeais et al., 2009).

Conclusion

The effort retraining program combined with various physical exercises improves the temporal-spatial parameters of walking, functional and cardiovascular capacity by increasing the maximum oxygen consumption of post-stroke Hemiplegic patients. The combination of an exercise training approach based on functional and motor improvement should make it possible to optimize post-stroke rehabilitation strategies.

In view of the positive effects of this approach, we suggest that it be tested, validated and promoted in all rehabilitation centers by rehabilitation experts both nationally and internationally.

Authors' Contribution

Study design: GK, Data collection: SNT, Statical Analysis: GK, CBN, Manuscript preparation GK, CKE, Funds collection: CBN, SNT.

Ethical Approval

The study protocol was approved by the Medical Ethics Committee of the Ministry of Public Health of the Democratic Republic of Congo and its approval number is N° 14 / CNES / BN / PMMF / 2022 of 11/20 /2022 association also known as the Declaration of Helsinki.

Funding

The authors declare that the study received no funding.

Conflict of interest

The authors declare that they have no conflict of interest. They are solely responsible for the writing and content of this article.

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https://dergipark.org.tr/en/pub/turkjkin

ORIGINAL RESEARCH

Comparison of static and dynamic balance ability according to gender in athletes- a cross sectional study

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Received: April 05, 2023

Accepted: June 04, 2023

Online Published: June 30, 2023

Abstract

The aim of the present study was to compare the balance ability between genders in elite athletes. A total of 152 athletes, 76 female and 76 male, from 10 different branches with similar demographic characteristics included to the study. A computerized balance platform (BT4, HUR Labs Oy, Tampere, Finland) was used to determine balance ability of the athletes. Static balance measurement, with eyes open and closed stability test on hard and soft ground; dynamic balance measurement was evaluated with forward, backward, left and right functional reach test and Romberg values calculated by the device. It was determined that the Romberg value of female athletes was higher than that of male athletes (p= 0.025). It was determined that the area scanned by female athletes in static balance ability on fixed ground with eyes open was less than that of male athletes (p= 0.025); the length drawn by female athletes in static balance ability on soft ground with eyes open was less (p= 0.010) and their scanning speed was slower (p= 0.007). Static balance ability of female athletes were significantly better than male athletes, and female athletes interpreted visual inputs better than male athletes in static balance ability. We recommend training with visual inputs and visual exercises in order to increase balance performance, especially in female athletes.

Keywords: Balance, gender, sports, performance, Romberg.

Introduction

Balance is defined as the ability to maintain the center of gravity of the body on the support surface (Nashner, 2014). In order to maintain balance, proprioceptive, visual and vestibular information coming from the outside is processed in the extrapyramidal system, cerebellum, reticular formation and cerebellar cortex. The nerve-muscle interaction that occurs as a result of the processed sensory data creates the body posture in which the support surface and the center of gravity are the most optimal, and the balance is maintained (Means et al., 1996). Balance is divided into two types: static and dynamic balance. The ability to control postural oscillations without moving on a stable ground is defined as static balance. The ability to create an appropriate posture of postural changes that occur during movement in accordance with stimuli coming from outside the body is defined as dynamic balance (Duncan et al., 1990). The factors affecting the balance are the center of gravity, the gravity line and the support surface (Nashner, 2014). Increasing the distance of the center of gravity to the support surface, narrowing the

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To Cite: Akınoğlu, B., Acar, H. Y., Paköz, B., & Kocahan, T. (2023). Comparison of static and dynamic balance ability according to gender in athletes- a cross sectional study. *Turk J Kinesiol*, 9(2), 91-98.

DOI: 10.31459/turkjkin.1277503

support surface and increasing the distance of the gravity line to the center of gravity adversely affect the balance (Lion et al., 2009; Nashner, 2014). The last limit which a person can reach without losing his/her balance by lying down without changing the support surface is defined as the limit of stability (LoS). When the body makes an oscillation that will go beyond the LoS limit, the person activates the protective mechanisms again by changing the support surface to maintain his/her balance, otherwise the balance will be disturbed and a fall will occur (Nashner, 2014).

Balance ability is one of the most important parameters related to sports performance (Hrysomallis, 2011; Jadczak et al., 2019). There are many studies in the literature on the balance ability of athletes (Jadczak et al., 2019). While there are studies showing that high balance ability in athletes have an effect on motor responses resulting from repetitive training rather than vestibular sensitivity (Balter et al., 2004; Šarabon & Kozinc, 2020), there are also studies showing that this high balance ability is due to the ability to pay attention to proprioceptive and visual inputs (Zipori et al., 2018). However, it is also known that there are differences in balance ability between different sports branches (Herpin et al., 2010; Hrysomallis, 2011; Mononen et al., 2007). For example, in the shooting sports branch, static balance is at the forefront and in an advanced state, while in the fencing sport, dynamic balance is at the forefront and in a more advanced state (Herpin et al., 2010). For this reason, the sports branch plays a big role under the sensory-motor adaptation mechanism (Hrysomallis, 2011; Mononen et al., 2007). There are also differences in balance abilities among athletes at different levels (elite-amateur) in the same branch (Hrysomallis, 2011; Jadczak et al., 2019). For this reason, the level of the athlete was also seen as a factor affecting the ability of dynamic and static balance (Gorman et al., 2012; Hrysomallis, 2011; Jadczak et al., 2019).

On the other hand, one of the factors affecting the balance is gender (Mickle et al., 2011). There are anatomical and physiological differences in male and female. These differences are likely to affect the balance ability. Studies examining the relationship between balance and gender in the literature have been conducted on participants in childhood and high school (Gorman et al., et al., 2012; Mickle et al., 2011), but studies evaluating the effect of the gender factor on balance ability in elite athletes are limited. For this reason, we aimed to compare the static and dynamic balance skills of male and female athletes matched in terms of sports branches, age and sports levels. Therefore, the purpose of this study is to compare the balance ability between genders in elite athletes.

Methods

This case matched study conducted at the Ministry of Youth and Sports, Sports General Directorship, Department of Health Services, Center of Athlete Training and Health Research, Ankara. Athletes were screened for eligibility criteria and included to the study from February 2021 and April 2021. The research data were provided from the athletes who applied to the department of sports health and education research center and volunteered to participate in the study. The athletes were informed about the details of the study. The necessary information about the study was provided to the athletes whose compliance with the criteria for inclusion in the study was determined by a sports medicine specialist. Verbal and written consent was obtained from the athletes older than 18 and parents of athletes under the age of 18 and their oral and written consent was obtained. Ethical approval was taken from Ankara Yıldırım Beyazıt University Social and Humanities Ethical Committee (2021/495/79), and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Procedure

Being at least 3 years license athletes, right leg dominance and voluntary to include to the study were determined as inclusion criteria. Being in sports for less than three years, ongoing pain in the lower extremities, an orthopedic problem or a surgical procedure performed on the lower extremities and being an acute or chronic sports disability or disease, left leg dominance were determined as exclusion criteria. The evaluation of the athletes who met the study criteria was carried out within one day. After the date of birth of the athletes was verbally informed, the dominant leg information was asked with which foot he/she hit the ball (Brophy et al., 2010), the height length was measured with a tape measure, and the body weight was evaluated with a digital scale and recorded by a physiotherapist. A general examination and evaluation was performed by a sports medicine specialist and evaluated their suitability for the study and after that the eligible athletes were send for evaluation. The balance ability was assessed by the same physiotherapist. The current or previous disease and/or injury history or presences of athletes were evaluated by a sports medicine specialist and their examinations were performed. Athletes who were not provided with similar age and demographic characteristics in female and male athletes were not included in the statistical analysis.

Participants

A total of 232 licensed athletes were invited to the study and 152 athletes who had the inclusion criteria included to the study. 76 female (age= 16.66 ±1.70 years, body height= 1.64±0.07 meter, body weight= 57.12±8.23 kg, body mass index= 21.17±2.30 kg/m^2, sport year= 6.34±2.92) and 76 male (age= 16.70±1.69 years, body height= 1.75±0.07 meter, body weight= 66.69±9.98 kg, body mass index= 21.86±2.89 kg/m^2, sport year= 6.47±3.28), who played the same sport and had similar demographic characteristics, were included in the study (Table 1).

Static and Dynamic Balance Measurements

The HUR Smart Balance measurement device (BT4, HUR Labs Oy, Tampere, Finland) was used to evaluate the static and dynamic balance of the athletes. Balance assessments were made between 9-11 am, as the athletes did not train and after breakfast. Before the actual measurement, the athletes were taught the test by making a trial. Athletes were allowed to step on the measuring floor of the device in a static position without any support with their bare feet. For static balance, the athlete was evaluated 4 times for 30 seconds each. The athlete was kept motionless on the hard floor with eyes open on the first measurement, eyes closed on the hard floor on the second measurement; eyes open on the soft floor (a soft foam of the device) on the third measurement, eyes closed on the soft floor on the fourth measurement. As a result of the measurements, the speed, distance, and area values of each assessment were recorded. As a result of the test, less scanned area and length and faster scanning indicates better balance. After the static balance measurement, the "Romberg Value (RQ)" was obtained by the device to determine the effects of visual inputs on postural stability (RQ= 100*(area with eyes closed/ area with eyes open)). The Romberg value is classified as low between 0-50, normal between 50-300, high between 300-350, and very high at values of 350 and above when the eyes are open. On the other hand, the Romberg value is classified as low between 0-65, normal between 65-365, high between 365-450, and very high at 450 and above when eyes are closed. High results at the Romberg value indicate significant effects of visual inputs on postural stability, while low results indicate that visual inputs have no effect on postural stability (BT4, HUR Labs Oy, Tampere, Finland User's Manuel).

Dynamic balance measurements were made on the device. In the dynamic balance measurement, the functional reach distance, which is the last point at which the athlete can reach right, left, forward and backward, without breaking the contact between the sole of the foot and the measurement ground, was recorded. A warm-up was done before each measurement. Dynamic balance measurement was evaluated for eight seconds in each direction with eyes open. Each measurement was repeated three times. The amount of reach of the athlete was calculated as the shift of weight transfer on the device. The mean of three measurements was used in statistical analysis.

Data Analyses

Statistical analysis was performed with IBM SPSS Statistics version 20.0 statistic package (SPSS Inc. NY, USA). The sample size was calculated using G*Power Software. The sample size with 0.80 effect size, 5% type I error, and 80% statistical power conditions was calculated at least 64 athletes in each group. However, to increase the power of the research, 76 athletes were included to each group based on volunteering. The conformity of the variables to the normal distribution was determined by analytical methods (Kolmogorov Smirnov test). The data were summarized by number % (percentage), mean and standard deviation. The results of balance parameters of female and male athletes were compared according to their eligibility level with Mann Whitney-U Test or Independent samples *t*-test. The statistical significance level was taken as $p<0.05$.

Results

A total of 152 athletes, including 76 female and 76 male, from 10 different branches with similar demographic characteristics participated in the study. It was determined that the ages of female and male athletes and their sports ages were similar and that they had similar body mass index ($p>0.05$). It was determined that the height lengths and body weights of female athletes were less than male athletes ($p<0.05$; Table 1).

Table 1
Demographic characteristics of athletes and information about the year of sports and sports branch.

Variables	Female Athletes (n= 76) Mean ± SD	Male Athletes (n= 76) Mean ± SD	*p*
Age (year)	16.66 ±1.70	16.70 ± 1.69	0.890¥
Height (m)	1.64 ± 0.07	1.75 ± 0.07	<0.001*
Body weight (kg)	57.12 ± 8.23	66.69 ± 9.98	<0.001*
BKI (kg/m^2)	21.17 ± 2.30	21.86 ± 2.89	0.139¥
Sports Year (year)	6.34 ± 2.92	6.47 ± 3.28	0.937¥
Sports branch	Athletics (n= 58), %38.1	Archery (n= 10), %6.6	Ski (n= 4), %2.6
	Gymnastics (n= 14), %9.2	Swimming (n= 10), %6.6	Karate (n= 28), %18.4
	Weightlifting (n= 2), %1.3	Taekwondo (n= 12), %7.9	Judo (n= 8), %5.3
	Curling (n= 6), %4		

*SD: Standard Deviation *: Independent Sample t-test, ¥: Mann Whitney U test, BKI: Body Mass Index*

It was determined that the Romberg value of female athletes was higher than that of male athletes (*p*= 0.025). The area scanned by female athletes in static balance ability on fixed ground with eyes open was less than that of male athletes (*p*= 0.025); the Romberg value was higher than that of male athletes (*p*= 0.037). The Romberg value was higher in the static balance ability of female athletes on a fixed floor with their eyes closed than in male athletes (*p*= 0.037). The length drawn by female athletes in static balance ability on soft ground with eyes open was less (*p*= 0.010) and their scanning speed was slower (*p*= 0.007). The weight transfer rates of male and female athletes on the left side and on the right side were similar in the position with eyes open and eyes closed and on two different floors (*p*>0.05. Female athletes had less right-reaching distances than male athletes (*p*= 0.014). There was no difference between the distances of reaching forward, backward, and left (*p*>0.05; Table 2).

Discussion

Balance ability is one of the most important parameters related to sports performance (Hrysomallis, 2011). As a result of this study, which was conducted to compare the balance ability of male and female elite athletes, it was determined that the balance ability of female athletes was better than male athletes, and female athletes used visual inputs more. However, it was determined that the weight transfer rates of male and female athletes to the right and left sides were similar, but that male athletes had more functional reach to the right side.

One of the most important parameters that form the basis of sports performance is balance. Balance ability is at the center of the fitness abilities unique to the sports branch of the person. Thanks to these ability, a person plays an important role in maintaining the position of the body during sudden changes in direction, stopping, starting, moving and holding an object in sports ability (Zemková, 2014). Due to the fact that men and women differ anatomically and physiologically, the balance ability of men and women have been compared by many researchers based on the idea that there may be differences between the balance ability of men and women (Condon & Cremin, 2014; Gorman et al., 2012; Mickle et al., 2011; Mnejja et al., 2022; Olchowik et al., 2015; Quintana et al., 2022). In these studies, there are studies showing that there are differences between the balance ability of men and women (Condon & Cremin, 2014; Mickle et al., 2011; Mnejja et al., 2022; Quintana et al., 2022). In the literature, it is stated that due to the anatomical and physiological differences between men and women, women's balance skills are better than men (Condon & Cremin, 2014; Gorman et al., 2012; Mnejja et al., 2022; Quintana et al., 2022). For this reason, in order to minimize the effect of anatomical and physiological differences, research is usually done in childhood when balance skills are not fully developed. In some of these studies conducted in the childhood age group, it is seen that girls have better balance ability than boys (Mickle et al., 2011; Condon & Cremin, 2014). We have not found any studies in the literature comparing the balance ability of male and female athletes. The results of this study, which compared the balance ability of female and male athletes, showed that the gender-based balance ability difference in the literature and reported

Table 2
Comparison of static and dynamic balance ability of athletes (Mean ± SD).

Variables			Female Athletes	Male Athletes	p
Romberg Value			1660.76 ± 11171.45	208.03 ± 137.02	0.025¥
Static Balance					
	Stable Ground with Eyes Open	Length (mm)	438.60 ± 2055.41	585.43 ± 3258.56	0.144¥
		Area (mm^2)	235.66 ± 939.79	533.04 ± 3235.34	0.025¥
		Speed (mm/sn)	14.52 ± 68.48	19.54 ± 108.64	0.101¥
		Romberg Value	1940.83 ± 11399.20	310.93 ± 892.59	0.037¥
		Left side weight transfer (%)	51.88 ± 47.64	51.89 ± 46.43	0.887¥
		Right side weight transfer (%)	59.96 ± 55.97	59.96 ± 57.09	0.887¥
	Stable Ground with Eyes Closed	Length (mm)	696.53 ± 3046.23	669.98 ± 2935.86	0.384¥
		Area (mm^2)	493.31 ± 2012.67	554.24 ± 2545.61	0.900¥
		Speed (mm/sn)	23.24 ± 101.52	37.36 ± 162.47	0.447¥
		Romberg Value	1940.83 ± 11399.20	310.93 ± 892.59	0.037¥
		Left side weight transfer	51.80 ± 48.69	51.94 ± 46.77	0.886¥
		Right side weight transfer (%)	60.04 ± 54.92	59.90 ± 56.75	0.886¥
	Soft Ground with Eyes Open	Length (mm)	488.95 ± 2283.54	614.89 ± 3140.02	0.010¥
		Area (mm^2)	291.19 ± 1022.93	558.20 ± 2952.77	0.131¥
		Speed (mm/sn)	16.25 ± 76.14	20.53 ± 104.70	0.007¥
		Romberg Value	832.08 ± 4591.22	431.55 ± 1047.92	0.252¥
		Left side weight transfer (%)	51.98 ± 49.23	51.87 ± 45.86	0.719¥
		Right side weight transfer (%)	59.87 ± 54.34	59.98 ± 57.67	0.719¥
	Soft ground with Eyes Closed	Length (mm)	893.78 ± 3859.51	871.28 ± 3674.00	0.809¥
		Area (mm^2)	941.82 ± 4111.26	777.16 ± 2547.56	0.707¥
		Speed (mm/sn)	29.76 ± 128.66	28.67 ± 122.53	0.580¥
		Romberg Value	832.08 ± 4591.22	431.55 ± 1047.92	0.252¥
		Left side weight transfer	51.92 ± 50.38	51.76 ± 46.68	0.638¥
		Right side weight transfer (%)	59.92 ± 53.16	60.08 ± 56.84	0.638¥
Dynamic Balance					
	Reaching Forward		4.25 ± 2.66	4.12 ± 2.71	0.722¥
	Reaching Backwards		4.51 ± 3.21	4.52 ± 2.87	0.957¥
	Reaching to the Left		5.98 ± 1.67	6.19 ± 1.49	0.415*
	Reaching to the Right		6.08 ± 1.37	6.65 ± 1.45	0.014*

**: Independent Sample T test, ¥: Mann Whitney U Test*

in the general population was valid for elite athletes, and revealed that female athletes had better balance ability than male athletes. However, there are various studies in the literature showing that anthropometric characteristics affect balance ability (Alonso et al., 2012; De Maio et al., 2021; Jeronymo et al., 2020). In a study, it was stated that the anthropometric variable that most affected the postural balance was the height, and this effect was higher especially in men than in women (Alonso et al., 2012). Many anthropometric features such as the pelvic structure of women due to their anatomical and physiological structures, their short stature and therefore their center of gravity close to the ground, and differences in lower extremity alignment may cause good balance even in women (Olchowik et al., 2015; Sekulic et al., 2013). Although the fact those women are shorter than men in our study is a finding that supports women's better balance skills than men, we think that this is not the only reason. For this reason, there is a need for further studies in which statistical analyzes with adjusted anthropometric factors are performed.

Vision has an effect on postural stability (Alcock et al., 2018; Zipori et al., 2018). In many studies conducted, it has been observed that postural oscillation is more in the closed position of the eyes compared to the open position of the eyes (Bruyneel et al., 2018; Saftari & Kwon, 2018). In this context, the Romberg value helps us to interpret the effects of visual inputs on postural stability, a high Romberg value indicates that visual inputs have significant effects on postural stability, while a low Romberg value indicates that visual inputs have no effect on postural stability (Bruyneel et al., 2018; Paolucci et al., 2018). When the results of our study were examined, it was determined that the overall Romberg value and the Romberg value on the fixed floor with the eyes open and closed and the Romberg value on the soft floor with the eyes open were higher in female athletes than in male athletes. This result can be interpreted as the fact that female athletes maintain their balance and postural stability better compared to men by interpreting visual inputs better when their eyes are open on a stable surface. For this reason, we can say that training with visual inputs and visual exercises especially in female athletes can also be effective in improving balance performance. Indeed, in a study conducted to investigate the effect of ocular-motor exercises on the limit of dynamic visual acuity and stability in female basketball players in a way that supports the results of our study, it is stated that oculo-motor exercises can be used to increase the stability limit and dynamic visual acuity in basketball players and other dynamic sports (Minoonejad et al., 2019). Similarly, there are studies in the literature showing that visual exercises also affect balance performance (Correia et al., 2021; Durall, 2012; Jandaghi et al., 2021). However, we think that more studies are needed to reveal the effects of these exercises on the balance of both female and male athletes.

Gender is one of the most important parameters affecting sports performance (Sandbakk et al., 2018). In a study that examined gender-specific balance and related parameters in athletes, it has been stated that balance ability is significantly related to agility performance in male athletes, but this relationship is not valid for women, and balance should be considered as a potential predictor of agility in male athletes (Sekulic et al., 2013). While balance ability is one of the parameters that affect sports performance, some other parameters that affect sports performance, such as fat percentage and muscle mass, affect balance ability. Studies have shown that whole body muscle strength, core muscle strength and extremity muscle strength affect balance ability (Granacher et al., 2013; Muehlbauer et al., 2015). As a result of the present study, although the ratios of weight transfer to the right and left sides of female and male athletes were similar, it was determined that the amount of functional reach of male athletes to the right side, which is the dominant side, was higher than female athletes. Considering that the dominant sides of the male and female athletes included in the study are the same and the right side, we think that this result may have been caused by other factors that may affect the balance. As a result of this study, the fact that male athletes have more functional reach to the right side, which is the dominant side, may be due to the greater muscle strength of male athletes. However, muscle strength measurement was not performed in our study i order to investigate the relationship that would support this idea. While this situation can be seen as a limitation of our study, it can also constitute a pioneering idea for future studies.

Our study has certain limitations. The limitations of this study are that not all of the athletes do the same sport (the development of different balance parameters, dynamic and static, of athletes in different branches) and that other performance parameters such as muscle strength that may affect the balance have not been examined. Therefore, our results may not be generalizable to athletes in all branches. We think that further studies are needed in which other parameters that are specific to the branch and may affect balance are normalized and compared between genders.

Conclusion

In conclusion the static balance ability of female athletes was significantly better than male athletes, and it was determined that female athletes interpreted visual inputs in static balance ability better than male athletes. For this reason, especially in female athletes, we recommend training with visual inputs and visual exercises in order to increase balance performance.

Authors' Contribution

Study Design: BA, HYA, BP, TK; Data Collection: BA, HYA, BP; Statistical Analysis: BA, HYA, TK; Manuscript Preparation: BA, HYA, TK; Funds Collection: BA, TK.

Ethical Approval

The study was approved by the Ankara Yıldırım Beyazıt University of Social and Humanities Ethical Committee (2021/495/79) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Funding

The authors declare that the study received no funding.

Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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ORIGINAL RESEARCH

A comparative examination of World Cup Champions of European and American origin of national football players in terms of "relative age effect"

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Received: April 07, 2023
Accepted: June 03, 2023
Online Published: June 30, 2023

Abstract

This study aimed to analysis the birth date distributions of the champion players between the years 1930-2022 to determine whether the FIFA World Cup champion national team football players between the years 1930-2022 were affected by the "Relative Age Effect" phenomenon. The universe of the research consisted of the national teams that were champions in the 1930-2022 FIFA World Cup Finals. The samples consisted of the football player group of the national teams that won the championship. The model of the research was determined as "Basic Qualitative Research". The data collection technique in the research was determined as "Document Analysis". The data analysis was made according to the Miles & Huberman model, which is a descriptive analysis form. In the study, the information of the athletes was detailed by looking at the squad structure for the FIFA World Cup champion national team football players between the years 1930-2022. In the highest level of professional football, it has been seen that the champion national team football players are numerically close to each other in terms of "relative age effect". As a result, it has been observed that the relative age effect in senior football decreases with increasing age. It was shown that the relative age effect in professional elite national teams changed negatively due to the high number of football players born in the second half of the year. In this case, it was not a negative situation for football players who transition to professionalism and reach the elite level, being born in the last months of the year. Looking at the intercontinental comparison, even considering the different football culture and structure, it has been revealed that late-born athletes have caught up with their peers at a professional level and even left them behind.

Keywords: FIFA, football, player, relative age effect, world cup.

Introduction

The “Relative Age Effect” refers to the asymmetry in the distribution of birth dates, which favors players born early in the election year and discriminates against participants born later in the year (Helsen et al., 2012). Grouping of athletes according to age is very common in sports. January is globally considered the start of the election year. In particular, categories in team sports correspond to annual or biannual competition cycles in which the athlete is included in competition groups according to his chronological age and a predetermined end date. The term “relative age effect” depends on the date of birth associated with the selection data used to place the child in a particular age group (Wattie et al., 2008). Parameters such as body size, strength, and strength in sports have a higher advantage over early-mature children of the age group than their late-

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To Cite: Çevik, A. (2023). A comparative examination of World Cup Champions of European and American origin of national football players in terms of "relative age effect". *Turk J Kinesiol*, 9(2), 99-105.
DOI: 10.31459/turkjkin.1278737

maturing or adolescent peers (Malina, 1994; Malina, 1998). This situation is often reflected in youth sports contexts and is understood as over-representative for athletes born in the first months of the year due to greater maturation development (Barnsley et al., 1985). For this reason, it is seen that relatively older athletes have more opportunities than younger peers in terms of reaching a higher sport level in selection and competition performance (Till et al., 2010). Oldies are more likely to be described as talented and transferred to top teams. Thus, early maturing athletes benefit from higher quality coach training and experience at higher levels of competition (Helsen et al., 1998; Sherar et al., 2007). Most of the explanations on this subject focus on anthropometric, physical and physiological parameters and highlights biological factors as the source of imbalance among athletes (Baker et al., 2010). However, as athletes raise to higher performance levels, it is unclear whether relatively older athletes have certain sporting and competitive advantages over their younger peers (McCarthy & Collins, 2014). For this reason, as the transition to team sports such as football progresses, the "Relative Age Effect" tends to decrease but does not disappear (Brustio et al., 2018; Gil et al., 2020). In recent years, many studies have investigated the relative age effect in sports like football. The "Relative Age Effect" has been studied from various approaches and purposes which existence in collective and individual sports contexts has been investigated (Papadopoulou et al., 2019; Steidl-Müller et al., 2019; Mon-López et al., 2020). However, it is not yet to clear whether a relative age effect is noticed before players are transferred to professional teams. The "Relative Age Effect" has been studied in many sports branches. Due to the number and quality of studies, two sports stand out among others. These are football and ice hockey (Grondin et al., 1984). Indeed, this study is extremely important for world football. The aim of this study; on the history of the FIFA World Cup Finals, which is the biggest football tournament between countries, it provides the opportunity to both side the data of elite football players and compare the data of successful footballers from two different continents in terms of examining champion footballers in terms of "Relative Age Effect".

Methods

The universe of the research was formed the national teams that were champions in the 1930-2022 FIFA World Cup Finals. The sample consisted of the players of the national teams that had won the championship. Density sampling was used in the sampling method of the study. Density sampling used in qualitative research includes the best or most informative examples of the investigated phenomenon rather than extreme or unusual situations (Morgan & Morgan, 2008). Among the qualitative research methods, heuristic-based research generally uses density sampling (Mays & Pope, 2000). The heuristic approach aims to discover and make sense of the nature of the studied event or phenomenon through self-experiences and the researcher's subjective explanations (Denzin & Lincoln, 2008). It enables the researcher to clearly express and make sense of the creative thought that exists within him. The heuristic approach is the only research approach that enables human experiences to establish subjective and creative connections between the researcher and the researched phenomenon (taking into account the researcher's tacit knowledge) (West, 2001). The method of the research was determined as "Basic Qualitative Research" and the data collection technique in the research was determined as "Document Analysis". In the analysis of the data, the Miles-Huberman model, which is a descriptive analysis form, was used.

Participants

Between 1930 and 2022, the national team football players who played a total of 22 FIFA World Cup finals and won the championship constituted the sample group. Working group; 490 football players who became FIFA World Cup champions at the national team level.

Data Collection Tools

The information of the football players is taken from the "transfermarkt.com" and "football.instatscout.com" web page. For the validity of the research, data triangulation was made and the data collected from 2 different sources were interpreted by making document analysis, thus increasing the internal validity of the study. In this study, document analysis technique was used as a data collection tool. The document review technique is based on interpretive philosophy. It is combined with rough technique (review, condensation, summarizing) with detailed analysis (category of refinement, hermeneutic interpretation, describing data). The aim is to produce common explanations by describing various data, explaining them in detail or comparing different data (Flick, 2013; Creswell & Creswell, 2017). It also includes understanding the essence of large amounts of data by reducing the volume of raw data, identifying important patterns and creating a logical chain of evidence for the researched phenomenon by making sense of the data (Patton, 2014).

Data of Analyses

This research aimed to form a basis for data analysis with the theory known as 'Embedded Theory'. This type of analysis was developed by Glaser and Strauss (Walker & Myrick, 2006). The embedded theory was used both as a research strategy and as a data analysis method. Today, it is called the most impressive paradigm for qualitative research method (Ilgar & Ilgar, 2013). In embedded theory, data collection and data analysis are directly related to each other. Each collected data is directly compared with the next data, and in this way the comparison is continued until the most common data is reached. The embedded theory method consists of systematic but flexible guidelines developed for collecting and analyzing qualitative data to construct theories embedded in and sourced from data (Charmaz, 2006). Data analysis in embedded theory is a well-defined process that begins with basic descriptions, continues with conceptual arrangement, and leads to theorization (Patton, 2002). The embedded theory was turned into an excuse presented to the scientific world for the qualitative approach by ensuring that qualitative research was evaluated according to quantitative standards (Atkinson, 1997). Qualitative data analysis is a collection of activities in which the data that can be obtained by different data collection methods and techniques such as document review, observation and interview are organized, categorized, themes are discovered, and ultimately this whole process is transferred to the report. In this context, the Miles and Huberman model qualitative data analysis is essentially carried out in three steps: The first step is data reduction. Data reduction is the selection, examination, simplification, summary and transformation of the data obtained at the end of the research. In the second stage, data is displayed. Data representation is to create an organized version of the collected data to reveal the results. The third stage is inference/validation. Deduction/validation is to test the results in terms of validity, along with revealing causal relationships, patterns and possible structures between events and objects (Miles & Huberman, 2016). The reality, which is uncertain at the beginning of the research process and remains hidden in the data, is discovered and brought to light in the final stage.

Results

This study examined the “relative age effect” distributions of 490 national team football players who were FIFA World Cup champions at the national team level.

Table 1 shows the average age and date of birth of those born in the first and last six months of the year, according to the relative age effect in the squads that won the FIFA World Cup. The FIFA World Cup Champion was classified the number of national team players according to the relative age effect, and examined the documents regarding the team rosters in the relevant World Cup finals for a total of 490 football players. The data were processed and the players' birth dates were determined individually.

Table 1

Numerical status of team rosters by birthday distribution.

FIFA	National Team	Number of Players Born in the First and Last 6 Months of the Year
2022	Argentina	18 – 8 (26 players)
2018	France	11 – 12 (23 players)
2014	Germany	12 – 11 (23 players)
2010	Spain	14 – 9 (23 players)
2006	Italy	11 – 12 (23 players)
2002	Brasil	14 – 9 (23 players)
1998	France	9 – 13 (22 players)
1994	Brasil	15 – 7 (22 players)
1990	Germany	10 – 12 (22 players)
1986	Argentina	8 – 14 (22 players)
1982	Italy	14 – 8 (22 players)
1978	Argentina	11 – 11 (22 players)
1974	Germany	9 – 13 (22 players)
1970	Brasil	9 – 13 (22 players)
1966	England	7 – 15 (22 players)
1962	Brasil	7 – 15 (22 players)
1958	Brasil	10 – 9 (19 players)
1954	Germany	10 – 12 (22 players)
1950	Uruguay	10 – 12 (22 players)
1938	Italy	11 – 11 (22 players)
1934	Italy	6 – 16 (22 players)
1930	Uruguay	12 – 10 (22 players)

Retrieved from https://www.transfermarkt.com/ and https://www.instatscout.com/, 23 January 2023

In Table 2, although it was shown that the athletes born in the first months of the year were mostly in the 8 champions national team, we saw a table dominated by the players born in the last months of the year in the 12 champion national teams. In 1938 and 1978, there was numerical equality among the champion national team football players.

For the FIFA World Cup, it was seen that there are 490 athletes managed to take part in the team squads in a total of 22 world cup finals. Among the 490 elite national athletes, the number of athletes born in the first months of the year was 238, while the number of athletes born in the last months of the year was 252. At this point, there was a positive trend in terms of the relative age effect. Already in Table 2, the superiority of the players born in the last half of the year as a team was in question. Between 1930 and 2022, a total of 22 FIFA World Cup finals were held and the Brazilian national team managed to become champions 5 times in these finals. The national teams of Germany and Italy became champions 4 times, Argentina 3 times, the national teams of France and Uruguay 2 times, and the national teams of England and Spain 1 time. When the intercontinental situation was evaluated, national teams became champions on only 2 continents, namely Europe and America (South) Continents.

As seen in the table 3, the numbers of champion athletes of the Brazilian, Argentina and Uruguay national teams from South America were 222, 114 of the athletes were born in the first months of the year and 108 athletes were born in the last months of the year. On the European continent, the numbers of champions from Germany, Italy, France, Spain and England national teams were 268, 124 athletes were born in the first months of the year and 144 athletes were born in the last months of the year. At this point, while the numbers of players born in the first half of the year were superior among South American football players, those born in the last months of the year were higher among European football players.

Table 2
Positive and negative situations of team cadres according to their birthday distribution.

FIFA	National Team	Born in First Half of the Year (Positive)	Born in Last Half of the Year (Negative)
2022	Argentina	✓	
2018	France		✓
2014	Germany	✓	
2010	Spain	✓	
2006	Italy		✓
2002	Brasil	✓	
1998	France		✓
1994	Brasil	✓	
1990	Germany		✓
1986	Argentina		✓
1982	Italy	✓	
1978	Argentina	=	=
1974	Germany		✓
1970	Brasil		✓
1966	England		✓
1962	Brasil		✓
1958	Brasil	✓	
1954	Germany		✓
1950	Uruguay		✓
1938	Italy	=	=
1934	Italy		✓
1930	Uruguay	✓	

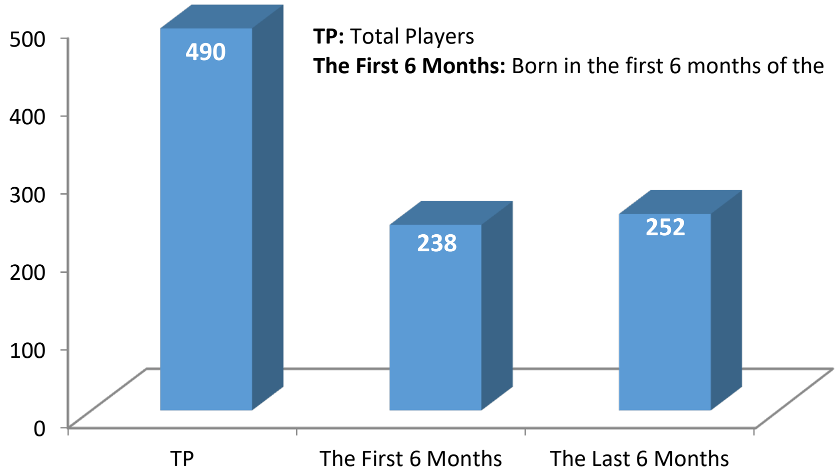

Figure 1. Disaggregation by relative age effect of players selected for FIFA World Cup Champion National Team Finals.

Table 3
The differences of Intercontinental national team players relative age distribution.

Intercontinental National Teams	Number of Players Born in the First Half of the Year	Number of Players Born in the Last Half of the Year	Total
America (South)	✓ 114	108	222
Europe	124	✓ 144	268
Total	238	✓ 252	490

Discussion

In the study, players of the same level but different chronological ages as professional football players were analyzed and the result was tried to be reached. It has been assumed that the relative age effect would decrease in higher-level leagues and teams, since maturity was argued to be the underlying reason for the existence of the relative age effect, since the relationship between physical superiority and performance is high at early ages. Similarly, it has been predicted that the relative age effect would become less pronounced in senior professional football than in junior football, as maturity differences disappear once adulthood was reached. Many studies have investigated the relative age effect in the sports setting. Comparing birth dates between junior and senior athletes in sports such as baseball, ice hockey, netball, rugby, soccer, and tennis revealed skewed birthdate distributions that favour individuals born prematurely in the election year (Musch & Grondin, 2001). Like other sports, football is characterized by a significant overrepresentation of players born early in the election year among youth (Baxter-Jones, 1995; Brewer et al., 1995; Musch & Hay, 1999; Vaeyens et al., 2005; Verhulst, 1992). In sports where body size, and strength are advantageous, early maturing children in one age group are therefore late maturing and puberty probably have an advantage over their peers, who are more frequently represented among athletes (Malina, 1994; Malina, 1998). Thus, veterans are more likely to be identified as talented and transferred to top teams, thus benefiting from higher quality coaching and experience at more advanced levels of competition (Sherar et al., 2007). However, with this study, it has been understood that the relative age effect disappeared in professional football at the elite level. In professional football at the elite level, the "relative age effect" was evenly distributed. In the champion national team squads, the athletes born in the first half of the year and the athletes born in the second half of the year produced results that were close to each other in percentage. Baumler (1996), based on a study of German professional adult football players, declared that the relative age effect in senior football decreases with increasing age. Similarly, recent findings suggest players born late in an election year are catching up with their adult peers. According to the findings of this study, it has been seen that the athletes born late in the election year caught up with their peers at the professional level and even surpass them. As a result, it has been observed that the relative age effect in senior football decreases with increasing age. The first study evaluating RAE in national teams was written by Barnsley et al. (1992), who found in the 1990 World Cup that 55% of players were born in the first half of the year. In the U-17 and U-20 World Cup, a greater bias was shown, as in the average of both, 79% of players were found to have been born in the first half of the year. Helsen et al. (2005) also analyzed the ranks of the national teams (U-21, U-18, U-17, U-16 and U-15) in the 1999-2000 season. The national teams of Germany (50.49% in the first quarter, 3.89% in the fourth quarter) and England (50% and 17%, respectively) were the ones with the greatest impact of RAE. RAE was not observed in Portugal in the U-21 male category. If these data are compared to those presented in the results section of the present study, it could be noted that RAE has been reduced over the years. Helsen et al. (2012) compared the RAE of professional soccer players in 10 European countries over a 10-year period (2000-2001 and 2010-2011 competitive seasons). Generally, results indicated no change in the RAE over the past 10 years in professional soccer. In this study, it has been observed that the relative age effect in professional elite national teams increased through last half of the year due to the high number of football players born in the second half of the year. In this case, it was not a negative situation for football players who transition to professionalism and reach the elite level, being born in the last months of the year. Looking at the intercontinental comparison, even considering the different football culture and structure, it has been revealed that late-born athletes have caught up with their peers at a professional level and even left them behind.

Authors' Contribution

Study Design: AÇ; Data Collection: AÇ; Statistical Analysis: AÇ; Manuscript Preparation: AÇ; Funds Collection: AÇ.

Ethical Approval

The study was approved by Kilis 7 Aralık University Ethics committee with the decision of 2023/02 E.17559/15. The study was carried out in accordance with the Declaration of Helsinki.

Funding

The author declares that the study received no funding

Conflict of interest

The author hereby declares that there was no conflict of interest in conducting this study.

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ORIGINAL RESEARCH

The examination of the relationship between body composition and acceleration

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Received: May 10, 2023
Accepted: June 20, 2023
Online Published: June 30, 2023

Abstract

The aim of this study is to investigate the effect of body composition on acceleration. A total of 63 men, who are recreationally active and part of different sports branches (soccer, judo, basketball, tennis, taekwondo, and athletics), participated in the research voluntarily. Some of the participants' characteristics were measured respectively including mean age (20.52±1.635 years), mean body height (179.25±7.121 cm), mean body weight (72.44±10.066 kg), and mean sports age (6.90±3.125 years). Data were collected through using a 3-door photocell, a measuring tape, and a Skinfold caliper. When the results were examined, mean body mass index (BMI=22.498±2.217 kg/m2), mean skinfold measurements (SM=8.34±2.975 mm), mean body circumference measurements (BCM=71.76±4.581 cm), mean body fat % (19.277±4.731), mean 10 m acceleration (1.74±0.096 sec) and mean 15 m acceleration (2.40±0.171 sec). It was concluded that one unit change in body fat percentage (BF%) affects 10 m acceleration performance at the rate of 0.006, while one unit change in BF% affects 15 m acceleration performance at the rate of 0.01. It was observed that the SM affected the acceleration performance of 10 m at the rate of 0.008, while it affected the acceleration performance of 15 m at the rate of 0.017. Additionally, it was determined that BMI affects 15 m acceleration performance at the rate of 0.19. In addition, the body fat percentage explains the 10 m acceleration performance by 9.4% ($p<0.05$), while the 15 m acceleration performance explains 7.7% ($p<0.05$). While the skinfold thickness explains the acceleration performance of 10 m by 7.5% ($p<0.05$), it explains the acceleration performance of 15 m by 8.3% ($p<0.05$). It was determined that the body mass index explained the 15 m acceleration performance by 6.3% ($p<0.05$). In conclusion, body composition has been found to affect acceleration performance. Moreover, as the running distance increases, the effect level of body composition also increases.

Keywords: Acceleration, body fat percentage, body mass index.

Introduction

Body composition is used to describe the body parts that form body weight. The human body consists of different tissues. The main components are musculoskeletal system, limbs, essential fatty tissue, and adipose tissues. The ratio of the musculoskeletal system and adipose tissue has a considerable place for sports branches (Lukaski, 2003). The main reason for the change in body composition is the changes in muscle and fat mass (Sun et al., 2003). Body composition is divided into two subcategories; fat mass and lean mass. While lean mass consists of muscle, bone and water, fat mass comprises of essential and non-essential fat stores. Essential fat tissue, which is used as an energy source and stored as fat, is found in the central nervous system,

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To Cite: Şahin, İ. H., & Sanioğlu, A. (2023). The examination of the relationship between body composition and acceleration. *Turk J Kinesiol*, 9(2), 106-114.
DOI: 10.31459/turkjkin.1295059

heart, lungs, liver, spleen, kidneys, muscles and bone marrow. Non-essential fat stores are used for energy and to protect the body during hunger. On the other hand, non-essential fat, known as tallow, found in the whole body around the organs and under the skin (Mahan et al., 2012). Since the measurements with skinfold demonstrate the amount of subcutaneous fat, the total amount of fat in the body has a significant relationship with the amount of subcutaneous fat (Gomes et al., 2020). Relevant studies indicate that skinfold thickness measurements obtained by a skinfold instrument provide information about the subcutaneous storage fat of the region where the measurement is made (Bauer et al., 2022; Bonilla et al., 2022; Can et al., 2023). Not only skinfold thickness measurements from different parts of the body provide comprehensive information about the total body fat ratio but also very important for the calculation of total BF% (Alves et al., 2021; Cherif et al., 2022).

Ideal body composition varies in different sports branches. However, the low amount of fat mainly affects sports performance in a positive way. Excessive amount of subcutaneous body fat influences many performance components adversely (flexibility, strength, speed, acceleration and agility) (Engels et al., 2002). One of these performance components is acceleration. It is an undeniable fact that acceleration performance has an important place in many sports branches. Most field-based team sports, such as soccer, baseball, softball, and basketball, benefit from short sprint workouts; thereby, the acceleration phase of the sprint has a considerable significance in terms of performance in team sports (Paton et al., 2001). Although each athlete has unique biomechanical differences, it is seen that the deviations in the characteristics of sprinting are more quantitative than qualitative (Nagahara et al., 2014). For this reason, body composition should also be taken into account when evaluating acceleration performance. Knowing how much the body fat ratio affects the body has an important place in terms of performance. In a study, it was observed that the force associated with body mass and strength affects the initial velocity and acceleration in a sprint run for 18.3 meters (Brechue et al., 2010). Murphy et al. (2003) stated that the acceleration performance should be evaluated at distances of 4.57 meters or 9.14 meters to evaluate the acceleration performance and obtain accurate results. In another study, 0-10 meters of a 100-meter sprint run was considered as the acceleration phase, the distance from 36 meters to 100 meters was considered as the maximum speed, and the distance between them was considered as the transition time (Nikolaidis et al., 2015). Therefore, the aim of this study is to examine the effect of body composition on acceleration values at 10 meters and 15 meters.

Methods

Participants

A total of 63 active amateur male athletes in different sports branches at the Faculty of Sports Sciences participated voluntarily. Some of the participants' characteristics were measured respectively including mean age (20.52±1.635 years), mean body height (179.25±7.121 cm), mean body weight (72.44±10.066 kg), mean sports age (6.90±3.125 years), mean body mass index (BMI=2.498±2.217 kg/m^2), and mean body fat % (19.277±4.731). Before conducting the study, participants were fully informed about the aims of the research, its potential risks and benefits. Furthermore, an informed consent form was obtained from the participants. This study was approved by the Ethics Committee at Selcuk University Faculty of Sports Sciences (approval: 2019-64). All the procedures adhered to the guidelines of the Declaration of Helsinki.

Design and Procedures

The acceleration performances of the participants were evaluated using a 3-door photocell. The first door is located at the starting point; the second door is located at the 10th meter and the third door at the 15th meter. Participants were run 2 times with a 3-minute rest interval for acceleration performance. Body circumference measurements of the participants were measured with a measuring tape (waist, hip, forearm, thigh, shoulder, chest, calf). Skinfold thickness was measured with a skinfold Caliper (biceps, triceps, supscapula, suprailiac, chest, thigh, abdominal).

The measurements were evaluated on the same day respectively environment, skinfold and acceleration performance, and the air temperature was 23 ^{0}C. Acceleration performance measurements were carried out on an athletics track in accordance with international standards.

Measures

Body mass index

It was calculated by dividing kilograms of body weight by the square of height in meters (kg/m^2).

Body Mass Index Calculation = weight (kg/m²) (Deurenberg et al., 1998; Woolford et al., 2021; Yang et al., 2023).

Skinfold thickness measurements

The skinfold thickness measurement of the participants was measured from 7 different regions (biceps, triceps, supscapula, suprailiac, chest, thigh, abdominal). Measurements were made with a Skinfold caliper (Holtain Brand Skinfold Caliper), which applies 10 g/sq mm pressure and measures with ± 0.2 mm precision. All measurements were made on the right side of the body and by the same person. The skin and subcutaneous fat were captured with the thumb and forefinger, the Caliper was placed 1 cm away from the thumb and forefinger. Measurements of each region were made twice. Body densities were determined with the Durnin-Womersley formula (Durnin & Womersley, 1974; Mollaoglu et al., 2006). Furthermore, the BF% of the subjects was calculated with the Siri formula (Siri, 1956). These formulas were given below.

Durnin Womersley Formula = 1.1468 – 0.074 * Log (tricepsskinfold + subscapularskinfold) (Durnin & Womersley, 1974; Mollaoglu et al., 2006).

Siri Formula = (4.95/ body density – 4.5)* 100 (Siri, 1956).

Body circumference measurements

Body circumference measurements were obtained from 7 different regions (waist, hip, forearm, thigh, shoulder, chest and calf). Measurements were performed using a 2 cm wide tape measure. During the measurement, the subject was kept standing still. Extremity measurements were applied on the right side of the body. During the measurement, care was taken that the tape measure was not loose and did not compress the area too much so as not to exert pressure. Measurements were made in duplicate for each region and the mean of the two measurements was taken (ACSM, 2009; Aktuğ et al., 2019).

Table 1
Physical and performance characteristics of the participants.

Variables	Mean ± SD (n=63)
Age (year)	20.52 ± 1.635
Height (cm)	179.25 ± 7.121
Weight (kg)	72.44 ± 10.066
Sports age (year)	6.90 ± 3.125
10 m acceleration (sec)	1.74 ± 0.096
15 m acceleration (sec)	2.40 ± 0.171
Total SM (mm)	8.34 ± 2.975
Total BCM (cm)	71.76 ± 4.581
BMI (kg/m^2)	22.498 ± 2.217
BF%	19.277 ± 4.731

SM: Skinfold measurements, BCM: Body circumference measurements, BMI: Body mass index, BF%: Body fat percentage.

Acceleration measurements

Acceleration performance was evaluated using 10 and 15 meter sprint durations. Three-door photocells (SmartSpeed Fusion Sport) were placed at the starting point, at a distance of 10 meters and 15 meters. Before the run, the participants exercise a dynamic warm-up for 15 minutes (5 min warm-up run, 1 min walking, 7 dynamic stretching exercises, and 2 reps: 10 m and 15 m short sprints). Participants ran the 15 meters 2 times. The best grade from the two running times was used for analysis. A 3-minute rest was given between measurements. Subjects, after taking a static standing position at the starting point (0 meters), with one knee in front and the other standing linearly at the back, ran the 15-meter distance at the highest speed, depending on their own will (Bloomfield et al., 2007).

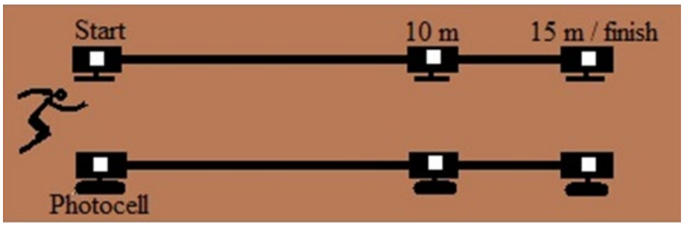

Figure 1. Acceleration test for 10 and 15 meters.

Data Analysis

SPSS IBM 22 statistics program were used for statistical analysis. The continuous variables of the study are presented in mean ± standard deviation. The Kolmogorov Smirnov test was applied to examine whether the variables show normal distribution. 10 and 15 m acceleration values are dependent variables while BMI, BF%, BCM and SM values are independent variables. Simple Linear Regression test was used to determine the effect of each independent variable on dependent variables. Pearson correlation test was used to determine the relationship between 10 and 15 m acceleration with BMI, BF%, BCM and skinfold thickness measurements. The data obtained in this study were tested at a confidence interval of 0.95.

Results

Table 1 shows demographic characteristics and accelerations and body composition measurements of the participants.

It has been determined that there is no relationship between BMI and BCM with 10 m acceleration performance of the subjects participating in the research. It is seen that the change in BMI and BCM did not affect the 10 m acceleration value (Figure 2a, Figure 2c). It has been determined that there is a significant relationship between BF% and SM with 10 m acceleration (Figure 2b, Figure 2d). It has been determined that BF% explains the 10 m acceleration value at the rate of 0.094. One unit change in BF% affects 10 m acceleration at the rate of 0.006. An increase in BF% by one unit worsens 10 m acceleration at the rate of 0.006. On the other hand, one unit decrease in BF% improves 10 m acceleration at the rate of 0.006 (Figure 2b; $p<0.05$). Moreover, it was observed that the SM explained the acceleration value of 10 m at a rate of 0.075. One unit change in SM affects 10 m acceleration at the rate of 0.008. One unit increase in SM worsens the 10 m acceleration at the rate of 0.008. On the other hand, one unit decrease in SM improves 10 m acceleration at the rate of 0.008 (Figure 2d; $p<0.05$).

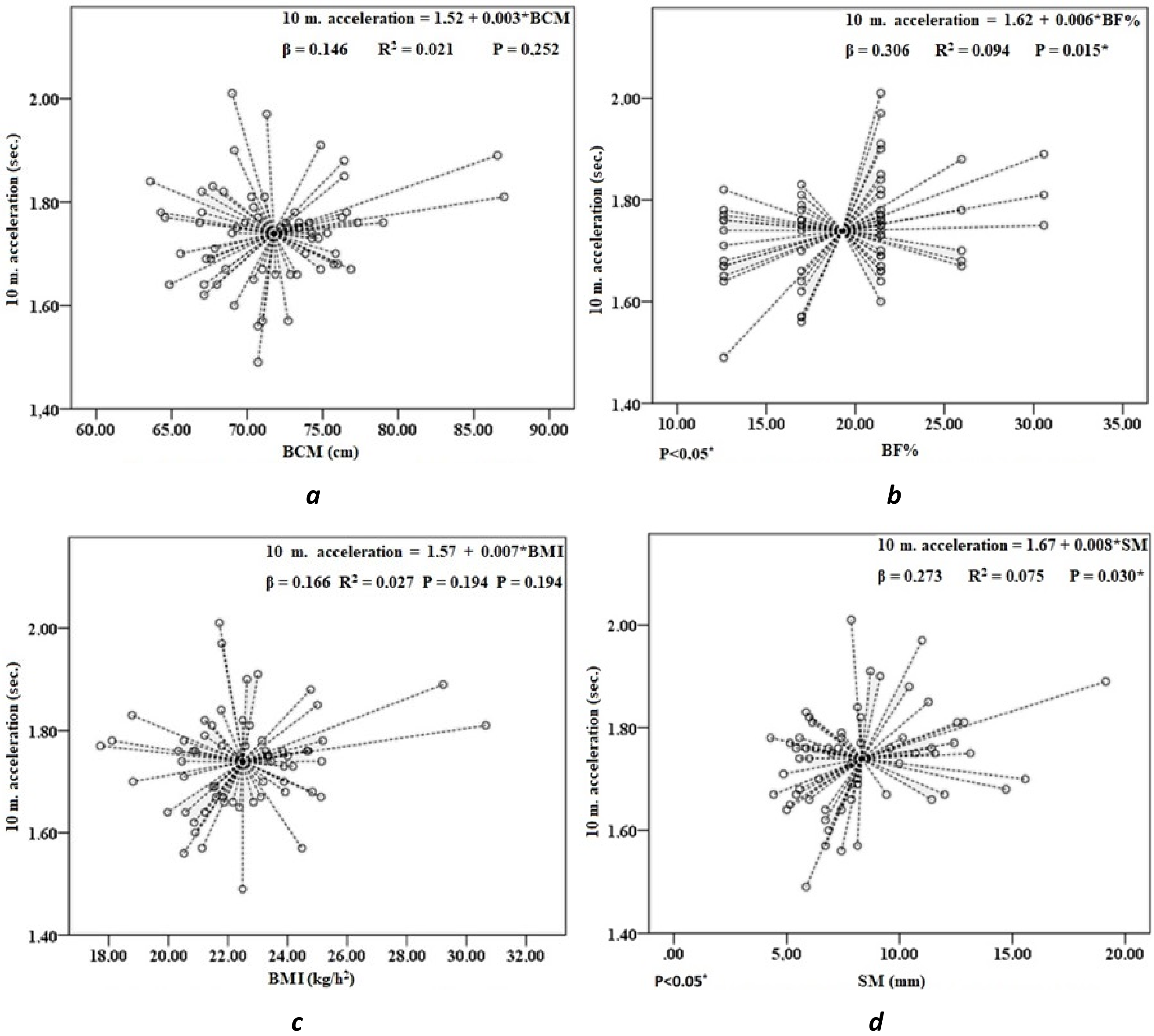

Figure 2. a: Relationship between 10 m acceleration and BMI, b: Relationship between 10 m acceleration and BF%, c: Relationship between 10 m acceleration and BCM, d: Relationship between 10 m acceleration and SM.

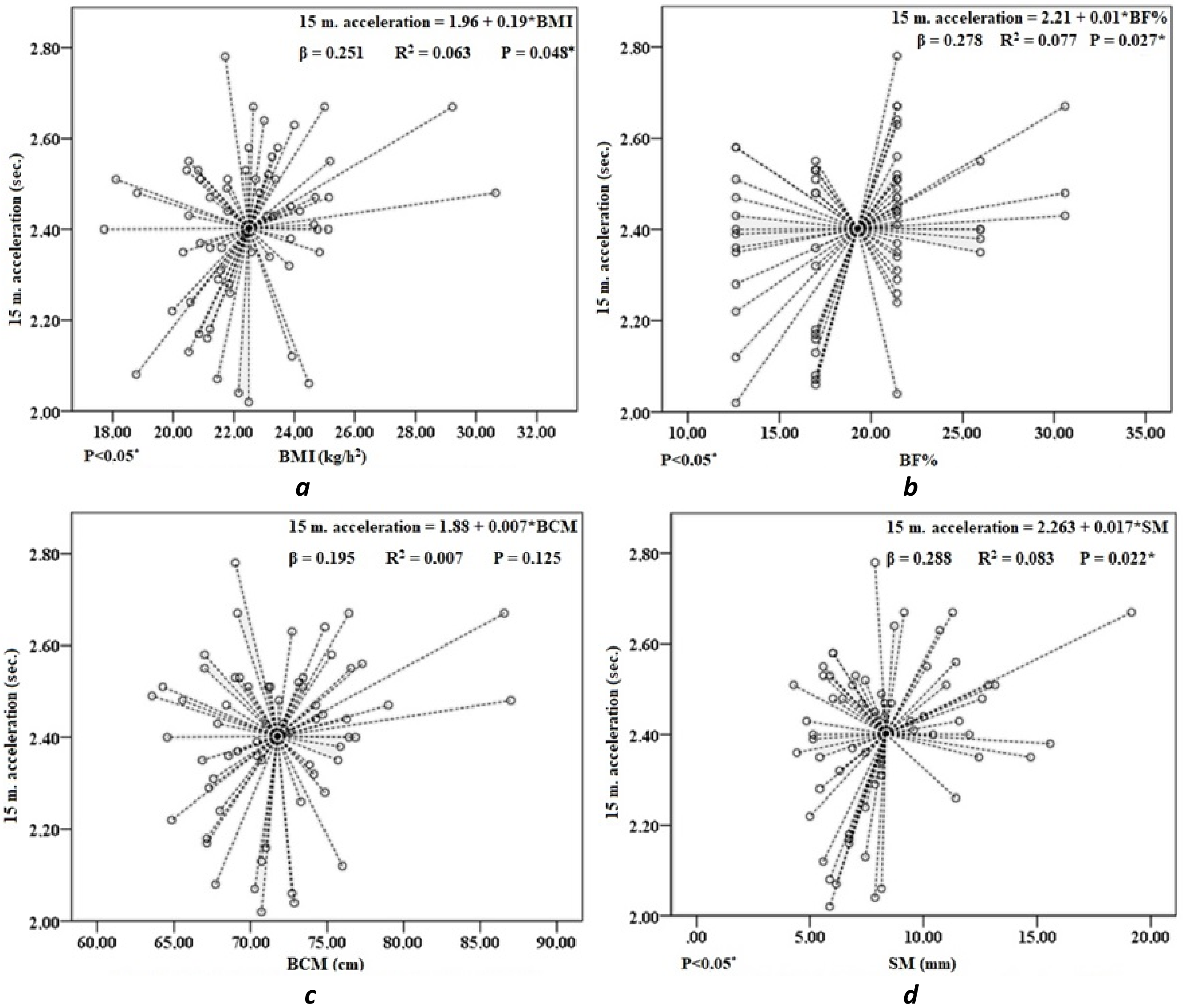

Figure 3. a: Relationship between 15 m and BMI, b: Relationship between 15 m acceleration and BF%, c: Relationship between 15 m acceleration and BCM, d: Relationship between 15 m acceleration and SM.

It was determined that there was no significant relationship between BCM and 15 m acceleration of the subjects participating in the study (Figure 3c). It has been determined that there is a significant correlation between BMI, BF% and SM with 15 m acceleration (Figure 3a, Figure 3b, Figure 3d). It was seen that BMI explained the acceleration value of 15 m at the rate of 0.063. One unit change in BMI affects 15 m acceleration at a rate of 0.19. One unit increase in BMI worsens 15 m acceleration at the rate of 0.19. In contrast, one unit reduction in BMI improves 15 m acceleration at the rate of 0.19 (Figure 3a; $p<0.05$). It was seen that BF% explained the acceleration value of 15 m at the rate of 0.077. One unit change in BF% affects 15 m acceleration at the rate of 0.01. One unit increase in BF% worsens 15 m acceleration at the rate of 0.01. In contrast, one unit reduction in BF% improves 15 m acceleration at the rate of 0.01 (Graphic b; $p<0.05$). In addition, it was observed that the SM explained the acceleration value of 15 m at a rate of 0.083. One unit change in SM affects the acceleration 15 m at a rate of 0.017. One unit increase in SM worsens the 15 m acceleration at the rate of 0.017. On the other hand, one unit reduction in SM improves 15 m acceleration at the rate of 0.017 (Figure 3d; $p<0.05$).

Discussion

This study, carried out to investigate the effect of body composition on acceleration, has revealed that there is no correlation between BCM and accelerations at both 10 m and 15 m. Moreover, it was determined that a correlation was found between acceleration at both 10 m and 15 m and both BF% and SM ($p<0.05$). While it was determined that there was no correlation between 10 m acceleration performance with BMI, there was a correlation between 15 m acceleration performance and BMI ($p<0.05$). It has been observed that %BF affects 10 m acceleration performance by 0.006 and 15 m acceleration performance by 0.01. It has been determined that SM affects 10 m acceleration performance by 0.008, while 15 m acceleration performance affects 0.017. In addition, it was determined that BMI affects the 15 m acceleration performance by 0.19.

The acceleration times of 10 m and 15 m in our study are similar to the acceleration times of the studies in the literature. In this study, 10 m acceleration performance was found as 1.74 ± 0.096 sec, and 15 m acceleration values were found as 2.40 ± 0.171 sec. In a study evaluating the acceleration of soccer players by Adalı (2019), acceleration performances at 10 m and 15 m distances were measured, and the 10 m acceleration value of the subjects was determined as 1.87±0.083 seconds and the 15 m acceleration values as 2.42±0.052. In a study evaluated the acceleration of professional soccer players by Delecluse (1997), the acceleration performance at a distance of 10 meters was measured and the acceleration value of the subjects was determined as 1.83±0.08 seconds. In a study conducted by Cochrane et al. (2004) in which the acceleration was measured at a total distance of 15 m, the times obtained among 5 m, 10 m, and 15 m distances were measured. Arı & Apaydın (2022) determined the acceleration performance of 10 m as 1.70±0.08 seconds, and the acceleration of 15 m as 2.43±0.09 seconds. In another study, the acceleration of professional soccer players was evaluated by running a distance of 10 meters as fast as possible and the acceleration value was found to be 1.83±0.08 seconds (Little & Williams, 2005).

In a study, when the results of correlation analysis between the body compositions of soccer players and their speed values are examined, it has been determined that there is a similar and moderate relationship between 10 m values and BF% and mass. Therefore, as the BF% and mass of the soccer players increase, the sprint times also increase. Furthermore, it is seen that the high BF% and mass affect the sprint characteristics of the soccer players negatively (Aktaş & Aslan, 2018). Ladwig et al. (2013) emphasized that body composition is matter to many sports branches in terms of maximum physical performance. More, they stated that as the level of body fat increases, it affects performance negatively. Additionally, excessive body age makes it difficult for oxygen to reach the muscles during exercise. They have highlighted that the preservation of low body fat has a serious importance particularly in sports branches with high intensity and high metabolic demands (such as basketball). Amonette et al. (2014) determined that 9.1 m sprint values were negatively correlated with lean body mass and positively correlated with BF% in young soccer players. A study by Silvestre et al. (2006a) evaluated the relationship between physical performance tests and body composition. The study concluded there was a significant negative relationship between total body fat and sprint, standing long jump, and pull-up tests in terms of performance level. In another study, the relationship between body composition and different physical performance tests on 27 soccer players was examined. Accordingly, it was stated that there were significant relationships among 6 different parameters (body fat ratio and lean body structure, sprint, vertical jump performance, total body strength and VO_{2max}) varying at $r = -0.67$ and $r = 0.61$ (Silvestre et al., 2006b). It was determined that the body fat ratio of soccer players was significantly negatively correlated with VO_{2max} at the level of $r = -0.67$; otherwise, significantly positively correlated with sprint performance at the level of $r = 0.60$ (Silvestre et al., 2006b). Özkan et al. (2010) stated that for all sports branches including aerobic or anaerobic exercises, the excess of fatty tissues in the body and the lack of lean body mass affect performance negatively. In the study conducted by Sheppard & Young (2006), a weak correlation was found between running speed and anthropometric variables, and the correlation coefficient between BMI and running speed was found to be $r = 0.21$. Çelik et al. (2022) examined the relationship between sprint performance and BF% of soccer players in their research. The results of the study showed that there is a weak positive correlation between 10 meters acceleration and BF%. Damayanti & Adriani (2021), in a study they conducted, found a positive and highly significant relationship between BF% with sprint performance. In the study conducted by Toro-Roman et al. (2021), it was determined that the 10 m acceleration performance was negatively affected as the % BF increased. Apaydın et al. (2022) found that there is a moderate negative correlation between the BF% and BMI of the athletes with their acceleration performance in their study. In another study conducted on 2342 male and 832 female high school students, it was found that excess fat had a negative effect on most physical performance tests (McLeod et al., 1983). Atakan et al. (2017) found a negative correlation between sprint times and body mass (p<0.05). They found that changes in the body composition of soccer players had a great importance in athletic performance, especially in sprinting and agility. Arı & Apaydın (2022) found that there was no significant relationship between BF% and acceleration performance in their study.

Conclusion

In conclusion, it was determined that the BCM did not affect the 10 m and 15 m acceleration performance. It was found that BF% and SM had an effect on both 10 m and 15 m acceleration performance. However, it was observed that BMI, BF% and SM affected the 15 m acceleration performance more. While BMI does not affect the 10 m acceleration performance, it affects the 15 m acceleration performance by 0.19. While BF affects 10% m acceleration performance by 0.006, it affects 15 m acceleration performance by 0.01. While SM affects 10 m acceleration performance by 0.008, it affects 15 m acceleration performance by 0.017. It is thought that as the acceleration distance increases, the effect level of BMI, BF% and SM increases. For a good acceleration performance, athletes should have ideal BMI, BF% and SM. Future studies should investigate sports branches separately, taking into account the gender variable.

Authors' Contribution

Study Design: İHŞ, AS; Data Collection: İHŞ, AS; Statistical Analysis: İHŞ, AS; Manuscript Preparation: İHŞ, AS; Funds Collection: İHŞ, AS.

Ethical Approval

The study was approved by the Selcuk University of Sports Science Faculty Ethical Committee (2019/64) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Funding

The authors declare that the study received no funding.

Conflict of interest

The authors hereby declare that there was no conflict of interest in conducting this study.

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ORIGINAL RESEARCH

The effect of technical training on physical parameters of 11-14 years old freestyle wrestlers

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Received: April 13, 2023
Accepted: June 20, 2023
Online Published: June 30, 2023

Abstract

This study aims to determine the physical changes resulting from technical training applied to adolescent wrestlers. Twenty-four male wrestlers volunteered to participate in the study. Participants were randomly divided into two groups: Experimental group (EG, n=14) and Control group (CG, n=14). The EG had a mean age of 12.54±0.82 years, a mean body weight of 48.36±8.23 kg, and a mean height of 156.18±8.58 cm. The CG had a mean age of 13.62±0.33 years, a mean body weight of 47.43±6.65 kg, and a mean height of 158.24±2.26 cm. The EG performed a 12-week technical training specific to freestyle wrestling while the CG continouned their regular wrestling training. Before and after the 12 week training period, skinfold thickness and body circumference measurements were carried out. There were significant differences between pre and post tests in subscapula, biceps, triceps, pectoral, abdominal, suprailiac, abdominal, suprailiac, and tight ($p<0.05$). No significant change was observed in the abdominal, suprailiac skinfold thickness measurements. Subscapula, biceps, triceps, triceps, pectoral, and tight parameters significantly decreased after the 12 week period ($p<0.05$). No significant difference was found between the pre-test and post-test in EG ($p>0.05$). There are significant changes between the pre and post tests in shoulder, chest, chest (inspiration), chest (expiration), abdomen, hip, thigh, forearm tight, calf, arm, arm circumference, forearm circumference measurements ($p<0.05$). After the technical training, all circumference measurements significantly decreased except for one shoulder. There was no significant difference between the pre test and post test in one shoulder and calf circumference measurements ($p>0.05$). However, there were significant changes in the pre test and post test in the CG. The houlder, chest, chest (inspiration), chest (expiration), abdomen, hip, thigh, forearm thigh, arm, arm circumference, and forearm measurement increased after a 12-week standart wrestling training period ($p<0.05$). As a result, this study revealed that a 12 week technical training specific to the wrestling declined skinfold thickness like regular wrestling training. Except single shoulder measurements, body circumference measurements demonstrated significant increases after technical training. These results indicate that technical training in freestyle wrestling positively contributes to the physical development of adolescent wrestlers.

Keywords: Physical parameters, technical training, wrestling.

Introduction

Wrestling significantly contributes to the overall development of both physical and mental capacities, motor skills, and the acquisition of technical and tactical knowledge. Over time, freestyle and armoured wrestling techniques and tactics have undergone significant improvements through physical, theoretical, and psychological studies, reaching high levels today. Wrestling competitions have transformed into

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To Cite: Güven, F. (2023). The effect of technical training on physical parameters of 11-14 years old freestyle wrestlers. *Turk J Kinesiol*, 9(2), 115-124. **DOI:** 10.31459/turkjkin.1282317

captivating performances. The sport's international evolution, facilitated by the systematic organization of annual continental competitions, has gained momentum, capturing the interest of an increasing number of countries. One of the major advantages of wrestling is its inclusion in the Olympic Games program since its inception (Neferu, 2014). Wrestling is a branch that intricately combines defense and offense organization, requiring quick application of techniques and constant struggle and effort while maintaining continuous contact with the opponent (Gümüş, 2005). In wrestling, various physical fitness components such as strength, speed, quickness, flexibility, balance, muscular endurance, and cardiovascular endurance greatly influence performance. Wrestling is a challenging sport that incorporates numerous physical and technical components within a short timeframe (Camic et al., 2009). It is crucial for wrestlers to apply appropriate techniques, as well as resist and counter the techniques employed by their opponents.

Flexibility is also vital for a wrestler's success, as it allows for more comfortable execution of techniques. Wrestlers' strength, speed, flexibility, power, endurance, aerobic and anaerobic capacities significantly impact wrestling performance, and these factors should be maximized through appropriate training programs to ensure success in wrestling (Nikitushkin, 2009). Wrestling is not solely a competition focused on defeating opponents, but also a sport that demands high levels of endurance, anthropometric characteristics, aerobic and anaerobic capacities, respiratory functions, strength, flexibility, speed, quickness, balance, reaction time, and strategy (Yoon, 2002). Wrestling encompasses various weight categories. When determining the weight classes for wrestlers, physical characteristics such as height, body weight, and body fat ratio are taken into consideration. Valuable qualities required for wrestlers, such as flexibility, speed, dexterity, and intelligence, are most apparent during adolescence and youth. However, it is essential to consider the age, anatomical, physiological, and psychological characteristics of adolescents and young adults to avoid causing irreversible physiological and mental trauma to their developing bodies. A significant portion of the bone tissue is covered with cartilage in young men, rendering their skeletal systems more adaptable due to the smaller amounts of calcium and phosphorus salts present in the bone tissue (Zatsiorsky, 2009).

The choice of body composition technique often depends on the purpose for which the data will be used and the specific context. In relation to high-performance sports, assessing body composition is considered a performance or selection criterion (Malina et al., 2011). Body composition is a crucial variable for performance. In weight-sensitive sports, many athletes resort to extreme methods to rapidly reduce mass or maintain low body mass to gain a competitive advantage. Optimal performance is achieved when wrestlers' body mass and shape align with their perceived body ideal (Juricskay & Mezey, 1994). While body fat can serve as a biomechanical counterbalance, adipose tissue also functions as a vital endocrine organ for overall health. Athletes facing increased risk of eating disorders encounter conflicting biomechanical and health requirements (Müller, 2009). Understanding and measuring athletes' body composition have been central to medical research for nearly a century. Although significant progress has been made through landmark studies and the utilization of new and combined analytical methods, ethical and methodological limitations have hindered the establishment of an absolute standard against which assessment methods can be compared in humans. Presently, no gold standard for body fat assessment achieves accuracy better than 1% (Balsevich, 2009).

Determining physical and physiological characteristics and monitoring their development play a vital role in achieving success in wrestling. The athlete's physical characteristics, correct technique, and motivation, as well as the physical-motor characteristics of young wrestlers based on their position during competitions, their ability to move effectively, and their decision-making skills, are crucial factors in determining success in wrestling. Therefore, the identification and development of wrestling-related characteristics can only be accomplished through scientific tests and studies (Mirwald et al., 2002). This study aims to determine the physical changes resulting from technical training applied to adolescent wrestlers.

Methods

Twenty-four male wrestlers volunteered to participate in the study. Participants were randomly divided into two groups: Experimental group (EG, n=14) and Control group (CG, n=14). The EG had a mean age of 12.54±0.82 years, a mean body weight of 48.36±8.23 kg, and a mean height of 156.18±8.58 cm. The CG had a mean age of 13.62±0.33 years, a mean body weight of 47.43±6.65 kg, and a mean height of 158.24±2.26 cm.

The study received approval from the families of the athletes, who were free from any health problems or injuries. Approval from the local Ethics Committee (date: 27.04.2023 and number: 09-2023/124) was obtained before beginning the studies.

The 12-week study involved the application of technical trainings specific to freestyle wrestling for the wrestlers in the EG, while the wrestlers in the CG received general wrestling training. Anthropometric measurements were taken on the first day of the study, subcutaneous fat thickness measurements on the second day, and body circumference measurements on the third day. These measurements were repeated before and after a 12-week technical training of the study.

Anthropometric Measurements

The participants' height was measured in centimeters (cm) using a precise stadiometer (Salus, Milan, Italy) with their heels together and their heads upright. Their weight was determined in kilograms (kg) using a precise weighing scale (Salus, Milan, Italy) (Cochrane et al., 2015).

Subcutaneous Fat Measurements

Subcutaneous fat thickness was measured by pinching the skin and subcutaneous fat between the thumb and index finger, perpendicular to the skin fold, on the right side of the body. The thickness of the subcutaneous adipose tissue and the double layer of the skin were measured in millimeters using a Skinfold caliper (Azzi et al., 2018). The following measurements were taken: Biceps, measured from the widest point of the biceps muscle; triceps, measured from the widest point of the triceps muscle; Subscapula, measured 2 cm below the inferior angle of the scapula; pectoral, measured diagonally from the lateral edge of the m. pectoralis towards the nipple; Abdominal, measured 3 cm lateral to the umbilicus; iliac, measured 1-2 cm above the iliac bone; quadriceps, measured from the widest point of the quadriceps femoris muscle; and calf, measured vertically from the widest part of the m. triceps surae muscle and medially.

Body Circumference Measurements

Circumference measurements were taken using a non-flexible tape measure (Aptamil brand) according to anthropometric measurement protocols. The tape measure was wrapped around the following points for circumference measurements: Single shoulder circumference, measured from the upper part of the deltoid muscle, encircling the shoulder; arm excitation circumference, measured from the midpoint of the humerus, surrounding the biceps and triceps muscles; arm contraction circumference, measured at the midpoint of the humerus, surrounding the biceps and triceps muscles, with the arm in the contracted position; forearm excitation circumference, measured from the widest region of the forearm proximally, in the relaxed position; forearm contraction circumference, measured at the widest part of the forearm, with the forearm in the contracted position; chest circumference, measured at the costasternal circumference; chest inspiratory circumference, measured from the underside of the nipples after a maximal inspiration (breath held at this point); chest expiration circumference, measured from the underside of the nipples after a maximal exhalation; abdominal circumference, measured starting from the umbilicus and encircling at the same horizontal plane; hip circumference, measured from the widest point of the gluteus maximus muscle, wrapping the tape measure horizontally and slightly upwards; thigh circumference, measured by wrapping the tape measure around the midpoint of the thigh with the knee flexed at ninety degrees; and calf circumference, measured by wrapping the tape measure around the widest points of the gastrocnemius and triceps surae muscles (Minetto et al., 2022).

Anthropometric Measurements

Participants' weight was measured in (cm) with a precision (Salus, Milan, Italy) stadiometer with the heels of the feet together and the head upright. Participants' weight was determined in kg with a precision (Salus, Milan, Italy) weighing scale (Cochrane et al., 2015).

Skinfold thickness measurements

Subcutaneous fat thickness was assessed by gently grasping the skin and underlying fat tissue between the thumb and index finger, pulling in the direction of the skin fold on the right side of the body. The measurement involved determining the thickness of both the subcutaneous adipose tissue and the double layer of the skin, and the values were recorded in millimeters. To obtain these measurements, a Skinfold caliper (Azzi et al., 2018) was used. The specific anatomical sites and corresponding measurement techniques were as follows:

Biceps: Measured at the midpoint of the widest region of the biceps muscle.

Triceps: Measured at the midpoint of the widest region of the triceps muscle.

Subscapula: Measured 2 cm below the inferior angle of the scapula.

Pectoral: Measured diagonally from the lateral edge of the m. pectoralis towards the nipple.

Abdominal: Measured 3 cm lateral to the umbilicus.

Iliac: Measured 1-2 cm above the iliac bone.

Quadriceps: Measured at the midpoint of the widest region of the quadriceps femoris muscle.

Calf: Measured vertically from the widest part of the m. triceps surae muscle, medially.

Body circumference measurements

Circumference measurements were taken from the following points with Aptamil brand non-flexible tape measure in accordance with anthropometric measurement protocols. It was measured surrounding the most prominent points of the deltoid muscles and by holding the tape measure over both shoulders.

Single shoulder circumference: It was measured from the upper part of the deltoid muscle and the tape measure was measured from the armpit to encircle the shoulder.

Arm excitation circumference: It was measured from the midpoint of the humerus surrounding the biceps and triceps muscles.

Arm contraction circumference: Measured with a tape measure at the midpoint of the humerus surrounding the biceps and triceps muscles and with the arm in the contracted position.

Forearm excitation circumference: Measured from the widest region of the forearm proximally in the relaxed position.

Table 1. The technical training program for wrestlers aged 11-14.

Monday	After at least 5 minutes of jogging run, at least 10 minutes of warm-up training was performed in the form of stretching and games for the whole muscular system, and the training was ended by applying basic technical training.
Tuesday	Technical training 3 minutes 60%-90% wrestling match training in groups of 3, 1 person in the middle and 2 people to be loaded, 1.30 minutes, 30 seconds rest in every 3 minutes, 3 sets were made. Complementary technical training on the mat and jogging for at least 5 minutes followed by at least 10 minutes of stretching of the whole muscular system.
Wednesday	Station work in pairs Only 1 set (1 minute rest-return time) At least 5 minutes jogging run followed by at least 10 minutes stretching of the whole muscular system. Technical training formats specific to age groups were applied.
Thursday	12 sets of press (alternating partners) 1min 6 sets with 6 sets of unloading 6 sets without unloading known technical tactical work with 60% 90% loading intensity with complementary strength at least 5 minutes jogging run followed by at least 10 minutes stretching of the whole muscular system.
Friday	After at least 5 minutes of jogging run followed by at least 10 minutes of stretching of the whole muscular system, technical training was performed with the game format and ended with stretching.
Saturday	Morning After warming up for 15 minutes, 4 km running and 400-200-100 m runs were done in 2 sets, jogging for at least 5 minutes, followed by at least 10 minutes of stretching of the whole muscular system. Afternoon After at least 5 minutes of jogging run followed by at least 10 minutes of opening and stretching of the whole muscular system, technical tactical work 4x3 minutes complementary weight training was done in the form of up and down. After at least 5 minutes of jogging run, it was finished with at least 10 minutes of whole muscle system stretching.
Sunday	Morning After 15 minutes of warm-up, 4 km running and 400-200-100 m runs, 2 sets of jogging for at least 5 minutes, followed by at least 10 minutes of stretching the whole muscular system. Afternoon After warming up, wrestling technical training was performed for 3 minutes each, 4 sets of matches, gymnastic movements without complementary strength and jogging for at least 5 minutes, followed by at least 10 minutes of stretching and opening of the whole muscular system.

Forearm contraction circumference: Measured at the widest part of the forearm with the forearm in the contracted position.

Chest circumference: It was considered as the costasternal circumference and measured.

Chest inspiratory circumference: Measured from the underside of the nipples after a maximum inspiration (breath held at this point).

Chest expiration circumference: Measured from the underside of the nipples after a maximal exhalation.

Abdominal circumference: The tape measure was measured starting from the umbilicus and encircling to the same point in the horizontal plane.

Hip circumference: It was measured from the widest point of the gluteus maximus muscle by wrapping the tape measure horizontally and slightly upwards.

Table 2
Demographic charactersitics of participants (Mean ± SD).

Variables	Tests	EG (n=14)	CG (n=14)
Age (year)		12.54 ± 0.82	13.62 ± 0.33
Weight (kg)	Pre-test	48.36 ± 8.23	47.43 ± 6.65
	Post-test	48.55 ± 6.45	47.86 ± 5.44
Height (cm)	Pre-test	156.18 ± 8.58	158.24 ± 2.26
	Post-test	157.08 ± 5.17	159.33 ± 4.51

EG: Experimental Group; CG: Control Group.

Thigh circumference: It was measured by wrapping the tape measure around the midpoint of the thigh with ninety degrees knee flexion.

Circumference: It was measured by wrapping the tape measure around the widest points of the gastracinemius and tricepssurae muscles (Minetto et al., 2022).

Technical Training

The EG performed the technical trainings specific to freestyle wrestling during 12 weeks (Table 1).

Data Analyses

The data obtained in the study were presented as mean and standard deviation. Normality analysis was performed using the Shapiro-Wilk test. Unpaired t-test was used for comparing groups, and paired t-test was used for comparing pre-test and post-test measurements. A significance level of 0.05 was considered. Data analysis was conducted using Jasp 0.16.1 software.

Results

Table 2 shows mean age, weight and heigh of the participants in EG and CG. Table 3 shows the results of pre-test and post-test subcutaneous measurements of the wrestlers in the EG. There were significant differences between pre and post tests in subscapula, biceps, triceps, pectoral, abdominal, suprailiac, abdominal, suprailiac, and tight ($p<0.05$). The skinfold thickness measurements in EG significantly decreased after the training.

Table 3
Comparisons of the pre and post tests skinfold thicknesses in EG.

Parameter	Tests	Mean ± SD	t	p
Subscapula	Pre-test	10.09 ± 6.62	3.627	0.005*
	Post-test	9.18 ± 5.87		
Biceps	Pre-test	6.86 ± 4.54	5.164	0.000*
	Post-test	6.13 ± 4.13		
Triceps	Pre-test	10.04 ± 4.17	9.083	0.000*
	Post-test	8.54 ± 3.74		
Pectoral	Pre-test	10.0 ± 6.95	5.367	0.000*
	Post-test	8.68 ± 6.17		
Abdominal	Pre-test	16.5 ± 9.02	6.13	0.000*
	Post-test	14.90 ± 8.29		
Suprailiac	Pre-test	7.90 ± 6.62	3.73	0.004*
	Post-test	7.18 ± 6.10		
Tight	Pre-test	16.36 ± 6.85	5.175	0.000*
	Post-test	15.04 ± 6.09		

** p < 0.05*

Table 4
Comparisons of the pre and post tests skinfold thicknesses in CG.

Parameter	Tests	Mean ± SD	t	p
Subscapula	Pre-test	11.04 ± 4.25	4.343	0.002*
	Post-test	10.55 ± 3.22		
Biceps	Pre-test	5.60 ± 6.04	6.536	0.000*
	Post-test	5.32 ± 7.19		
Triceps	Pre-test	10.24 ± 3.06	7.118	0.000*
	Post-test	9.78 ± 6.28		
Pectoral	Pre-test	10.55 ± 6.95	3.87	0.000*
	Post-test	9.87 ± 5.25		
Abdominal	Pre-test	15.7 ± 6.133	4.55	0.645
	Post-test	16.02 ± 5.44		
Suprailiac	Pre-test	7.02 ± 6.44	4.11	0.214
	Post-test	7.25 ± 6.27		
Tight	Pre-test	16.05 ± 5.54	6.731	0.001*
	Post-test	14.89 ± 5.01		

** p < 0.05*

Table 5
Body circumference measurements in EG.

Variables	Tests	Mean ± SD	t	p
Shoulder	Pre-test	93.72 ± 6.05	-7.416	0.000*
	Post-test	95.72 ± 6.14		
One Shoulder	Pre-test	38.63 ± 2.76	0.636	0.539
	Post-test	36.36 ± 11.11		
Chest	Pre-test	77.27 ± 5.04	-10,456	0.000*
	Post-test	79.09 ± 5.20		
Chest (inspiration)	Pre-test	80.54 ± 4.86	-16.166	0.000*
	Post-test	83.09 ± 5.28		
Chest (expiration)	Pre-test	75.36 ± 5.22	15.588	0.000*
	Post-test	72.90 ± 5.01		
Abdomen	Pre-test	72.72 ± 7.68	11.739	0.000*
	Post-test	70.81 ± 7.66		
Hip	Pre-test	80.09 ± 7.66	-3.184	0.010*
	Post-test	81.18 ± 7.04		
Thigh	Pre-test	43.63 ± 4.49	-11.656	0.000*
	Post-test	44.77 ± 4.25		
Front Arm Thigh	Pre-test	43.90 ± 4.5	-8.714	0.000*
	Post-test	45.13 ± 4.41		
Calf	Pre-test	31.90 ± 2.67	-12.279	0.000*
	Post-test	33.18 ± 2.77		
Arm	Pre-test	23.81 ± 2.56	-9.69	0.000*
	Post-test	25.0 ± 2.55		
Arm Circumference	Pre-test	25.45 ± 2.60	-9.238	0.000*
	Post-test	26.90 ± 2.94		
Front Arm	Pre-test	22.54 ± 1.55	-15.588	0.000*
	Post-test	23.77 ± 1.55		

Table 6
Body circumference measurements in CG.

Parameter	Tests	Mean ± SD	t	p
Shoulder	Pre-test	94.06 ± 5.35	-6.313	0.000*
	Post-test	96.03 ± 5.21		
One Shoulder	Pre-test	38.44 ± 4.11	0.571	0.351
	Post-test	37.23 ± 8.64		
Chest	Pre-test	77.33 ± 5.35	-11,726	0.000*
	Post-test	79.65 ± 5.04		
Chest (inspiration)	Pre-test	81.33 ± 5.03	-15.103	0.040*
	Post-test	83.14 ± 542		
Chest (expiration)	Pre-test	76.15 ± 5.11	14.333	0.000*
	Post-test	74.02 ± 5.23		
Abdomen	Pre-test	72.12 ± 7.49	10.687	0.020*
	Post-test	71.44 ± 7.15		
Hip	Pre-test	80.61 ± 6.54	-3.416	0.010*
	Post-test	82.33 ± 6.63		
Thigh	Pre-test	42.88 ± 4.24	-9.762	0.020*
	Post-test	44.03 ± 4.16		
Front Arm Thigh	Pre-test	43.71 ± 4.33	-9.315	0.010*
	Post-test	44.89 ± 4.61		
Calf	Pre-test	32.24 ± 2.67	0.345	0.217
	Post-test	31.45 ± 2.34		
Arm	Pre-test	23.81 ± 3.14	-10.560	0.000*
	Post-test	24.44 ± 2.27		
Arm Circumference	Pre-test	25.02 ± 2.87	-8.952	0.020*
	Post-test	25.90 ± 2.26		
Front Arm Measurement	Pre-test	22.23 ± 165	-14.319	0.000*
	Post-test	23.44 ± 1.07		

Table 4 shows the results of the pre-post test subcutaneous measurements in the CG. No significant change was observed in the abdominal, suprailiac skinfold thickness measurements. Subscapula, biceps, triceps, triceps, pectoral, and tight parameters significantly decreased after the 12 week period ($p<0.05$).

Table 5 presents the body circumference measurements in EG. When compared the one shoulder measurements in EG, no significant difference was found between the pre-test and post-test ($p>0.05$). There are significant changes between the pre and post tests in shoulder, chest, chest (inspiration), chest (expiration), abdomen, hip, thigh, forearm tight, calf, arm, arm circumference, forearm circumference measurements ($p<0.05$). After the technical training, all circumference measurements significantly decreased except for one shoulder.

Table 6 shows the body circumference measurements before and after the training in CG. Paired t-test results showed that there was no significant difference between the pre test and post test in one shoulder and calf circumference measurements ($p>0.05$). However, there were significant changes in the pre test and post test in the CG. The houlder, chest, chest (inspiration), chest (expiration), abdomen, hip, thigh, forearm thigh, arm, arm circumference, and forearm measurement increased after a 12-week standart wrestling training period ($p<0.05$).

Discussion

The development of technical training and body composition in adolescent wrestlers is crucial for their overall performance and success in the sport. In addition to regular wrestling training, incorporating specific technical training exercises can have a significant impact on the athletes' body composition and ultimately improve their wrestling abilities. This discussion aims to explore the importance of integrating technical training alongside regular wrestling training to enhance body composition in adolescent wrestlers.

Previous studies have examined similar aspects of adolescent wrestlers, including anthropometric measurements (such as height, weight, skinfolds, and body composition) and motor tests (speed, flexibility, and endurance) for wrestlers aged between 10 and 14 years. These studies have shown a significant relationship between physical characteristics and motor abilities, indicating the impact of physical attributes on performance (Acar & Koca, 2020; Camic et al., 2010; Aksoy et al., 2020a). Furthermore, the training age and type of training have been identified as factors that may influence the outcomes of such studies (Aksoy et al., 2020b). In another study focused on improving the anthropometric and body composition profiles of wrestlers, the relationship between anthropometric variables and physiological, fitness, and technical factors was highlighted. The study emphasized the importance of anthropometric characteristics and body composition in determining an athlete's performance (Cieslinski, 2020b).

The present study evaluated the subcutaneous measurement results of various parameters, including subscapula, biceps, triceps, pectoral, abdominal, suprailiac, and thigh, for the wrestlers of the EG. The results showed a significant changes between the pre-test and post-test measurements ($p<0.05$). However, in the CG, only the parameters of subscapula, biceps, triceps, pectoral, and thigh demonstrated a significant changes, while abdominal and suprailiac subcutaneous measurements did not show a significant change. These findings align with a similar study that reported significant correlations in subcutaneous measurements of various body regions (Addo & Himes, 2010). Furthermore, a study involving 114 adolescent female wrestlers examined body composition variables (such as body mass index, body fat percentage, fat-free mass, and fat-free mass index) and fitness measures (including grip strength, back strength, sit-up, rope climbing, and endurance running tests). The study observed a significant increase in back strength but no changes in height and body mass (Arakawa et al., 2020b).

Regarding the impact of technical training on the wrestlers, the present study found no significant difference in the pre-test and post-test measurements of single shoulder circumference for both the experimental and control groups. However, significant changes were observed in the pre-post test results of other circumference measurements, such as shoulder, chest, chest (inspiration), chest (expiration), abdomen, hip, thigh, forearm, calf, and arm circumferences. These findings indicate that technical training influenced various body measurements, except for the single shoulder circumference.

Another study analyzed changes in body composition and motor characteristics in 19 wrestlers who underwent 8 months of wrestling training. The study evaluated various measurements, including body weight, circumferences of different body parts, regional muscle strength, anaerobic strength, skinfold thickness, and body fat percentage. The results indicated a positive effect of wrestling training on leg strength, biceps, triceps, and abdominal skinfolds (Demirhan, 2020b).

As training methods become more advanced, athletes are expected to deviate from general morphological norms in order to maximize their efficiency (Müller et al., 2006b). Therefore, understanding the morphofunctional characteristics of wrestlers, especially at an early age, and incorporating modern training methods are crucial in the early stages of sports specialization (Stewart & Hannan, 2000). Psychological training is also important for wrestlers to master and effectively use wrestling techniques. Different techniques can provide a competitive advantage, and their effectiveness can be influenced by the physical and psychological characteristics of the wrestlers (Hsi-Po et al., 2020a).

Technical training in wrestling focuses on developing specific skills, techniques, and strategies required in the sport. It involves a combination of drills, repetitions, and practice sessions that aim to improve various aspects of wrestling, such as takedowns, escapes, pins, and transitions. While regular wrestling training primarily focuses on improving overall strength, endurance, and conditioning, technical training places a specific emphasis on refining wrestling-specific skills. By incorporating technical training into their routine, adolescent wrestlers can enhance their technical proficiency, tactical understanding, and decision-making abilities during matches (Hsi-Po et al., 2020b).

One significant benefit of technical training is its impact on body composition. Body composition refers to the proportion of lean mass (muscle, bone) and fat mass in the body. Achieving an optimal body composition is essential for wrestlers as it directly influences their strength, power, speed, and agility. Technical training, with its focus on skill development, often involves dynamic movements, explosive actions, and bodyweight exercises that contribute to the development of lean muscle mass and reduction of body fat (Demirhan, 2020a). Integrating technical training exercises that target specific muscle groups and movement patterns can lead to improvements in overall body composition. For example, exercises that involve explosive takedowns, quick transitions, and rapid change of directions can enhance muscular power, speed, and agility while simultaneously promoting fat loss. Additionally, techniques that require wrestlers to maintain a low center of gravity, such as stance and motion drills, can engage the lower body muscles, improving leg strength and stability (Aksoy et al., 2020a). Furthermore, technical training can also contribute to improved muscular endurance. Wrestling matches often require sustained effort and repeated exertion of strength over a prolonged period. By incorporating drills that simulate match conditions and involve high-intensity intervals, wrestlers can enhance their muscular endurance and maintain optimal performance throughout a match (Arakawa et al., 2020a).

It is important to note that technical training should be supplemented with proper nutrition and recovery strategies to maximize its impact on body composition. Adequate protein intake is essential to support muscle repair and growth, while a balanced diet with appropriate caloric intake is necessary to fuel training sessions and optimize body composition changes. Sufficient rest and recovery periods allow the body to adapt and respond positively to the training stimulus, ensuring optimal gains in lean muscle mass and reduction in body fat (Cieslinski, 2020a).

In conclusion, incorporating technical training alongside regular wrestling training can significantly contribute to the development of body composition in adolescent wrestlers. The specific exercises and drills involved in technical training help improve muscle strength, power, speed, agility, and endurance while promoting a favorable body composition with increased lean muscle mass and reduced body fat. By implementing a well-rounded training program that encompasses both technical and physical aspects, coaches and athletes can enhance their performance and achieve their full potential in the sport of wrestling (Müller et al., 2006a). As a result, this study revealed that a 12 week technical training specific to the wrestling declined skinfold thickness like regular wrestling training. Except single shoulder measurements, body circumference measurements demonstrated significant increases after technical training. These results indicate that technical training in freestyle wrestling positively contributes to the physical development of adolescent wrestlers. The results are consistent with previous research highlighting the relationship between physical characteristics, training methods, and performance outcomes in adolescent wrestlers. Further studies should continue to explore the long-term effects of technical training on wrestlers and consider additional factors such as psychological training and different wrestling techniques.

Authors' Contribution
Study Design: FG; Data Collection: FG; Statistical Analysis: FG; Manuscript Preparation: FG; Funds Collection: FG.

Ethical Approval
The study was approved by the Karamanoğlu Mehmetbey University Ethic Committee with the decision of the ethics committee dated 27.04.2023 and numbered 09-2023/124. The study was conducted in accordance with the Declaration of Helsinki.

Funding
The author declares that the study received no funding.

Conflict of Interest
The author hereby declares that there was no conflict of interest in conducting this study.

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REVIEW ARTICLE

Effect of caffeine on the cardiovascular system and performance: A systematic review

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Received: March 10, 2023

Accepted: April 16, 2023

Online Published: June 30, 2023

Abstract

Caffeine is a compound found in the leaves, seeds and fruits of plants such as coffee and guarana. The aim of the systematic review was to determine the influence of caffeine on cardiorespiratory functions and physical performance. The method was the collection of relevant literature in the period from 2011-2022, and their analysis. The results clearly show the benefit and positive influence of caffeine on both investigated areas. The recommended consumption of caffeine should be higher than 75mg in order to expect positive changes and effects. Also, doses above 600mg should not be exceeded due to side effects, especially on the heart. It is necessary to consume caffeine for at least 45 minutes before the planned activity to ensure complete absorption. Caffeine is a very powerful supplement, it is only necessary to take care of the method and amount of dosage.

Keywords: Activity, blood pressure, caffeine, HR, training, VO_{2max}.

Introduction

Caffeine use is increasing worldwide. The main motives are mainly concentration and improvement of memory and improvement of physical performance. Caffeine affects the cardiovascular system, with its positive inotropic and chronotropic effects, and the central nervous system by stimulating locomotor activity and anxiogenic effects (Lavie et al., 2019). Caffeine abuse and dependence are becoming more common and can lead to caffeine intoxication, putting individuals at risk of premature and unnatural death. This review summarizes major findings regarding caffeine's mechanisms of action (focusing on adenosine antagonism, intracellular calcium mobilization, and phosphodiesterase inhibition), use, abuse, dependence, intoxication, and lethal effects. It also suggests that the concepts of toxic and lethal doses are relative, doses below the toxic and/or lethal range may play a causal role in intoxication or death (Cappelletti et al., 2015; Dos Santos et al., 2018).

Caffeine is one of the most widely used dietary supplements in the general population and is therefore one of the most researched dietary supplements. Research carried out in the form of a survey of the population of US citizens found that 85% of the population consumes at least one beverage a day that contains caffeine, i.e. an average daily value of caffeine of 165 mg, where coffee is the primary contributor to caffeine intake in all age groups (Mitchell et al., 2014).

Caffeine is both a nutrient and a supplement at the same time and can very easily be classified in the category of "highly effective supplements" (Guest et al., 2021) Considering the huge amount of different supplements both on the world market and on our

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To Cite: Bjelica, B., Aksović, N., Zelenović, M., Pržulj, R., & Radenković, O. (2023). Effect of caffeine on the cardiovascular system and performance: A systematic review. *Turk J Kinesiol*, 9(2), 125-132.

DOI: 10.31459/turkjkin.1263307

market, the question is often asked which supplements or nutritional supplements are effective for their purpose. Vitamins and minerals are essential nutrients for our body and their deficit causes various health problems, so their effect is the prevention of various problems (Ford et al., 2019). The question of effectiveness is a frequent topic of various studies that deal with testing supplements and their effect on athletes. Those studies have long classified caffeine in the category of nutrients that have a positive, and easily measurable, effect on athletes and therefore sports results, and to the extent that caffeine was a prohibited substance by WADA (World Anti-Doping Agency) until 2004. Caffeine was then considered an illegal substance. A large number of supplements have no measurable positive effect on performance, further demonstrating how unique caffeine is (Deventer et al., 2011).

The action of caffeine has several functions: The most important one is the blocking of the binding of adenosine to receptors, which directly reduces our subjective feeling of fatigue because the binding of adenosine to its own receptors causes an increase in the feeling of fatigue (Bjelica et al., 2020). In this way, it has a direct effect on the central nervous system and that is why athletes use it to delay the feeling of fatigue and to be more concentrated; with more focus during a race, match or game (Aksović et al., 2020). The effect is noticeable in practically every individual and this is probably one of the main reasons why a large number of people consume coffee, black tea or products and supplements with added caffeine.

Diaz-Lara et al. (2016) prove the effectiveness of caffeine on sports performance in order to improve performance in elite Brazilian Jiu-jitsu athletes. In their experimental research, they used a dose of 3mg/kg of caffeine, which they compared with the performance when the participants consumed a placebo. With the aforementioned research, they proved the effectiveness of caffeine on the strength of the hand grip, on the height of the jump during the countermovement jump (CMJ), the result of the 1RM (one-repetition-maximum) performance, and on the mean strength value during the bench press exercise.

Grgic et al. (2019) investigated the difference and effects of three doses of caffeine (2, 4 and 6 mg/kg) on muscle strength and endurance. Strength was assessed through 1RM and endurance through the number of repetitions until immediate muscle failure with a load equal to 60% of 1RM. In their studies, they proved a correlation between the dose of caffeine and the effect on the strength of the upper limbs, that is, a significant improvement in performance with doses of 4 and 6mg/kg.

Therefore, the aim of the systematic review is to determine the effect of caffeine on cardiorespiratory functions and performance.

Methods

Research data for the purposes of this paper were collected through electronic databases, Google Scholar, PubMed, and ResearchGate. The search for papers was carried out for the period from December 2011 to January 2022. When researching databases, the following keywords were used: caffeine, activity, training, HR, and blood pressure. The found research titles, abstracts, and full texts were then read and analyzed.

In order for the research to be accepted for the final analysis, it had to meet three basic criteria: the first criterion refers to the issue of the influence of caffeine on physiological parameters, the second to the influence of caffeine on motor performance (abilities), and the third criterion is the implementation of the analysis of papers in the selected period.

Research that met the set criteria was then analyzed and presented based on the following parameters: reference (author's first letter and year of publication of the research), sample of participants, applied treatment and research results.

Results

Based on keywords, 164 studies were identified. The number of studies that were immediately excluded based on the title, duplicate papers, as well as papers that were excluded based on the period when they were published is 81, while 83 studies were included in the further analysis.

Through further analysis of 83 studies, 31 studies were excluded based on several criteria: abstracts, because they were systematic review studies, as well as inadequate information needed for our research. The remaining five studies met the set criteria, which are studies published in the period from 2011 to 2021 and focused on the influence of caffeine on the cardiovascular system, six studies in the period from 2015 to 2022 give an account of the influence of caffeine

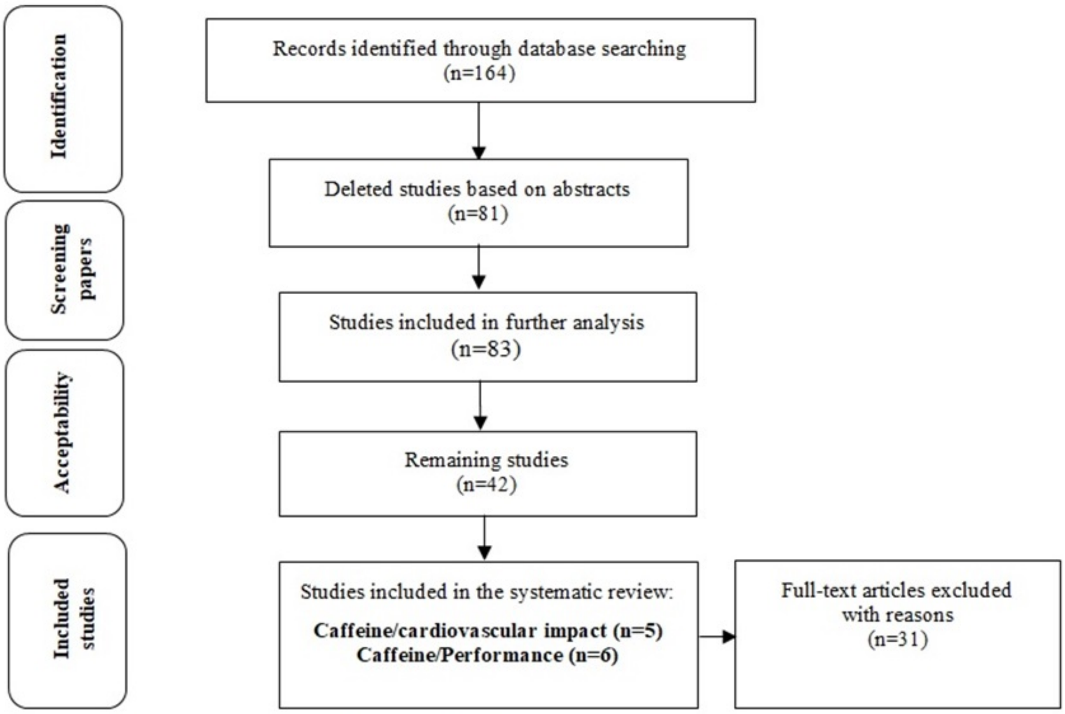

Figure 1. Flow chart diagram of the study selection.

on physical performance. The procedure of collection, analysis and elimination of found studies are shown in Figure 1.

Discussion

Effect of Caffeine on Cardiovascular Changes

Table 1 shows five studies. All research was of an experimental nature, i.e. they had a control and an experimental group. In three studies (Rezaimanesh et al., 2011; Norian et al., 2014; Sampiao-Jorge et al., 2021) the sample consisted of athletes, and in the remaining two studies recreational exercisers and students (Gonzaga et al., 2017; Malhas, 2018). The total number of participants included in the review was 136, of which 15 were female in the research (Malhas, 2018). Caffeine consumption most often ranged from 5-6mg/kg or in total from 300-498mg.

Analyzing all research in detail, it can be seen that in most research there was an increase in heart rate, systolic and diastolic pressure. If we analyze the study (Malhas, 2018) in more detail, we can see that the author believes that a higher caffeine intake of 400mg could cause side effects, while this is not the case in the study (Norian et al., 2014).

CAF intake is associated with a series of reversible and transient physiological effects in general, and cardiovascular effects in particular. This report attempts to understand where demarcations exist in caffeine intake and corresponding cardiovascular effects among different subpopulations. The available literature suggests that the cardiovascular effects experienced by caffeine consumers at levels up to 600mg/day are in most cases mild, transient, and reversible, with no lasting adverse effects. The point at which caffeine intake can cause damage to the cardiovascular system has not been partially identified, as data on the effects of daily intakes greater than 600mg are limited. However, the evidence reviewed in this review suggests that typical moderate caffeine intake is not associated with increased risks of overall cardiovascular disease; arrhythmia; heart failure; changes in blood pressure in regular coffee drinkers; or hypertension in baseline populations (Turnbull et al., 2017).

Energy drinks and other energy products have exploded in popularity in recent years; however, their use is not without risk. Caffeine is the main active ingredient in energy drinks, and excessive consumption can cause acute caffeine poisoning, resulting in tachycardia, vomiting, cardiac arrhythmias, seizures and death. The effects of chronic intake of high doses of caffeine in children and adolescents are unknown. Caffeine can raise blood pressure, disrupt adolescent sleep patterns, worsen psychiatric illness, cause physiological dependence, and increase the risk of subsequent dependence (Wolk et al., 2012). Caffeine is the most popular 'drug' in the world, and tea and coffee are a part of daily life. As a psychoactive stimulant, there is potential concern about adverse cardiovascular creaking. Cardiovascular conditions, including hypertension, coronary artery disease, arrhythmias, and heart failure, affect billions of patients worldwide. Tea and coffee intake, especially in moderate doses, does not appear to be harmful and may even be beneficial in a number of cardiovascular conditions, including coronary artery disease, heart failure, and arrhythmias (Voskoboinik et al., 2019). The main objective of this review was to collect, present and analyze the available information, including the latest findings on the effects of caffeine on human health and the functioning of human body systems. In short, we can conclude, however, that caffeine has a multidirectional effect on various organs of the human body, and due to its antioxidant properties, it was, and still is, an interesting topic for research, including those aimed at developing new therapeutic strategies (Rodak et al., 2021).

Although the effects of excess caffeine have been widely studied, little information is available on potential interactions between other active ingredients in energy drinks and caffeine. One of the active ingredients that often mentioned as a candidate for caffeine interaction is beta-amino acid, taurine. Although taurine is considered a conditionally essential nutrient for humans and is thought to play a key role in several human diseases, clinical studies evaluating the effects of taurine are limited. However, based on this review of possible interactions between caffeine and taurine, we conclude that taurine should counteract several of the side effects of excess caffeine. In accordance with this conclusion, in March 2003, the European Union's Scientific Committee for Food published a report summarizing their research on the potential interactions of energy drink ingredients. At the cardiovascular level, they concluded that "if there are any interactions between caffeine and taurine, taurine could reduce the cardiovascular effects of caffeine." Although these interactions have yet to be further investigated in humans, the physiological functions of taurine appear to be inconsistent with adverse cardiovascular symptoms associated with excessive consumption of caffeine-taurine-containing beverages (Schaffer et al., 2014).

Table 1
Effect of caffeine on the cardiovascular system.

References	Population	Grouping	Treatment	Protocol	Results
Rezaimanesh et al., 2011	2 EG+CG M, - yo	Athletes n=45	EG1+EG2 5 mg/kg	60 min. before the activity 180 min. before the activity Monarch bike + Alstead	HR↑ SIS+DIA pressure ↑ Glucose ↑
Norian et al., 2014	EG+CG M, 23.6 yo	Soccer players n=30	Caffeine 6 mg/kg Approximately 498 mg	60 min. before the activity Different forms of sprints	$V0_2max$ ↑ HR ↑
Gonzaga et al., 2017	EG+CG M, 23.5 yo	Recreational people n=32	Caffeine 300 mg	Treadmill/Bruce protocol Activity duration 30 min.	DIA pressure ↓ SpO2~ HR~
Malhas, 2018	EG+CG F, 25.5 yo	Students n=15	Caffeine 400 mg	Bicycle ergometer Activity duration 15/30/60/90/120 min.	Pressure~ HR~ More caffeine= Nus appearance +
Sampaio-Jorge et al., 2021	EG+CG M, 34.1 yo	Cyclists n=14	Caffeine 6mg/kg x 4 days 474 mg/1896 mg	Caffeine 60 min. before the activity Time trial 16km	Cardio effect ↑ Vagus tone ↑

M: Males; F: Females; n: Number of participants; EG: Experimental group; CG: Control group; ↑: Statistically significant increase p<0.05, p<0.01; ↓: Statistically significant decrease p<0.05, p<0.01; SIS: Systolic pressure; DIA: Diastolic pressure; HR: Heart rate.

Effect of Caffeine on Sports Performance

Table 2 shows six studies. All research was of an experimental nature, ie. they had a control and an experimental group. In three studies (Lara et al., 2015; Abian et al., 2015; Del Coso et al., 2016) the sample consisted of athletes, and in the remaining three studies recreational exercisers, athletes and swimmers (Prins et al., 2016; Peveler, 2017; Yuet al., 2022). The total number of participants included in the review was 112 and all persons are male. Caffeine consumption most often ranged from 3-6mg/kg or in total from 163-240mg.

Analyzing all researches in detail, it can be seen that in most researches there was an increase in performance in the form of jumpiness, speed as well as an increase in intensity during the activity.

Regarding sports performance, caffeine improves general and muscular endurance, increases the mobilization of fat from adipose tissue and muscle cells and increased the number of engaged muscle fibers were noted. Also, it reduces the perception of fatigue and increases motor activity. In small doses (1-2mg/kg) it improves attention, visual information, reaction time and alertness. However, these positive effects are caused by caffeine only if applied up to a certain dose. Beyond that limit, there is no improvement, and negative ones can also occur, i.e. harmful consequences. When evaluating the ergogenic effect of caffeine on athletes, it is very important to determine the right experimental design. Namely, large inter-individual differences in the effect of caffeine in athletes are even more pronounced, and the habit of drinking coffee causes tolerance to the effect of caffeine. Thereby, there are several mechanisms of action of caffeine, some of which have not been fully or not investigated at all. If we add to this that there are different physical, psychomotor and psychological demands in sports, the problem becomes more complicated. Because of the above, the examination of the ergogenic effect of caffeine on athletes must take into account all these factors.

Table 2
Effect of caffeine on the sport performance.

References	Population	Grouping	Treatment	Protocol	Results
Lara et al., 2015	EG+CG M, 20.2 yo	Swimmers n=14	Caffeine 3 mg/kg Approximately 221 mg	60 min. before the activity Activity duration 45 s.	Performance ↑ Side Effects -
Abian et al., 2015	EG+CG M, 25.4 yo	Badminton n=16	Caffeine 3 mg/kg Approximately 215 mg	60 min. before the activity Activity duration 45 min.	Performance ↑ Jumps + Movement +
Del Coso et al., 2016	EG+CG M, 23.2 yo	Hockey players n=13	Caffeine 3 mg/kg Approximately 228 mg	60 min. before the activity Activity duration 50 min.	Performance ↑ Sprint + Intensity + Speed +
Prins et al., 2016	EG+CG M, 20.4 yo	Athletes recreationists n=18	Caffeine Approximately 160 mg	60 min. before the activity Activity duration 20 min.	Performance ↑ Running 5km +
Peveler et al., 2017	EG+CG M, 22.9 yo	Swimmers recreationists n=15	Caffeine x 2 80 mg 163 mg	60 min. before the activity Activity duration 15 min.	Performance~ Blood pressure +
Yu et al., 2022	EG x 3+CG M, 24.7 yo	Recreational people random selection n=36	Caffeine x 2 240 mg 237 mg	60 min. before the activity Activity duration 5, 10, 15 min. and after activities	Performance ↑ Heart recovery ↓ HR ↑ Blood pressure~

M: Males; F: Females; n: Number of participants; EG: Experimental group; CG: Control group; ↑: Statistically significant increase p<0.05, p<0.01; ↓: Statistically significant decrease p<0.05, p<0.01; SIS: Systolic pressure; DIA: Diastolic pressure; HR: Heart rate.

Caffeine is known to have a negative effect on particularly fine motor skills by causing tremors (in sports such as archery), in ball control and passing accuracy in soccer (which are skills that also require fine motor skills) caffeine did not have a negative effect on performance, on the contrary. And for sports on which caffeine has an ergogenic effect, it is important to know the following. It is considered that the dependence of the achieved effects on the consumed dose of caffeine has the form of an inverted U-shaped curve; lower doses have positive effects on performance, while doses higher than 500 mg decrease performance. Participants in the studies subjectively assessed how they felt after consuming caffeine; lower doses were associated with positive feelings of a burst of energy, while higher doses were associated with anxiety and tension. As with many other food supplements and medicines, the following pattern is visible in this case; the ergogenic, positive effects of caffeine increase with the dose, until at some point the side effects do not overpower them (Foskett et al., 2009).

A large number of studies have proven the ergogenic effect of caffeine in activities of longer duration, and that is why Davis & Green (2009) direct their study towards activities of strength and power, that is, activities of shorter duration and very high intensity. They emphasize that the existing hypothesis about the action of the caffeine mechanism, where the increased oxidation of free fatty acids by adrenaline leads to the saving of glycogen, cannot be valid for anaerobic activities. The authors attach importance to a new hypothesis that explains the effect of caffeine on the central nervous system, that is, its antagonistic effect on adenosine receptors and the arousal and perception of effort and pain.

The mentioned problem of the mechanism of action of caffeine is nicely explained by the authors in their study (Grgic et al., 2018), where they indicate the perception of effort and the perception of pain as key mechanisms of the positive effect of caffeine on performance in training with external load. In addition to the above, they add that these are the conclusions of current research and indicate the importance of future studies.

Duncan & Oxford (2011) examined the effect of 5mg/kg caffeine versus placebo on the bench press exercise. Testing was performed with the condition of 60% 1RM with the aim of achieving the maximum number of repetitions, that is, until immediate muscle failure. In addition, they monitor the mood state reaction before and after the test. Subjects achieved a significantly higher number of repetitions in the caffeine condition compared to the placebo condition. Furthermore, in the caffeine condition, their mood was better while the level of fatigue rating was lower.

Grgic et al. (2018) meta-analysis determined that caffeine has significant ergogenic effects on muscle strength and power. The meta-analysis covered research that had as a method of measuring 1RM for the manifestation of maximum muscle strength and vertical jump for the manifestation of strength. The authors of the study conclude that caffeine has a significant impact on the strength of the muscles of the upper versus lower part of the body and a significant impact on strength, and that further research is needed to determine the optimal dose and form of caffeine intake due to its individuality and variability among research participants.

Conclusion

Caffeine can cause sleep disturbances, especially if it is consumed in quantities greater than 100 mg immediately before going to bed. It is believed that caffeine increases alertness and attention, improves performance and endurance during training if it is consumed in a dose higher than 75mg. Caffeine stimulates the central nervous system and small doses (1.5 - 3 mg/kg) improve sports performance, especially in endurance sports, such as running, swimming, cycling and the like. Side effects with a total consumption of ~200-250mg/kg are minimal or absent. Recommended consumption is 30-60 min. before the activity, so that the effects are complete. Caffeine is a permitted substance in sports, which makes it a very popular supplement around the world. People suffering from hypertension, cardiovascular patients and people whose families have recorded cases of acute myocardial infarction should be especially careful. A large number of studies have proven the acute effect of caffeine on performance in tests and improvement of physical performance, and a further step would be to investigate the effects of caffeine on long-term adaptations of certain physical abilities.

Authors' Contribution

Study Design: BB; Data Collection: NA; Manuscript Preparation: MZ; Funds Collection: RP, OR.

Ethical Approval
No ethical approval is required.

Funding
The authors declare that the study received no funding.

Conflict of Interest
The authors hereby declare that there was no conflict of interest in conducting this study.

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