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ORIGINAL ARTICLE

Acute effects of proprioceptive neuromuscular facilitation stretching, massage and combine protocols on flexibility, vertical jump and hand grip strength performance in kickboxers

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

Abstract

Background and Study Aim	Strength, power and flexibility are among the features that provide advantage against the opponent in kick boxers. There are many factors that can affect the development of these parameters in a positive and negative way before the competition. These factors may differ according to the type and intensity of warm-up and stretching exercises, depending on psychological and physiological conditions. The aim of this study is to evaluate the effects of proprioceptive neuromuscular facilitation (PNF) stretching, massage, PNF+massage on flexibility, vertical jump and hand grip strength performance in kickboxers.
Material and Methods	The sample group of the study consisted of 12 men (age: 18.50 ± 0.97 years, height: 161.60 ± 4.47 cm, body weight: 62.20 ± 9.07 kg, BMI: 23.77 ± 2.63), who did kick-box regularly for at least 3 years. This group performed 4 different stretching and warm up protocols on non-consecutive days. Warm up and stretching protocols were determined as follows: light jogging for only 5 minutes (NSM), PNF stretching (PNF), massage (M), PNF stretching+massage (PNF+M). After warm up and stretching protocols, participants completed vertical jump, flexibility and hand grip strength.
Results	There was a significant improvement on flexibility performance in order from low to high respectively NSM, PNF, PNF+M, M. Moreover, there was a significant difference between NSM and PNF, NSM and M, NSM and PNF+M in flexibility ($p<.05$). There was a significant difference between PNF and PNF+M, M and PNF+M in favour of PNF+M in vertical jump ($p<.05$). There was a significant decrease in right- and left-hand grip strength for all protocols.
Conclusions	As a result of the study, PNF and massage can be recommended to kickboxers before flexibility performance. However, PNF and massage are not recommended before activities that affect the lower extremity, such as strength and vertical jump.

Keywords: active warm up, combat sports, exercise, jogging, passive warm-up

Introduction

Kickbox, karate is a combat sport derived from thai box and west box and relies mainly on kick and punch for self-defense. A kick box match consists of 3 rounds and each round lasts 2 minutes. This sport requires not only speed, technical ability, but also high strength and endurance [1]. Also, maintaining optimal body mass is an important element of the training process and allows the competitor to choose the weight class in which he/she performs best. Kickbox is an individual sport that requires direct coach supervision and constantly follows a training process. Supervision of the coach allows the athlete to progress through training faster, which may result in a greater number of success. It is reported that a kickbox match works all muscle groups, requires coordination and activates both aerobic and anaerobic metabolism [2]. With a situation constantly changing during a competition, athletes may need to demonstrate a sharp level of proprioception, quick response time, both simple and complex, good hand-eye coordination, spatial orientation and responsiveness [3]. Preferred efforts during both match and training are based on maximum loads [4]. It is stated that the contribution of energy system to kick box is 70-80% anaerobic and 20-30% aerobic [5]. During a kickbox match, more than 50% of Adenosine Triphosphate (ATP) is provided by aerobic metabolism [6]. For this reason, it is very important for kickboxers to have a high level of aerobic and anaerobic capacity, to maintain high-intensity efforts and increase recovery between matches [7].

In particular, warm up, stretching and massage are traditional methods used to increase performance and reduce the risk of muscle injury through biomechanical, neural and physiological mechanisms [8, 9]. Warm-up exercises usually start with low-intensity aerobic jogging and increase in intensity over time. Athletes do proprioceptive neuromuscular facilitation (PNF) stretching exercises after running. PNF stretching exercises are

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divided into types within themselves. Contract relax antagonist contract (CGAC), one of the most widely used techniques, involves additional contraction of the agonist muscle during stretching before additional stretching of the target muscle. A number of individual studies show that PNF is more effective than static or dynamic stretching for improving range of motion (ROM) [10, 11]. Stretching exercises are performed by trainers and athletes in the belief that such exercises improve performance and can reduce the risks associated with injury. However, recent studies have shown that PNF stretching exercises before competitions and training do not affect vertical jump and explosive strength [12, 13]. It shows that it increases flexibility and hand grip strength [14, 15]. Knowing the different effects of PNF stretching exercises on sports performance has led sports scientists, coaches and athletes to find an alternative approach.

One of the alternative methods to PNF exercises is massage. Like PNF stretching, massage is one of the methods commonly used by athletes. It is reported that massage increases blood flow rate in the muscle, blood circulation in the skin, parasympathetic activity, relaxation hormone, tissue adhesion, muscle harmony, and joint range of motion. It has also been reported to reduce active and passive stiffness, pain, muscle tension and spasm, and neuromuscular excitability [16]. Massage is believed to relieve muscle tension, reduce muscle pain, improve flexibility and range of motion, increase muscle blood flow; and enhance clearance of substances such as blood lactate or creatine kinase [17]. A limited number of studies conducted to evaluate the effects of massage on sports performance have reported that it affects different parameters depending on the type, duration and frequency of massage used. When the literature is examined, different results have been reported on vertical jump [18, 19, 20], flexibility [21, 22] and hand grip strength [23]. A very limited number of studies in the literature indicate that there is not yet enough strong evidence to suggest the positive effects of physical massage on sports performance after massage. However, it is assumed that, alone or in combination with other warm-up exercises, massage has positive effects on sports performance: increased range of motion (active and passive), decreased muscle stiffness, increased blood flow, an increase in arterial pressure and muscle temperature [20].

Coaches and athletes may prefer PNF stretching exercises because of their preventive effects on injury-related micro-trauma, but research shows that there is no increase in performance if such exercises are performed before physical activities that require high energy output. However, they can see a positive effect in flexibility activities. Athletes tend to prefer more than one type of exercise before athletic performance. Although the effects of massage, PNF stretching or active warming exercises have been determined, the exact effect of massage performed immediately after PNF stretching has not yet been clarified. This study aims to evaluate the effect of PNF Stretching, Massage and PNF stretching followed by massage on flexibility, hand grip strength, vertical jump and anaerobic performance change.

Material and Methods

Participants

Twelve male volunteers, who regularly participated in kick-box training for at least 3 years and competed actively in international competitions, (mean age 18.50 ± 0.97 years, mean height: 161.60 ± 4.47 cm, mean body weight: 62.20 ± 9.07 kg, body mass index: 23.77 ± 2.63) participated in the study. Before starting the study, the volunteers were given detailed information about the content, purpose and methodological model of the study. Informed consent form was signed by the subjects who stated that they volunteered to participate in the study. Prior to the study, participants were asked to sleep for at least 8 hours before each testing session. In addition, they were asked to come full, provided that they ate at least two hours before the morning and evening sessions. All test and measurement applied in this study were approved by the Institute's Clinical Research Ethics Committee (Approval Number: 2021/2515).

Experimental Design of the Study

In the study, the anthropometric measurements of the participants were determined. Measurements were made in the Sports Hall of the Faculty of Sports Sciences. All volunteers who agreed to participate in the study were informed in detail about the content of the study before the test. Before the application started, the participants were given necessary information about the content, place and time of the study. Research consist of PNF stretching (30-40% heart rate (HR), 4 min jogging + 8 min seven contract relax antagonist contract (CRAC), massage (30-40% HR, 4 min running + 8 min lower extremity massage) and PNF stretching + massage (30-40% HR, 4 minutes running+4 minutes CRAC PNF stretching+4 minutes lower extremity massage) and NSM (only 30-40% HR, 12 minutes running) protocols. After each protocol vertical jump, hand grip strength and flexibility tests were performed (morning: 09:00-11:00), with at least 2 days between test sessions. This study continued approximately 12 days. All protocols continued consecutive days. In addition, the reason why these time periods of the day were chosen for the research is related to the fact that kickbox competitions started in the morning hours.

Stretching and Warm-up Protocols

NSM: The warm up rate was determined according to the 30-40% heart rate of each subject [24]. Subjects were light jogging for only 12 minutes under the control of the experts. In this way, both warm up intensity and warm up differences between participants in the training were eliminated. After 12 minutes light jogging, subjects' vertical jump, hand grip strength and flexibility tests were performed.

PNF: This protocol consisted on 4 min jogging + 8 min seven contract relax antagonist contract (CRAC). Stretching exercises as advanced seated hip adductor stretch, intermediate lying knee extensor stretch, hip external rotator and back extensor stretch, beginner seated hip external rotator stretch, advanced standing lower-trunk lateral flexor stretch, intermediate wrist flexor stretch, Shoulder and Elbow Flexor Stretch determined [25]. Stretching exercises were aimed at primary muscles in terms of affecting vertical jump, flexibility and hand grip strength (Table 1). Each stretch consisted of 5 seconds of passive initial stretching to a mild stretch or restriction point followed by 5 seconds of isometric contraction of the target muscle. The subject was then instructed to contract the opposite muscle group for an additional 5 seconds using a concentric contraction providing a new starting point. After 5 seconds, the procedure was repeated and 20 seconds was determined as the total duration of CRAC exercise in a single region. A certified athletic trainer was used as an assistant during total stretching exercise time in the study and data was recorded during CRAC PNF protocol. A pre-recorded tape is included to ensure consistency of CRAC PNF protocol. When the lead investigator was ready for the first stretching exercise, the assistant pressed the play button to start the shooting. This provided commands for the lead investigator that allowed for consistency of the duration of contraction and active movement during CRAC PNF and the time it took to switch to another muscle group.

M: This protocol consisted on 4 min running + 8 min lower extremity massage. In the traditional (Swedish) 8-minute massage of the lower extremities of kickboxers, the musculature massaged was the same muscles that were stretched with the CRAC PNF stretching exercises in the previous protocol. Massage techniques included effusion, friction, petrissage, percussion, and vibration.

PNF+M: This protocol consisted on 4 minutes running+4 minutes CRAC PNF stretching+4 minutes lower extremity massage.

Countermovement Jumps (CMJs)

Volunteer kickboxers were asked to perform three counter movement jumps (CMJs) on a strength platform (Newtest 2000, Oulu, Finland) with 1 minute rest in between. The starting and ending positions were made upright, standing at hip width, hands on hips. Movement of the hands was not allowed during the entire measurement so as not to affect the jump height. Upon command, the participant lowered their center of mass by bending their knees to a degree of their own choosing, and immediately jumped vertically as high as possible after reaching the lowest position [26, 27]. The highest jump height was used for the analysis. Anaerobic power (peak and average) of kickboxers was calculated using the Johnson & Bahamonde Formula [28], which allowed calculation of jump distance, body weight and height data.

Flexibility Test

The volunteer who performed the sit-reach test stood on the test bench with their ankles straight in 90-degree flexion, sitting on the floor with bare feet, and leaning forward with his body without bending the knees, they reached the farthest point on the table with their hands and remained there. After one trial, the volunteer's best score of three trials was recorded [29].

Hand grip strength (HGS)

During measurement, the participant stood upright, his arm was free at the side, and hand dynamometer was perpendicular to the ground and asked to be squeezed downwards. The volunteer squeezed the tool with all his might and the number on the screen was kg. recorded in type [30]. Hand grip strength values were measured three times, right and left, with the "TAKEI GRIP-D" brand hand dynamometer for the reliability of the test [31].

Statistical Analyses

Data analysis was performed by the SPSS software version 26.0 (SPSS, (SPSS, Inc., Chicago, IL, USA) program. Data were expressed as mean ± standard deviation (SD) in bar graphs. Repeated measures anova was used to analyze the differences of flexibility, vertical jump and hand grip strength according to four exercise protocols (NSM, PNF, M, PNF+M). Variances were found to be homogeneous for all protocols. Significance level was interpreted according to $p<.05$, $p<0.1$ and $p<.001$.

Results

In Figure 1, there was a significant increase in flexibility for NSM, PNF, M, PNF+M [$F_{(1.27)=}$ 8.92 $p=.000$, partial eta squared: .448]. Moreover, there was a significant difference between NSM and PNF, NSM and M, NSM and PNF+M (p<.05).

In Figure 2, there was a significant increase in vertical jump for NSM, PNF, M, PNF+M [$F_{(1.15)=}$ 7.883 $p=.013$, partial eta squared: .417]. Moreover, there was a significant difference between PNF and PNF+M, M and PNF+M in favour of PNF+M (p<.05).

In Figure 3, there was a significant decrease in right hand grip strength for NSM, PNF, M, PNF+M [$F_{(2,093)=}$6,743 $p=.005$, partial eta squared: .380]. Moreover, there was a significant difference between

Table 1. PNF stretching exercises and the major muscles used

PNF stretching exercises	The major muscles used
Shoulder and Elbow Flexor Stretch	Pectoralis major, pectoralis minor, anterior deltoid, coracobrachialis, biceps brachii, brachialis, brachioradialis
Hip external rotator and back extensor stretch	Gluteus maximus, gluteus medius, gluteus minimums, piriformis, gemellus superior, gemellus inferior, obturator externus, obturator internus, quadratus femoris, lower latissimus dorsi, erector spinae
Advanced seated hip adductor stretch	Gracilis, adductor magnus, adductor longus, adductor brevis, pectineus, middle sartorius, lower erector spinae, lower latissimus dorsi
Intermediate lying knee extensor stretch	Right vastus intermedius, right rectus femoris, right psoas major, middle and upper right sartorius
Beginner seated hip external rotator stretch	Gluteus maximus, gluteus medius, gluteus minimums, piriformis, gemellus superior, gemellus inferior, obturator externus, obturator internus, quadratus femoris
Advanced standing lower-trunk lateral flexor stretch	Rectus abdominis, left external oblique, left internal oblique
Intermediate wrist flexor stretches	Brachioradialis, flexor carpi radialis, flexor carpi ulnaris, flexor digitorum profundus, flexor digitorum superficialis, palmaris longus

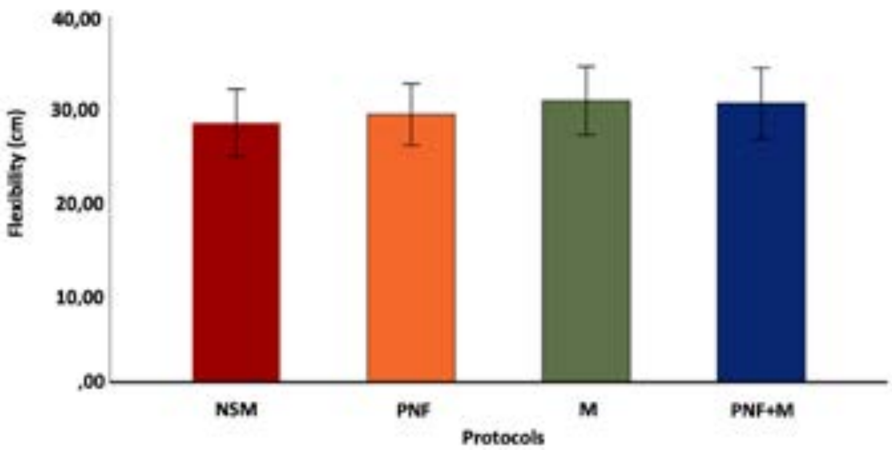

Figure 1. Flexibility performance of four warm up and stretching protocols

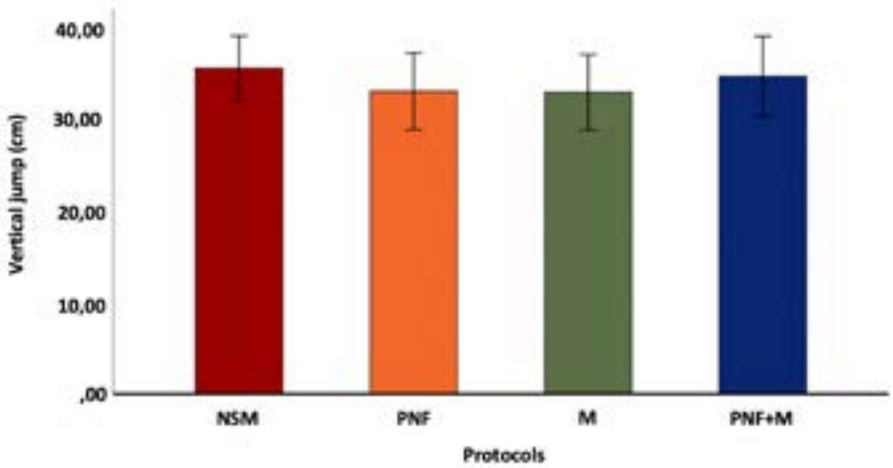

Figure 2. Vertical jump performance of four warm up and stretching protocols

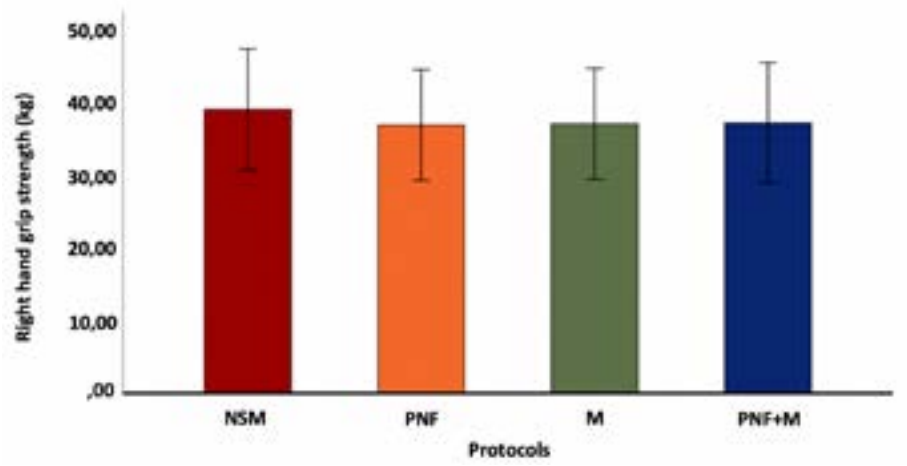

Figure 3. Right hand grip strength performance of four warm up and stretching protocols

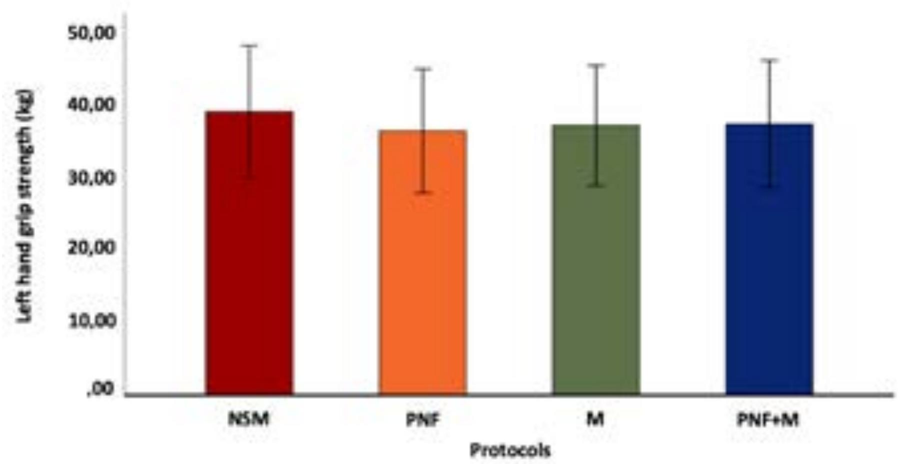

Figure 4. Left hand grip strength performance of four warm up and stretching protocols

NSM and PNF, NSM and M, NSM and PNF+M (p<.05).

In Figure 4, there was a significant decrease in left hand grip strength for NSM, PNF, M, PNF+M [$F_{(2,176)=}$3,497 *p*=.043, partial eta squared: .241]. Moreover, there was a significant difference between NSM and PNF (p<.05).

Discussion

For many years, athletes do warm-up and stretching exercises before physical activity or competition. The purpose of warm-up and stretching is to improve physiological, biomechanical and psychological performance of the athlete by increasing their body temperature and range of motion. However, coaches and athletes haven't yet determined which is the most appropriate warm-up or stretching protocol to increase performance improvement in sports such as kickboxing. Coaches and athletes often perform stretching exercises after general warm-up exercise. Studies examining the effects of stretching and massage sessions after general warm-up may add originality to the literature for kickboxers. The aim of our study was to evaluate the effects of different stretching and massage protocols on vertical jump, flexibility and hand grip strength in kickboxers. From our hypotheses, it was confirmed that PNF+M, M and PNF can reduce vertical jump performance. The hypothesis that stretching and massage protocols might produce different results versus flexibility was also confirmed.

To the best of the authors' knowledge, this is the first study with repeated measurements comparing the acute effects of NSM, PNF, M, and PNF+M protocols on performance in vertical jumps, sit and reach, and hand grip performance in kickboxers. The main results were the performance reductions in vertical jump tests after PNF+M and PNF, PNF+M and M protocols. In addition, decreases in right hand grip strength were found after NSM and PNF, NSM and M, NSM and PNF+M. The differences in flexibility between NSM and PNF, NSM and M, NSM and PNF+M. Furthermore, decreases in left hand grip strength were found after NSM and PNF protocols.

The results of the present study are partially consistent with previous studies that examined the use of massage in pre-event warm-up. For example, Arabaci [21] showed a significant worsening in the vertical jump (VJ) and significant improvement in sit and reach test (SR) test. The results of stretching intervention were similar to those of the massage intervention. Hunter at al. [32] found a decline in mean force from pre to post-intervention for the massage condition. McKechnie et al. [33] found no significant change in the power measures following massage. Yildiz et al. [20] found that static stretching (SS) and combined static stretching and massage (SSM) protocols demonstrated 12% and 16% respectively greater flexibility than the control protocol. Countermovement jump (CMJ) and squat jump (SJ) performances were significantly decreased 10.4% and 5.5% respectively after the SS protocol. McKechine et al. [33] suggested that pre-event massage can increase the plantar flexors' flexibility. However, Barlow et al. [34] suggested that a single massage of the hamstring muscle group was not associated with any significant increase in sit and reach performance immediately after treatment in physically active young men. Capobianco et al. [22] found that self-massage prior to stretching improves flexibility in young and middle-aged adults. Koumantakis [35] indicate that muscle flexibility was positively influenced immediately after a single intervention of instrument assisted soft tissue mobilization (IASTM), vibration massage or light hand massage. There are some reasons why flexibility performance can increase after massage and decrease or no change vertical jump and hand grip strength performance. Massage can produce mechanical pressure, which is expected to increase muscle compliance resulting in increased range of joint motion, decreased passive stiffness and decreased active stiffness (biomechanical mechanisms). Mechanical pressure might help to increase blood flow by increasing the arteriolar pressure, as well as increasing muscle temperature from rubbing. Depending on the massage technique, mechanical pressure on the muscle is expected to increase or decrease neural excitability as measured by the Hoffman reflex (neurological mechanisms) [16].

Bradley et al. [36] claimed that PNF or static stretching should not be performed immediately prior to an explosive athletic movement. Moreover, there are lots of studies showed that PNF didn't have a significant effect on vertical jumping [37, 12]. This may be due to the muscles being stretched too far outside of their capacity, causing inhibition following the stretching [11]. PNF stretching should reduce muscle activation and possible inhibition of autogenic and reciprocal inhibition through some degree of reflexive disfacilitation with reduced muscle spindle receptor activity of the nuclear bag and nuclear chain [38]. Increased tolerance to stretch, decreased viscoelasticity, and to some extent decreased muscle-tendinous stiffness due to PNF exercises may contribute to the sustained increase in elastic ROM [39, 40].

Conclusions

As a limitation, this study did not include measurement instruments that could directly identify the neurophysiological mechanisms mentioned as being responsible for the reduction in physical performance after the different stretching methods and male kickboxers joined this study. Therefore, future studies should include evaluations that enable comparisons of the influence of mechanical and neural factors, or their association, on performance after PNF, M and PNF+M protocols.

Based on the results found in this study, PNF, M and PNF+M protocols do not promote positive effects on vertical jump and hand grip strength performance. However, PNF, M and PNF+M protocols should be viewed with caution, especially because of the higher intensities reached in these methods and the extensive possibility of negative effects on performance in activities involving vertical jumps. Thus, physical trainers in kickbox can include PNF, M and PNF+M protocol sessions similar to those in this study in their warm-up routines during training sessions, allowing kickboxers to increase their levels of flexibility without further negative effects on performance in vertical jump activities.

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Conflict of interest

The authors report no conflict of interest.

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ORIGINAL ARTICLE

The effect of 8-week plyometric training on jump height, agility, speed and asymmetry

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

Abstract

Background and Study Aim Plyometric training is one of the most preferred methods for athletic performance improvement. This study was designed to measure the effect of 8 weeks of additional plyometric training on jump performance, lower extremity asymmetry, speed, and agility performances of adolescent fencers.

Material and Methods This study was carried out with 26 fencers who participated in national competitions. The fencers were randomly divided into plyometric training (PLY, n = 14) and the control (n = 12) group. The PLY group did plyometric training 3 days per week for 8 weeks in addition to their fencing training. The control group only continued their fencing training. All participants performed countermovement jumps (CMJ), pro-agility, 0-5-m, 5-15–m, 0-15-m sprints, and asymmetry tests before and after 8 weeks.

Results Statistically significant differences were found in CMJ, (p = 0.001), pro-agility (p = 0.001), and 0-5-m (p = 0.036), 5-15-m (p = 0.018), and 0-15-m (p = 0.001) sprint results in the PLY group. However, asymmetry contact time and asymmetry flight time values did not show statistical differences. In addition, group x time interactions of CMJ (p < 0.001), pro-agility (p = 0.001), and 0-5-m (p = 0.015) and 5-15-m (p = 0.009) sprint tests were also found statistically significant.

Conclusions Thus, it can be said that plyometric training contributes positively to the jumping, agility, and speed of fencers. Adolescent fencers and their trainers may be advised to focus on additional plyometric training programs. However, individual differences and training experience should also be taken into account in the determination of plyometric programs.

Keywords: plyometric, vertical jump, change of direction, fencing.

Introduction

Fencing includes anaerobic power, agility, and speed, and a fencing bout is shaped by interactions with the opponent. In this branch, where the capacity of the lower extremities is crucial [1], there may be power differences between the extremities due to the application of technical movements.

Plyometric training has an important place in branches where lower extremity development is critical [2]. The positive effect of plyometric training, which includes quick movements, is related to the system called the stretch-shortening cycle [3]. This training method, which is indispensable for many branches, can be used for many different age groups with appropriate methods. In a study conducted on male athletes aged 13-14 years, it was reported that 8 weeks of plyometric training had a positive effect on speed and explosive strength properties [4]. In another study, basketball players with an average age of 20.1 years performed plyometric training for 6 weeks in addition to their training. At the end of this implementation, it was stated that there was an improvement in strength and agility compared with those who did not do additional plyometric training [5]. Although the performance benefits of plyometric training are frequently shown in the literature [6, 7], more studies are needed to understand the effects of different training methods on athletes of certain age groups and branches. In addition, when using this training method, it should be remembered that the inability to set exercise levels correctly can lead to injuries, so the selection of the exercises according to age and performance level is important.

Although there is not much movement in fencing that is directly applied by jumping, improving the jump will contribute to the fencer's performance [8]. As in many other branches [9, 10], studies are investigating jumping performance in fencing [11]. Investigating asymmetry is also a frequently encountered situation in terms of athletic performance. However, it is considered normal to develop a certain amount of asymmetry in branches where one-way movements are dominant, such as fencing [12]. However, it is important to control the degree of asymmetry and to provide support with appropriate training methods to maintain performance and prevent injuries.

In fencing, where quick responses are made

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as a result of one-to-one interaction in the game, speed and agility are also features that should be emphasized. The practicality of measurement methods and portable devices continue to make the evaluation of these parameters popular in sports sciences. It should not be forgotten that many features such as speed and agility, are intertwined with each other [13]. The current study aimed to examine the effects of plyometric training applied to fencers for 8 weeks on jumping performance, lower extremity asymmetry, speed, and agility.

Material and Methods

A randomized method was used in this study to investigate the effects of plyometric training on vertical jump, agility, speed, and jump asymmetries. The fencers were randomly divided into two different groups as the plyometric training group (PLY, n = 14) and the control group (n = 12). The control group did not do any additional training while continuing their fencing training, but the PLY group performed an additional plyometric training program along with their fencing training. Plyometric training was performed 3 days per week/ 8 weeks. An adjustment session was applied to the PLY group before the measurements. The training program is presented in the Table 1.

Participants

In this study, 26 athletes who trained regularly and participated in national competitions voluntarily took part. The descriptive characteristics of the participants are presented in Table 2. Necessary legal permission was obtained from the Local Research Ethics Committee (Decision Number: 2021/10-39). In addition, fencers and legal representatives of them were informed about the protocol, and each signed approved informed consent forms.

Procedures

Athlete's heights were measured with a metal tape measure. Body weights and body fat ratios were determined by body composition analysis scale (Tanita BC 730, Japan). The participants were given a 10-minute warm-up. After that, CMJ for vertical jump, pro-agility, 0-15-m sprint, and jump asymmetry tests were performed, respectively.

Countermovement Jump: Two repetitions were performed with the hands free on the mat (Smart Speed Pro-Fusion Sport, Australia). There were 45 seconds of rest between repetitions. The highest value was used for analysis.

Pro-agility Test: An electronic photocell system (Smart Speed Pro-Fusion Sport, Australia) was used for the test. Each participant performed the test twice and the best duration was used.

0-15–m sprint: The times of the participants at 5 m and 15 m were recorded. Smart Speed Pro-Fusion Sport (Australia) was used for measuring (Figure 1).

Figure 1. 0-15-m sprint test design

Asymmetry test: In the jump test measured using My Jump 2 (IOS app), the participants' right and left foot depth jumps (40-cm bench height) were recorded. Thanks to the high-speed video recording feature, the first moment of contact with the ground, the first moment of the flight phase, and the first moments of contact with the ground were marked, and the level of asymmetry between the contact and flight times of the two feet was calculated as a percentage.

Statistical Analyses

The pre and post-test values of the data were evaluated in order using boxplots, the Shapiro-Wilk normality test, homogeneity of Levene variances, box's M tests, and covariances. Two-way mixed pattern analysis of variance was used for the main effects and interactions of the plyometric training. The effect sizes were evaluated as partial Eta-squared and converted to Cohen's d. Descriptive statistics were showed as mean ± standard deviation and statistical significance was determined as <0.05. Lastly, for analyses, the IBM SPSS Statistics Ver. 20 program (Armonk, NY: IBM Corp., 2011) was used.

Results

The demographic data of the participants are presented in Table 2.

After 8 weeks of training, the performance improvement of the PLY group in 0-5-m sprints (-0.128 ± 0.04 sec, p = 0.04) were statistically significantly different compared with the control group. As a result of the training, the increase in the CMJ results of the PLY group was not statistically significant compared with the control group (0.687 ± 3.04 cm, p = 0.823). Likewise, there were no significant differences in the pro-agility test (-0.120 ± 0.15 sec, p = 0.437), 5-15-m sprint (-0.037 ± 0.06 sec, p = 0.577), 0-15-m sprint (-0.148 ± 0.10 sec, p = 0.164), asymmetry contact time (3.482 ± 3.00%, p = 0.258), and asymmetry flight time values (3.285 ± 3.72%, p = 0.387).

CMJ test results showed a statistical difference in the PLY group [F(1,13) = 28.915, p = 0.001, ηp2 = 0.690)] before and after 8 weeks of training, but in the control group [F(1,11) = 2.736, p = 0.126), ηp2 = 0.199)], no statistically significant difference was observed.

Table 1. Training programme

Week	Bounce	Plyometrics	Set x Reps	Workload
1st	90	Side to side ankle hops	2 X 15	Low
		Standing jump and reach	2 X 15	Low
		Front cone hops	5 X 6	Low
2nd	120	Side to side ankle hops	2 X 15	Low
		Standing long jump	5 X 6	Low
		Lateral jump over a barrier	2 X 15	Moderate
		Double leg hops	5 X 6	Moderate
3rd	120	Side to side ankle hops	2 x 12	Low
		Standing long jump	4 x 6	Low
		Lateral jump over a barrier	2 X 12	Moderate
		Double leg hops	3 X 8	Moderate
		Lateral cone hops	2 X 12	Moderate
4th	120	Side to side ankle hops	2 x 12	Low
		Standing long jump	4 x 6	Low
		Lateral jump over a barrier	2 X 12	Moderate
		Double-leg hops	3 X 8	Moderate
		Lateral cone hops	2 X 12	Moderate
5th	140	Diagonal cone hops	4 X 8	Low
		Standing long jump with lateral sprint	4 X 8	Moderate
		Lateral cone hops	2 X 12	Moderate
		Single-leg bounding	4 X 7	High
		Lateral jump, single leg	4 X 6	High
6th	140	Diagonal cone hops	2 X 7	Low
		Standing long jump with lateral sprint	4 X 7	Moderate
		Lateral cone hops	4 X 7	Moderate
		Cone hops with 180-degree turn	4 X 7	Moderate
		Single-leg bounding	4 X 7	High
		Lateral jump, single leg	2 X 7	High
7th	140	Diagonal cone hops	2 X 7	Low
		Standing long jump with lateral sprint	4 X 7	Moderate
		Lateral cone hops	4 X 7	Moderate
		Cone hops with 180-degree turn	4 X 7	Moderate
		Single-leg bounding	4 X 7	High
		Lateral jump, single leg	2 X 7	High
8th	120	Diagonal cone hops	2 X 12	Low
		Hexagon drill	2 X 12	Low
		Cone hops with a change of direction sprint	4 X 6	Moderate
		Double-leg hops	3 X 8	Moderate
		Lateral jump, single leg	4 X 6	High

Table 2. Anthropometric characteristics of the participants

Variables	Plyometric Group	Control Group
	Mean±SD	Mean±SD
Age (year)	15.16 ± 0.74	15.22 ± 0.86
Height (cm)	166 ± 0.08	172 ± 0.08
Weight (kg)	61.82 ± 15.33	63.30 ± 11.36
BMI	22.18 ± 4.77	21.22 ± 3.02
BFR %	22.45 ± 8.63	18.43 ± 6.85

BMI: Body mass index, BFR: Body fat ratio

The duration of the pro-agility test did not differ significantly between the pre-test and post-test values in the control group [F(1,11) = 1.523, p = 0.243, ηp2 = 0.122)], but a statistically significant difference was found in the PLY group [F(1,13) = 27.291 p = 0.001, ηp2 = 0.677)].

A significant difference was observed between pre-test and post-test values in 0-5-m [F(1,13) = 5.500 p = 0.036, ηp2 = 0.297)], 5-15 m [F(1,13) = 7.255, p = 0.018, ηp2 = 0.358)] and 0-15-m [F(1,13) = 22.837. p = 0.001, ηp2 = 0.637)] sprint performance in the PLY group. No difference was observed between the pre-test and post-test values in the 0-5-m [F(1,11) = 1.993, p = 0.186, ηp2 = 0.153)], 5-15-m [F(1,11) = 3.975, p = 0.072, ηp2 = 0.265)] and 0-15-m [F(1,11) =0.029, p = 0.868, ηp2 = 0.003)] sprint performance in the control group.

Asymmetry contact time pre-test and post-test values in the PLY group [F(1,13) = 0.018 p = 0.894, ηp2 = 0.001)] and the control group [F(1,11) = 2.401, p = 0.150, ηp2 = 0.179)], did not show statistical differences. Similarly, there were no significant differences in asymmetry flight time values in the PLY [F(1,13) = 1.063 p = 0.321, ηp2 = 0.076)] and control groups [F(1,11) = 2.373, p = 0.152, ηp2 = 0.177)].

Group, time and group x time interactions as Anova outcomes are presented in Table 3.

Discussion

The effect of 8-week plyometric training on the performance parameters of fencers was investigated in the current study. The important findings of the current study were that the CMJ, pro-agility, and sprint results at different intervals of the participants who performed the plyometric program in addition to their regular training showed better results and these differences were not observed in the other group. In addition, the increase in the 0-5-m sprint after the plyometric program was different compared with the control group.

It has been shown in the literature that plyometric training has positive effects on athletic performance in young athletes age group [14]. It is important to perform the movements with the correct technique to see the expected effect from plyometric training. If the correct technique can be performed, the benefits of training can be seen regardless of the level of the athletes [15]. Although the athletes in this study were not adults, they all had similar fitness levels and had been training for many years. The improvements seen as a result of the study may show that the training is suitable for athletes at this level and that technique is not impaired while performing the movements.

Considering the improvement in CMJ

Table 3. Mean and SD of the outcome measures for each group before (pre) and after (post) the intervention period.

Parameters	**PLY (n = 14)**		**CN (n = 12)**		**ANOVA outcomes**		
					Group	**Time**	**Group X Time**
	Pre	Post	Pre	Post	F (1,24), p (d)	F (1,24), p (d)	F (1,24), p (d)
CMJ	35.94±7.08	38.03±7.10	37.57±8.64	37.34±8.43	F=0.024, 0.878 (0.001)	F=18.028, **<0.001**** (0.429)	F=27.761, **<0.001**** (0.536)
Pro-agility (sec)	5.82±0.24	5.51±0.34	5.61±0.43	5.63±0.43	F=0.109, 0.744 (0.005)	F=20.015, **<0.001**** (0.455)	F=24.897, **0.001*** (0.509)
0-5-m (sec)	1.19±0.09	1.14±0.08	1.25±0.10	1.27±0.12	F=6.571, **0.017*** (0.215)	F=1.482 0.235 (0.058)	F=6.897, **0.015*** (0.223)
5-15-m (sec)	1.68±0.11	1.62±0.14	1.64±0.19	1.65±0.19	F= .000 0.984 (0.001)	F = 4.276, **0.050*** (0.151)	F =7.994, **0.009*** (0.250)
0-15-m (sec)	2.87±0.19	2.76±0.21	2.89±0.28	2.90±0.31	F=0.879, 0.358 (0.035)	F = 2.500, 0.127 (.094)	F= 3.687, 0.067 (0.133)
Asymmetry contact time (%)	11.13±8.02	10.72±6.98	9.77±8.37	7.23±8.33	F=0.916, 0.348 (0.037)	F= 0.661, 0.424 (0.027)	F=0.342, 0.564 (0.014)
Asymmetry flight time (%)	7.27±4.67	10.93±10.07	8.40±8.53	7.65±8.73	F=0.174, 0.680 0.007	F=0.565, 0.459 (0.023)	F=1.296, 0.266 (0.051)

*P<0.05, P<0.01, PLY: plyometric training group; CN: control group; sec: second; ANOVA: analysis of variance; d: by converted partial eta squared to Cohen's d.

performance, it should be emphasized that Ntai, Tsolakis [16] stated that CMJ was an important parameter that reflected the step-lunging exercise, which is a necessary technique for fencing. Based on this finding, it can be said that participants whose CMJ performance improved as a result of additional plyometric training in this study achieved improvements that could directly contribute to fencing performance. It is also important to see improvement in pro-agility results since fencing athletes frequently change their direction when the execute special training and also in championships [17]. In addition, it is known that the results of the pro-agility test may be related to features such as jumping and sprinting [18]. Thus, it can be concluded that the 8-week program performed on the athletes in the study provided a versatile contribution to their athletic performance. When evaluated specifically for the sprint, the improvement seen in every sprint distance can be an indication that it contributes to both acceleration and the speed in the total distance run.

In this study, no significant difference was found between the percentages of asymmetry contact time and asymmetry flight time in both groups after 8 weeks. It is expected that some asymmetry will occur in a branch where the same leg is always in front and the same arm is holding a weapon. The percentages of asymmetry in this study are also within the normal range [19]. The lack of a significant change in the rates with the effect of plyometric training may be because all participants continued their daily fencing training, which included asymmetrical technical movements.

Finally, there was a significant difference in the group x time interaction of the CMJ, pro-agility, and 0-5–m and 5-15–m sprint tests. In another study investigating the effect of 8-week balance and plyometric training on performance, group time interactions were significant for drop jump and change of direction tests, but not for CMJ or sprint tests [20]. Parameters such as the branches of the participants, their sports backgrounds, their anthropometric characteristics, the content of the training performed, and whether the participants performed it correctly may cause different results. To interpret the reasons for the differences between studies from a physiologic point of view, measurements such as muscle cross-section area or motor unit activation should also be performed [21].

Conclusions

It was seen that additional plyometric training performed 3 days per week for 8 weeks improved jumping, agility, and speed parameters in adolescent fencers. Regular plyometric training will contribute to performance in branches such as fencing, where lower extremity strength is so important. For this reason, it can be recommended for coaches to perform plyometric training while the athletes are in the adolescence period. However, points such as individual differences and sports experience should be carefully evaluated and appropriate programs should be selected for athletes.

Conflicts of Interest

The authors declare no conflicts of interest.

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ORIGINAL ARTICLE

The influence of health-improving fitness classes on the degree of fat deposition in women of the second mature age

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Contribution of authors: A - Research design; B - Data collection; C - Statistical analysis; D - Preparation of the manuscript; E-Funds Collection.

Abstract

Background and Study Aim Purpose of the research: analysis of the influence of health-improving fitness classes of various orientations on the degree of fat deposition in women of the second mature age.

Material and Methods Participants: group 1 – 40 women, (43.33 ± 0.93) years, group 2 – 25 women, (44.40 ± 0.93) years. The participants trained for 8 months, three times a week for 1 hour. Group 1 – classes in dance aerobics (Monday), strength fitness (Wednesday) and stretching (Friday). Group 2 – stretching only. Before the start and after the end of the program, the body weight and length were determined, the degree of fat deposition using a calipermeter at 17 points, the body mass index was calculated.

Results In group 1, there was a significant decrease in body weight, BMI, a decrease in the thickness of skin and fat folds at all points. In group 2, a significant decrease in body weight, BMI, a decrease in the thickness of folds at 13 points in 60-96% of participants was established. At the end of the study, group 1 had a smaller size of the folds of the thighs and left forearm compared to group 2. Regular exercise leads to a decrease in body weight BMI, a decrease in body fat. Complex classes have a more pronounced effect compared to stretching. This type of training is more effective in terms of the dynamics of the criteria used and the number of participants with the established changes. The sessions provided an increase in the number of persons with a normal BMI and a decrease in the number of obese participants.

Conclusions The applied indicators and methods can be recommended for use in health monitoring in health fitness.

Keywords: fitness program, stretching, fat deposition, caliperometry.

Introduction

Wellness fitness is an effective means of optimizing your health. Regular exercises allow to improve well-being, increase the level of basic physical qualities, positively influence the composition of the human body, and optimize the quality of life. Currently, physical activity is considered as a preventive measure against many chronic diseases [1]. A special program "Men on the Move" was developed for Irish men with physical inactivity. The program consisted of classes twice a week for 12 weeks. Confirmed a pronounced positive effect on aerobic capacity, body weight and waist circumference.

Regular exercise can prevent and correct hypertension [2]. A taekwondo training program was used for health-improving purposes. Participants worked for 90 minutes, three times a week, for 12 weeks. Improvement in body composition and physical fitness was confirmed in elderly women with hypertension compared with the control group.

Physical activity can slow down the aging process in the elderly [3]. An exercise program for four months has been shown to improve metabolic processes in elderly women.

Regular exercise counteracts motor regression and adverse changes in body composition in older adults. An 8-month training program was developed for people over 40 years old [4]. The program was based on individually selected loads with a gradual increase in the volume and intensity of classes. A decrease in body weight, a decrease in adipose tissue, an improvement in physical fitness and flexibility have been established.

The effect of exercise on body composition and cardiorespiratory capacity in obese South African women was studied in another study [5]. The participants practiced for 12 weeks 4 times a week for 40-60 minutes. A decrease in the mass of subcutaneous adipose tissue, an increase in the rate of fat oxidation, and an increase in functional capabilities were confirmed.

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Wellness fitness is inextricably linked to monitoring the health of the population. This requires the development of new original criteria for analysis and forecast. It was proposed to use the analysis of body fat as an indicator of cardiometabolic risk [6]. The presence of links between the level of fat deposits on the neck and body weight, body mass index, muscle mass, adipose and visceral adipose tissue was confirmed.

The relationship between adaptive capacity and the distribution of abdominal fat in overweight adults has been studied [7]. The indicators of the cardiorespiratory system were assessed according to the results of stress tests. An inverse relationship of these indicators with the content of visceral and subcutaneous fat has been established.

Another study [8] examined the relationship between epicardial adipose tissue volume and cardiorespiratory fitness in Japanese people of different ages and both sexes. Epicardial adipose tissue volume was significantly negatively associated with peak cardiac output and peak oxygen consumption. A strong negative correlation was found between adipose tissue and peak heart rate. Correction of adipose tissue significantly improves hemodynamics and functionality of the cardiorespiratory system.

The influence of aerobic exercise of medium and high intensity on the endocrine profile and the amount of adipose tissue in young healthy men with different phenotypic characteristics has been confirmed [9]. Lipolysis rate, hormonal and metabolic responses to aerobic exercise depend on the phenotype of the individual. The type, duration and intensity of exercise must be strictly individualized depending on the phenotype for optimal effect.

Literature confirms the possibility of using wellness fitness to reduce body fatty tissue. Proceeding from this, the aim of the study was to analyze the effect of health-improving fitness of various orientations on the degree of fat deposition in women of the second mature age.

Materials & Methods

Participants.

65 women were divided into two groups. Group 1 – 40 women, average age (43.33 ± 0.93) years. Group 2 – 25 women, average age (44.40 ± 0.93) years. All the participants had no medical contraindications for training. The participants were engaged in wellness fitness for 8 months, three times a week for 1 hour. Group 1 studied according to the developed complex program. The program consisted of dance aerobics (Monday), strength fitness (Wednesday) and stretching (Friday). Participants of the 2nd group were engaged in stretching. This study was approved by the Bioethics Committee for Clinical Research and conducted according to the Declaration of Helsinki. All participants gave their written consent to research and were informed about the purpose and test procedures and about the possibility of withdrawal of consent at any time for any reason.

Study design

The design of the study involved the determination of body length and weight, the degree of fat deposition before and after the start of the program. The measurements were carried out in accordance with the requirements of the international unified method of anthropometric research [10]. Body length was measured with a medical stadiometer, body weight was measured on an Aurora AU 311 electronic balance (China).

The body mass index (kg / m2) was calculated as the ratio of body weight (kg) to body length (m) squared. The indicator was evaluated according to the following scale: less than 19 kg/m^2 – body weight deficit, 19-24 kg/m^2 – normal, 24-30 kg/m^2 – overweight, over 30 kg/m^2 – obesity.

The degree of fat deposition was determined using a mechanical caliper (China). The folds were measured at 17 anthropometric points. The biceps were measured vertically in the middle of the muscle on the right and left. Triceps were measured vertically in the upper third of the muscle on the right and left. The forearm was measured vertically on the front surface at the widest point on the right and left. The back was measured at the lower angle of the scapula vertically to the right and left. The ribcage was measured vertically along the front line at the X ribs on the right and left. The abdomen was measured vertically at the level of the navel, to the right of it, at a distance of 5 cm. The pelvis was measured at the iliac crest on the right and left. The thigh was measured in the supine position on the front of the thigh at the beginning of the sartorius muscle on the right and left. The lower leg was measured in the prone position vertically on the back surface of the lower leg at the level of the lower corner of the popliteal fossa on the right and left.

Statistical analysis.

Statistical analysis of the data obtained was carried out using licensed Excel spreadsheet packages. Descriptive statistics indicators were determined: arithmetic mean, standard deviation and mean error. The significance of differences in the groups was assessed using the parametric Student's test (t) and nonparametric tests of signs (z) and Rosenbaum (Q). The dynamics of indicators was assessed according to the t and z criteria, the groups were compared according to the t and Q criteria. Differences were considered significant at $p<0.05$.

Results

The research results are shown in Table 1.

Table 1. Somatometric and somatoscopic indicators of the participants

Indicator	1 group (n=40) Beginning of experiment	End of experiment	2 group (n=25) Beginning of experiment	End of experiment
Body length, cm	163.78±1.19	163.78±1.19	164.72±1.07	164.72±1.07
Body weight, kg	73.27±2.58	67.52±2.13	71.67±3.26	70.98±2.93
Body mass index, kg/m^2	27.30±0.88	25.18±0.74	26.56±1.10	26.33±1.00
The thickness of the skin-fat folds, mm				
Right biceps	21.23±1.421	14.50±1.03	17.17±1.65	15.98±1.42
Left biceps	22.20±1.521	15.43±1.11	17.39±1.64	16.15±1.37
Right triceps	15.43±1.391	19.93±1.17	23.30±2.00	21.28±1.61
Left triceps	26.38±1.391	19.90±1.24	22.72±1.91	21.28±1.61
Right forearm	10.64±0.701	7.28±0.51	8.87±0.90	8.01±0.72
Left forearm	11.13±0.751	7.74±0.55	8.93±0.89	8.05±0.69
Back to the right	27.50±1.781	20.43±1.63	24.70±2.76	23.07±2.44
Back to the left	28.50±1.871	20.88±1.68	24.74±2.84	22.93±2.57
Chest to the right	18.18±1.421	13.58±1.20	17.00±2.13	15.91±1.82
Chest to the left	18.45±1.471	13.90±1.23	17.41±2.19	16.04±1.84
Pelvis to the right	20.13±1.531	14.03±1.13	16.17±1.91	14.93±1.51
Pelvis to the left	19.70±1.531	14.20±1.23	16.96±2.23	15.37±1.70
Right thigh	40.60±1.671	29.90±1.422	37.65±2.20	36.17±2.04
Left thigh	40.43±1.701	30.35±1.462	36.83±2.30	35.76±2.18
Calf right	26.00±1.851	19.70±1.54	21.61±1.97	20.41±1.82
Calf left	26.23±1.791	19.33±1.52	21.52±2.04	20.39±1.86
Abdomen	35.90±2.291	23.20±1.67	31.65±3.43	29.43±2.97
The average fold thickness	14.12±0.731	8.74±0.49	12.39±0.951	9.89±0.70

Notes: 1 - differences in the dynamics of the study are reliable (p <0.05); 2 - the differences between the groups are significant (p <0.05)

There were no significant differences between groups at the beginning of the experiment.

The implementation of the program provided in group 1 a decrease in body weight (z = 2), BMI (z = 2). The thickness of the skin-fat folds decreased on the right biceps (t = 3.83, z = 0), left biceps (t = 3.60, z = 0), right triceps (t = 3.52, z = 0), triceps left (t = 3.48, z = 0), right forearm (t = 3.87, z = 0), left forearm (t = 3.65, z = 0), back to the right (t = 2.93, z = 0), back to the left (t = 3.03, z = 0), chest to the right (t = 2.47, z = 0), chest to the left (t = 2.37, z = 0), pelvis to the right (t = 3.20, z = 0), pelvis to the left (t = 2.80, z = 0), right thigh (t = 4.89, z = 0), left thigh (t = 4.49, z = 1), calf right (t = 2.61, z = 0), calf left (t = 2.94, z = 0), abdomen (t = 4, 47, z = 0). The average fold thickness decreased significantly (t = 5.18, z = 2).

In group 2, there was a decrease in body weight (z = 7), BMI (z = 7). The thickness of the skin-fat fold decreased on the right biceps (z = 4, n = 18), left biceps (z = 6, n = 23), right triceps (z = 5, n = 21), right forearm (z = 4, n = 18), left forearm (z = 5, n = 22), back to the right (z = 5, n = 20), back to the left (z = 4, n = 19), chest to the right (z = 3, n = 18), chest to the left (z = 4, n = 19), right thigh (z = 3, n = 21), calf right (z = 1, n = 15), calf left (z = 5, n = 19), abdomen (z = 4, n = 24). The average fold thickness decreased significantly (t = 2.13; z = 1).

The size of folds at the end of the study on the right and left thighs, on the left forearm in group 1 was significantly less than in group 2, respectively, (t = 2.52), (t = 2.06) and (Q = 8).

An individual analysis of the BMI structure in groups and its dynamics was carried out. The normal indicator was in group 1 at the beginning of the program (30.00 ± 7.25)%, at the end (45.00 ± 7.87)%. The body weight deficit was, respectively, (2.50 ± 2.47)% and (5.00 ± 3.45)% of the participants. Excess weight was established, respectively, in (32.5 ± 7.41)% and (35.00 ± 7.54)% of the participants. Obesity was, respectively, (35.00 ± 7.54)% and (15.00 ± 5.65)% of the participants. The implementation of the program led to a significant reduction in the proportion of participants with obesity (t = 2.12).

Normal BMI was in group 2 at the beginning of the program (28.00 ± 8.98)%, at the end - in (32.00 ± 9.33)%. The body weight deficit was, respectively, (4.00 ± 3.92)% and (4.00 ± 3.92)% of the participants. Excess weight was established, respectively, in (36.00 ± 9.60)% and (36.00 ± 9.60)% of the participants. Obesity was, respectively, (32.00 ± 9.33)% and (28.00 ± 8.98)% of the participants. There were no significant changes in the specific gravity. There were no differences between the proportions in the groups after the end of the program.

Discussion

A characteristic feature of the health of middle-aged women is an increased likelihood of developing obesity. Wellness fitness is an effective means of preventing and correcting overweight and obesity. The development of health-improving programs of this orientation is widely represented in the literature. The development of such a program was the goal of the study [11]. The authors developed a TRX training program and evaluated its effect on the amount of adipose tissue in the participants. The duration of the program was 12 months, the age of the participants was 30-40 years. A more intense reduction in adipose tissue has been confirmed compared to other health-improving activities.

Kang et al. [12] studied the effects of regular resistance exercise for 12 weeks on obese women. Regular resistance exercise is more effective in reducing weight and body fat in postmenopausal women than in premenopausal women.

The positive influence of dancing and strength fitness classes on the morphological parameters of women was confirmed in another study [13]. Expansion of the adaptive-compensatory potential of the participants was found under the influence of regular training.

The goal was to compare the effect of complex and selective health programs. This design is widely used. Ponomareva [14] compared changes in the level of physical fitness and physiological parameters of students as a result of aerobics and traditional types of exercises.

A similar design was used by Meszler et al. [15]. The authors compared the health benefits of strength training and stretching in healthy young women after 8 weeks of training.

A similar design is used by Dianatinasab et al. [16]. The authors examined the effects of aerobic exercise, resistance exercise, and combined exercise on anthropometric and metabolic performance. The duration of the training was 8 weeks. A significant increase in muscle mass and a decrease in adipose tissue were confirmed in all types of exercises.

The pronounced effect of a comprehensive health-improving program was confirmed in another study [17]. The use of classes of various orientations in the weekly cycle provided a pronounced improvement in morphological and functional indicators, an expansion of functional capabilities, an increase in adaptive potential.

The main criterion for achieving the research goal is to confirm the effect of the program. The effect depends on the duration of its application and the evaluation criteria.

The duration of the wellness program forms the effect of its implementation. The works cited above contain information about health programs lasting 8-32 weeks [1-4, 11, 12, 15, 16]. This study was designed for 8 months of sessions (32 weeks). Somatotype changes must occur during this period.

The choice of criteria for assessing the effectiveness of the classes was carried out taking into account the focus of the program. Jagiełło et al. [18] emphasize the importance of monitoring the morphological and functional indicators of athletes for the management and correction of training. The accuracy of the prediction can be increased through an integrated approach to assessing the condition. The effectiveness of the use in monitoring of biochemical tests, psychophysiological studies, indicators and indices of physical development has been confirmed [19-21].

Body weight and body fat are among the most common anthropometric criteria. Caliperometry is used to determine the degree of fat deposition along with densitometry, bioimpedance, magnetic resonance imaging. This method is considered one of the most informative and valid. Increasing the accuracy of caliperometry results is achieved by increasing the number of measurement points. The use of measurement results at 17 points significantly increases their information content.

Hong et al. [22] note the need for a combination of anthropometric studies and functional tests in the analysis of the performance of persons engaged in health-related exercises.

Body mass index is used to analyze health, nutritional status, and the effectiveness of health improvement activities. The use of indices is due to their simplicity and clarity, the possibility of using them in monitoring the condition of athletes and amateurs [19, 21]. The use of a battery of indices makes it possible to predict success in various types of martial arts.

The absence of differences between the groups at the beginning of our experiment confirms the closeness of the physical condition of the participants. This illustrates the correctness of dividing them into groups. Compliance with this condition increases the objectivity of the analysis.

Losing body weight and decreasing BMI confirms the effectiveness of wellness fitness. This effect was confirmed in both groups. All the options used for the exercise had a pronounced effect on adipose tissue.

This assumption is confirmed by the dynamics of the thickness of the skin and fat folds. Classes for 8 months led to a decrease in this indicator at all measurement points in group 1. In group 2, a decrease in the thickness of folds was found only in 13 points. All participants in group 1 had a decrease in this criterion. A decrease in the thickness of folds was confirmed in 60-96% of participants in group 2 at different measurement points.

Our data confirm the results of other studies [4, 5, 23, 24]. This proves the correctness of the chosen study design, the developed fitness program. Another study [24] aimed to analyze the effect of physical activity on body composition. Exercising for 5 months provided a significant reduction in adipose tissue and an increase in muscle mass. Reducing body fat decreases total body weight, and the difference between fat and total body weight is statistically significant.

In our study, it was established that the average size of folds in both groups decreased significantly. The magnitude of the decrease in group 1 was 38.1% of the initial value. The amount of fold reduction in group 2 was less and amounted to only 20.17% of the initial value. The results obtained are explained by the peculiarities of the organization of classes. Participants of the 1st group used a complex version of the lessons. These included aerobic, strength and stretching exercises. Various activities significantly enhance the effect, provide a complex effect on the body. Classes in group 2 belonged to the so-called "mental fitness". They are aimed at improving flexibility, increasing the range of motion in the joints. The fat burning effect of stretching is less pronounced.

Our results confirm the data of the review by Rao et al. [25]. The review evaluates the effectiveness of exercise and pharmacotherapy for reducing visceral fat. Exercise has been shown to reduce visceral fat more effectively than body weight.

Interesting facts were established by comparing the size of the skin and fat folds at the end of our experiment. Participants in group 1 had a smaller number of folds on the thighs. This can be explained in terms of age-related changes. The greatest deposition of fat is observed in the thighs and pelvis in women in this age group. A decrease in the size of folds on the thighs reflects the pronounced fat burning effect of exercises, the greater effectiveness of complex exercises for reducing body fat. Perhaps the decrease in the thickness of the folds on the forearm is due to the increase in these muscle groups. Group 1 was engaged in strength fitness. This option provided an impact on all muscle groups. Group 2 participants performed stretching exercises. They practically do not affect muscle volume. These results are corroborated by data from Chambers et al. [26]. The authors examined the effects of lifelong aerobic exercise on skeletal muscle size, function, and body fat. Aging and prolonged aerobic exercise affect muscle size, function, and fat infiltration. Higher training intensity throughout life provided better muscle condition and protection against obesity.

Nankam et al. [27] evaluated the effect of 12-week combined resistance training and aerobic exercise on inflammatory and oxidative status of abdominal and gluteal subcutaneous adipose tissue in obese black South African women. Changes in markers of systemic oxidative stress correlated with a decrease in body fat.

In our study, an individual analysis of BMI also allows us to assess the effectiveness of health-improving activities. At the beginning of the experiment, more than half of the participants in group 1 were overweight and obese. This allows them to be attributed to the risk group. An increase in body weight above normal significantly increases the risk of developing metabolic syndrome, the formation of chronic non-infectious diseases. The number of participants with normal body weight increased by 1.5 times at the end of the experiment. The number of obese participants decreased 2.3 times. These changes occurred due to a decrease in the fat component of body weight under the influence of exercise. Overweight participants moved to the normal weight group. This led to an increase in this subgroup. The size of the subgroup of obese participants decreased due to the transition of participants to the overweight subgroup. Therefore, the size of the overweight subgroup did not change significantly.

Our results are consistent with those of Nayor et al. [28]. The authors confirmed that metabolic changes are related to exercise. An increase in body mass index in women leads to adverse metabolic changes.

BMI changes in group 2 were less pronounced. The number of participants with a normal score at the end of the study increased by 4%. The size of the overweight subgroup remained virtually unchanged. The number of obese people has decreased by 4%. These changes confirm once again the assumptions made earlier. Stretching exercises have less fat burning effect.

The study of the characteristics of the somatotype makes it possible to assess the specificity of the influence of various activities on the human body. The somatotype allows you to distinguish people depending on the regularity of the exercise [Jagiello et al., 2014]. The use of various methods allows evaluating the effectiveness of training in various sports. In this study, the dynamics of body weight, body mass index and the results of caliperometry were used to assess the effectiveness. This made it possible to significantly increase the information content of the results obtained.

Conclusions

The influence of health-improving fitness on body weight and the degree of fat deposition in women of the second mature age has been confirmed. Regular exercise for 8 months leads to a decrease in body weight and BMI, and a decrease in body fat. Complex classes have a more pronounced effect compared to stretching. This type of training is more effective in terms of the dynamics of the criteria used and the number of participants with the established changes. The sessions provided an increase in the number of persons with a normal BMI and a decrease in the number of obese participants. The applied indicators and methods can be recommended for use in health monitoring in health fitness.

Conflicts of Interest

The authors declare there are no competing interests.

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ORIGINAL ARTICLE

Comparing the gross motor performance levels of 7–10 age group children with autism spectrum disorder and typical developing

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Abstract

Background and Study Aim The children and adolescents with Autism Spectrum Disorder lead a sedentary lifestyle and, as a result, they are more affected by health problems such as being overweight and obese. They are physically less active than their peers showing typical developing. The aim of the study is to carry out a general comparison of the gross motor performance levels of elementary school-age children living in Germany diagnosed with autism spectrum disorder and children showing typical developing.

Material and Methods A total of 68 children diagnosed with autism spectrum disorder and 73 children showing normal development between the ages 7 and 10 participated in the study. Of the participants, 55 were diagnosed with autism spectrum disorder were boys and 13 were girls, and the average age of the boys was 8.40±1.09 years, while the average age of the girls was 8.85±1.14 years. Of the 73 participants, 36 showing typical development consisted of boys and 37 of them consisted of girl students, and the average age of the boys was 8.56±1.08 years while the average age of the girls was 8.43±1.21 years. The Body Coordination Test for Children was used to evaluate gross motor performance components in the study.

Results The results of the study showed that girls had lower general body coordination than boys on average. It was concluded that children who had an autism spectrum disorder diagnosis displayed statistically lower total motor performance in all of the administered tests compared to their peers showing normal development ($p<0.05$).

Conclusions It is considered that the data obtained will provide important clues about the motor coordination values and body composition of children with autism spectrum disorder and will contribute to taking precautions against the health risks of children with autism spectrum disorder, who are more affected by a sedentary lifestyle compared to their normally developing peers.

Keywords: autism spectrum disorder, epilepsy, epileptic seizures, physical activity

Introduction

It is estimated that the prevalence of autism spectrum disorder (ASD) is approximately 4% worldwide. However, the diagnosis rate is between 0.3% and 1.0% [1]. While an ASD diagnosis was given to one in every 10000 people in the 1980s, it is estimated that one in 125 people in 2004 and 1 in 59 people in 2018 were diagnosed with ASD [2]. As the incidence and diagnosis rate of ASD increases, it can be observed that interest relating to the health and development of these individuals has also increased. In the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM-5), ASD is evaluated as a neurodevelopmental disorder characterized by differences in social communication skills, sensory processing difficulties, restricting and repetitive behaviors and verbal or nonverbal deficiencies [1, 3]. Deficiencies and difficulties are seen in language and communication skills, social skills and social behaviors in the diagnosed individuals [4-6]. In addition to these characteristics, it is stated that individuals with ASD may experience delays, troubles and deficiencies in their development of motor behavior [7-8], and motor limitations can be commonly observed regardless of the presence of mental disability [9]. It is also observed that diagnosed children and adolescents are more affected by a sedentary lifestyle due to the difficulties they encounter in the communication, social, behavioral and motor domains [10-11].

It is estimated that adolescents with ASD leading sedentary lifestyles [10-11] are also subject to health problems such as being overweight or obese, and that their risk probability is higher than their peers showing typical developing [10, 12-13]. It is emphasized that obesity, which has tripled in the last two decades, has become an important health problem for children [14], and it is thought that this rate may increase in those leading a sedentary lifestyle.

Studies that investigated the relationship between physical activity and motor proficiency have shown that children and adolescents with ASD who are

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affected by a sedentary lifestyle are physically less active than their peers showing typical developing [13,15-17]. It has been observed that the trainer, the place that an activity takes place [18], social circles [19], family [20], transportation difficulties [21], number of activities and inadequacies in variety [22] are among the important factors that affect participation in an activity. As a result of inadequate participation in an activity, individuals with ASD have a higher probability of facing difficulties in gross and fine motor skills [23], gross motor performance [7, 24], balance [17, 25], throwing and catching [4, 26], flexibility [27-28], posture [29], walking [30] and movement speed [28, 31] and thus, have lower gross motor performance [7, 24] when compared to their peers showing typical developing.

Motor proficiency is accepted as an important part of motor development [32]. Although it is not a definitive criterion for determining diagnosis, 83% of children with ASD have difficulty performing age-appropriate motor skills [27, 33] and that motoric delays are frequently observed [4, 9, 17, 23, 27, 33]. As such, timely and correct intervention has an important role in eliminating or reducing these difficulties. It is also thought that being able to diagnose only 0.3% to 1.0% of the prevalence rate of about 4% worldwide [1] delays the initiation of intervention programs such as physical activity, and that this delay makes it difficult for children and adolescents with ASD to live healthy lives. Thus, early diagnosis is crucial to alleviate and eliminate symptoms [35]. Motoric tests can help determine the diagnosis and motor proficiency should be included when determining diagnoses [36].

In recent years, sports sciences have made significant progress in their field and developed tests that help evaluate motor proficiency simply and objectively. The primary aim of these tests is to help detect children and adolescents who have motor development disorders and troubles (32). Moreover, such methods used in a similar way should be applicable to the widest possible age range, be economical and the type that children would enjoy [37].

A review of existing literature shows that different tests are used to determine the gross motor performance levels of children and adolescents. However, there are a few test batteries in which gross motor skills are determined with the same test in both children and adolescents with typical developing and those with disabilities or impairments and motoric problems. Although The Body Coordination Test for Children (Körperkoordination Test für Kinder=KTK) is one of these, it has been seen that the studies conducted mostly focus on children and adolescents showing typical developing.

Hypothesis. The children and adolescents with ASD lead a sedentary lifestyle and, as a result, they are more affected by health problems such as being overweight and obese. This study, assuming that the general gross motor performance scores of children with an ASD diagnosis would be lower than their peers showing typical developing.

Purpose. The aim of the study is to carry out a general comparison of the gross motor performance levels of elementary school-age children of 7–10 age living in Germany diagnosed with ASD and children showing typical development (TD).

Materials and Methods

Participants.

The participants consisted of a total of 141 elementary school-age students, 68 diagnosed with ASD (*DSM* 5 299.00) [1] and 73 showing typical developing, living in Germany between the ages of 7 and 10.

Of the participants, 55 were diagnosed with ASD were boys and 13 were girls, and the average age of the boys was 8.40±1.09 years, while the average age of the girls was 8.85±1.14 years.

It was determined that 68 students were diagnosed with mild ASD from their identification cards issued by local governments. According to the psychiatric or medical diagnosis report, a mental disability accompanying ASD and a secondary obstacle restricting participation in physical activity were not encountered. Of the 73 participants, 36 showing typical developing consisted of boys and 37 of them consisted of girl students, and the average age of the boys was 8.56±1.08 years while the average age of the girls was 8.43±1.21 years. The 68 students with an ASD diagnosis constituted the ASD group, the 73 students showing typical developing constituted the TD group. Acute diseases, injuries, the usage of antidepressants, chronic inflammations, medication usage affecting the muscle/bone system and their simultaneous inclusion in another test were used as exclusion criteria from the study.

Data collection was performed in accordance with the provisions of "Federal Data Protection Act" (BDSG). The required approvals were obtained from relevant federation and Germany TV Eberbach Health, Rehabilitation and Disability Sport Department (TVE/GS 2018-3011). Participation in the study was voluntary, families were informed about the aims, content and data protection of the study according to the Helsinki Declaration and a signed parent consent form was obtained from the families.

Research Design

Procedures: Before the study, in order to determine the ASD group, a prepared informational brochure was given to families of children with ASD in the cities of Heidelberg and Eberbach, Germany, and its surroundings, through the school the students attend and the Rehabilitation Sports Club. A total of 179 brochures were distributed and feedback was received from 83 families. A total of 83 families were informed about the inclusion criteria of the children in the study, either face-to-face or by phone, and information about the children's health status was obtained. After the briefing, 15 people with epilepsy, mental or physical disabilities, using antidepressants and drugs affecting the muscle/bone system or chronic inflammation, who were simultaneously involved in another sports test were not included in the study, and an ASD group of 68 was created. To determine the TD group, families who were a member of TV Eberbach Sports Club were informed via email, and feedback was received from 81 families. A 73 people TD group was created due to eight students being unable to participate in the test due to various reasons such as illness, injuries, etc. The application of the tests were conducted by an instructor (researcher) with a rehabilitation sports license in the neurology, orthopedics, sensory and mental domains.

Data Collection Tools: KTK was used to evaluate gross motor performance components in the study. The KTK applied by Kiphard and Schilling [37-38] is commonly used in Germany to determine the gross motor performance in children and adolescents between the ages of 5 and 14 showing typical developing with brain damage and behavioral disorders. It is evaluated as a test that is applied very easily by taking simple precautions and with very low operating costs (39).

KTK consists of four sub-tests measuring total gross motor performance:

(1) Backstepping (MQ1): Three trials were made for varying widths on the basis of stepping backwards on a balance beam of 6 cm, 4.5 cm and 3 cm width, 5 cm height and 3 m length. Each trial has a maximum of eight points and is based on a maximum possible score of 72 points.

(2) One-foot jump (MQ2): Three trials were made for each height in the test performed with the principle of jumping with one foot over a total of 12 (50 cm x 20 cm x 5 cm) sponges. The 7–8 age group started with three (15 cm) sponges while the 9–10 age group started with five (25 cm) sponges, and another sponge was added after each successful trial. Three, two and one point was given to performances that were successful on the first, second and third trials, respectively. The maximum test score was 39 points for each leg, reaching a total of 78 points for both legs.

(3) Sideways jump (MQ3): A springboard (100 cm x 60 cm) fixed to the ground is divided into two from the middle with a lath (60 cm x 4 cm). The participants were asked to jump right and left over the lath as quickly as possible within 15 seconds and the total number of jumps was recorded.

(4) Sideways stepping (MQ4): Non-slip feet-shaped markers with a height of 3.7 cm were attached on the bottom of two wooden platforms measuring 25 cm x 25 cm x 1.5 cm. The test started when the child was on a platform and they were asked to switch to the empty platform by putting their hands on the side. This application continued for 20 seconds and a second trial started after an interval of at least 10 seconds. The total number of successful switches at the end of two trials were recorded [37-38].

For the application of KTK, the children were taken into a hall in small groups of 2–3 people in the ASD group and 4–5 people in the TD group. The test's procedure was explained by the researcher and practically demonstrated, following which the participants were allowed to do a trial for each test item. The test application started when the students were certain about how the test works. The same student did not do all of the test items back to back. It was passed on to the next student after each test item, and thus, the opportunity to rest between the test items was provided. This cycle continued until the four test items were completed.

According to Kiphard and Schilling [37-38], the raw scores are inadequate to evaluate the results. In order to conduct the evaluation, each test item was converted to norm values in accordance with the original manual of KTK, and the total motor values (TMQ) were determined by combining norm values. In the evaluation, *out of classification* (< 56), *distinct impairment* (56–70), *inadequate* (71–85), *normal* (86–115), *good* (116–130) and *high* (131–145) estimated motor performance classification made through *standard motor values* (MQ) [37-38].

Body Mass Index (BMI), applied to obtain information about the participants' body composition and determined by standardized height and weight measurements, was found to be highly reliable (Doolittle et al., 1969). The measurements were made using the height and body mass Seca 769 digital weight/height measurement tool. BMI was calculated using the formula BMI = Body Mass (kg.)/Height square (m^2) from the obtained data. The interpretation and classification of the BMI percentage values were determined using the AGA reference values, the most common method of determining obesity in Germany [40].

According to the WHO [41] standards, slim, normal weight, overweight and obese classifications were used when looking at the BMI values.

Statistical Analysis

The SPSS 26 program for Mac was used in the analysis of the data. Kolmogorov–Smirnov test was used to determine whether the data fit normal distribution, alongside skewness-kurtosis values and histogram graphs, which are other assumptions of normal distributions. The distribution of the data was accepted as normal because the skewness–kurtosis values were within the range of ±2 [42]. A t-test (independent samples t-test) was used in the comparison of two independent groups, one-way variance analysis was used in the comparison of two or more groups. The relationship between variables was analyzed using the Pearson correlation coefficient. The significance level of 0.05 was used as the criterion for the interpretation of the values obtained.

Results

Upon examining Table 1, it can be seen that 21.8% of the boys with ASD who participated in the study had normal weight, 61.8% of them were overweight and 16.4% were obese. Further, 23.1% of the girls in this group had normal weight, 61.5% of them were overweight and 15.4% were obese. On the other hand, 55.6% of the boys in the TD group had normal weight, 41.7% of them were overweight and 2.8% were obese, while 78.4% of the girls had normal weight and 21.6% of them were overweight. Overall a total of 21.1% of the children in the ASD group had normal weight, 61.8% of them were overweight and 16.2% were obese, while a total of 76.1% of the children in the TD group had normal weight, 31.5% were overweight and 1.4% were obese.

Whether the measurement values used in the study differed significantly according to the groups and gender was examined with an independent samples t-test. According to the obtained data (Table 2), it was determined that the MQ1, MQ2, MQ3, MQ4 and TMQ measurement values did show a statistically significant difference according to groups ($p < 0.05$).

MQ1 values show a statistically significant difference between groups [$t(139)=-26.37$ $p<0.05$]. It can be seen that the children in the ASD group (65,75±6,29) have lower values of the MQ1 measurement values compared to the children in the TD group (104,52±10,50). The calculated MQ1 ($\eta2 = 0.83$), effect size value show that the differences between the groups are ample. It can be said that 83% of the variance change in the MQ1 values is caused by the differences between the groups.

MQ2 values show a statistically significant difference between groups [$t(139)=-14.98$ $p<0.05$]. It can be seen that the children in the ASD group (61.10±6.93) have lower values of the MQ2 measurement values compared to the children in the TD group (88.93±13.77). The calculated MQ2 ($\eta2 = 0.62$), effect size value show that the differences between the groups are ample. It can be said that 62% of the variance change in the MQ2 values is caused by the differences between the groups.

Table 1. Percentage values of normal weight, overweight and obese classes of the ASD and TD Groups

		Normal Weight		Overweight		Obese	
Variables	**Gender**	**N**	**%**	**N**	**%**	**N**	**%**
ASD Group	Boys n=55	12	21.8	34	61.8	9	16.4
	Gils n=13	3	23.1	8	61.5	2	15.4
	Total	15	22.1	42	61.8	11	16.2
TD Group	Boys n=36	20	55.6	15	41.7	1	2.8
	Girls n=37	29	78.4	8	21.6	-	-
	Total	49	67.1	23	31.5	1	1.4

ASD: Autism Spectrum Disorder, TD: Typical developing

Table 2. Results of Comparing Measurement Values According to Groups (Independent Samples T-Test)

Variables	Groups	n	M±SD	t	df	p	η2
MQ1	ASD	68	65.75±6.29	-26.37	139	0.01	0.83
	TD	73	104.52±10.50				
MQ2	ASD	68	61.10±6.93	-14.98	139	0.01	0.62
	TD	73	88.93±13.77				
MQ3	ASD	68	54.99±9.38	-16.50	139	0.01	0.66
	TD	73	89.36±14.60				
MQ4	ASD	68	56.22±10.19	-17.77	139	0.01	0.69
	TD	73	94.64±14.87				
TMQ	ASD	68	71.87±5.61	-12.02	139	0.01	0.51
	TD	73	92.95±13.41				

ASD: Autism spectrum disorder, TD: Typical developing, M: Mean, SD: Standard deviation, BMI: Body mass index ($weight/height^2$), MQ1: Motor values/backstepping, MQ2: Motor values/one-foot jump, MQ3: Motor values/sideways jump, MQ4: Motor values/sideways stepping, TMQ: Total motor values

MQ3 values show a statistically significant difference between groups [t(139)=-16.50 p<0.05]. It can be seen that the children in the ASD group (54.99±9.38) have lower values of the MQ3 measurement values compared to the children in the TD group (89.36±14.60). The calculated MQ1 (η2 = 0.66), effect size value show that the differences between the groups are ample. It can be said that 66% of the variance change in the MQ3 values is caused by the differences between the groups.

MQ4 values show a statistically significant difference between groups [t(139)=-17.77 p<0.05]. It can be seen that the children in the ASD group (56.22±10.19) have lower values of the MQ3 measurement values compared to the children in the TD group (94.64±14.87). The calculated MQ4 (η2 = 0.69), effect size value show that the differences between the groups are ample. It can be said that 69% of the variance change in the MQ4 values is caused by the differences between the groups.

TMQ values show a statistically significant difference between groups [t(139)=-12.02 p<0.05]. It can be seen that the children in the ASD group (71.87±5.61) have lower values of the TMQ measurement values compared to the children in the TD group (92.95±13.41). The calculated TMQ (η2 = 0.51), effect size value show that the differences between the groups are ample. It can be said that 51% of the variance change in the MQ1 values is caused by the differences between the groups.

According to the data specified in Table 3, it was determined that the MQ1, MQ2, MQ3, MQ4 and TMQ measurement values did show a statistically significant difference according to gender (p<0.05). When the average values are examined, it can be observed that boys have a higher average gross motor performance score as compared to girls in all of the tests.

As with the original research, engine performance was classified as *unclassified* (56), *significant disorder* (56 – 70), *insufficient* (71 – 85), *normal* (86 – 115), *good* (116 – 130), and *advanced* (131 – 145) over the standard MQ values (Table 4).

According to the classification, 12.7% of the boys with ASD were "unclassified" and 87.3% were in the "significant disorder" category, while 76.9% of the girls with ADS were "unclassified" and 23.1% were in the "significant disorder" category. 16.7% of boys with typical development scored "inadequate", 83.3% scored "normal", while 10.8% of girls scored "significant disorder", 46% scored "inadequate", and 43.2% scored "normal". In general, 25% of ASD participants performed "out of classification", while 75% demonstrated "significant disorder". While 5.5% of participants in the typical development group demonstrated "significant disorder", 31.5% demonstrated "inadequate" performance, and 63% demonstrated "normal" performance. According to

Table 3. Results of Comparing the ASD/TD Groups Measurement Values According to Gender

Items	Groups	Gender	n	M±SD	t	df	p	η2
MQ1	ASD	Boys	55	67.11±5.78	4.07	66	0.01	0.20
		Girls	13	60.00±5.13				
	TD	Boys	36	108.47±9.33	3.40	71	0.01	0.14
		Girls	37	100.68±10.24				
MQ2	ASD	Boys	55	62.69±6.19	4.38	66	0.01	0.22
		Girls	13	54.38±5.95				
	TD	Boys	36	96.08±12.25	5.07	71	0.01	0.26
		Girls	37	81.97±11.52				
MQ3	ASD	Boys	55	57.65±7.77	5.93	66	0.01	0.34
		Girls	13	43.69±7.03				
	TD	Boys	36	97.36±11.36	5.47	71	0.01	0.29
		Girls	37	81.57±13.20				
MQ4	ASD	Boys	55	59.04±9.05	5.67	66	0.01	0.32
		Girls	13	44.31±4.64				
	TD	Boys	36	98.14±14.27	2.12	71	0.04	0.05
		Girls	37	91.24±14.85				
TMQ	ASD	Boys	55	73.87±3.87	8.97	66	0.01	0.54
		Girls	13	63.38±3.43				
	TD	Boys	36	100.58±11.80	5.78	71	0.01	0.32
		Girls	37	85.51±10.44				

*p<0.05, M: Mean, SD: Standard deviation, BMI: Body mass index (weight/height^2), Min.: Minimum, Max.: Maximum, ASD: Autism spectrum disorder, TD: Typical developing, MQ1: Motor values/backstepping, MQ2: Motor values/one-foot jump, MQ3: Motor values/sideways jump, MQ4: Motor values/sideways stepping, TMQ: Total motor values these findings, children with typical development have higher values than children with ASD, and girls have lower values in both groups. According to the classification identified, it can be interpreted that children with ASD exhibited *inadequate* performance but had a higher tendency towards the *distinct impairment* category, while children with TD exhibited *normal* performance, but had a higher tendency towards the *inadequate* category.

The relationship between variables was examined using the Pearson correlation coefficient (Table 5). While there was no statistically significant relationship between age and the MQ1, MQ3, MQ4 and TMQ variables ($p > 0.05$), it was determined that there was a statistically low significant negative correlation between age and MQ2 values ($r = -0.20$, $p < 0.05$). It was determined that there is a statistically low significant negative correlation between BMI values and the MQ1, MQ2, MQ3, MQ4 and TMQ values ($p < 0.05$).

A one-way ANOVA test was used to compare the measurement values used in the study according to BMI categories and the Bonferroni multiple comparison test, a post-hoc test, was used to determine which motor performance categories the difference was in (Table 6).

MQ1 values show a statistically significant difference according to BMI classes [$F(2,138)=16.91$ $p<0.05$]. According to the Bonferroni multiple comparison tests used to determine which BMI classes differ, people with normal weights have significantly higher MQ1 values than those who are overweight or obese.

MQ2 values show a statistically significant difference according to BMI classes [$F(2,138)=5.92$ $p<0.05$]. According to the Bonferroni multiple comparison tests used to determine which BMI classes differ, people with normal weights have significantly higher MQ2 values than those who are overweight or obese.

Table 4..The results of a comparison of performance classification values by group and gender.

		ASD Group		TG Group	
Gender	**Performance Categories**	**N**	**%**	**N**	**%**
Boys	unclassified (<56)	7	12,7	0	0
	significant disorder (56-70)	48	87,3	0	0
	insufficient (71-85)	0	0	6	16.7
	normal (86-115)	0	0	30	83.3
Girls	unclassified (<56)	10	76,9	0	0
	significant disorder (56-70)	3	23,1	4	10.8
	insufficient (71-85)	0	0	17	46
	normal (86-115)	0	0	16	43.2
Boys/Girls Total/	unclassified (<56)	17	25	0	0
	significant disorder (56-70)	51	75	4	5.5
	insufficient (71-85)	0	0	23	31.5
	normal (86-115)	0	0	46	63
	Total	68	100	73	100

ASD: Autism spectrum disorder TD: Typical developing.

Table 5. Examining the Relationship between Variables

Items		**Age**	**BKI**
MQ1	r	0.09	-0.25
	p	0.29	0.01*
MQ2	r	-0.20	-0.25
	p	0.02*	0.01*
MQ3	r	-0.08	-0.28
	p	0.32	0.01*
MQ4	r	0.02	-0.27
	p	0.79	0.01*
TMQ	r	-0.03	-0.22
	p	0.74	0.01*

*p<0.05, BMI: Body mass index (weight/height^2), MQ1: Motor values/backstepping, MQ2: Motor values/ one-foot jump, MQ3: Motor values/sideways jump, MQ4: Motor values/sideways stepping, TMQ: Total motor values

Table 6. Results of Comparing the Measurement Values According to the KTK Motoric Performance Categories

Items	Groups	M±SD	Coefficient of Variance	Sum of squares	df	Mean of squares	F	p	η2	Post hoc
	Normal Weight¹	95.54±19.22	Between Groups	12500.673	2	6250.337				
MQ1	Overweight²	79.59±20.11	Within Group	50999.894	138	369.564	16.91	0.01	0.19	1>2.3
	Obese³	67.75±12.92	Total	63500.567	140					
	Normal Weight¹	80.78±16.86	Between Groups	3488.364	2	1744.182				
MQ2	Overweight²	71.88±18.20	Within Group	40654.870	138	294.601	5.92	0.01	0.07	1>2.3
	Obese³	67.08±11.82	Total	44143.234	140					
	Normal Weight¹	80.48±20.31	Between Groups	7782.965	2	3891.483				
MQ3	Overweight²	67.78±20.29	Within Group	55049.219	138	398.907	9.75	0.01	0.12	1>2.3
	Obese³	58.75±15.68	Total	62832.184	140					
	Normal Weight¹	85.23±22.06	Between Groups	10310.604	2	5155.302				
MQ4	Overweight²	69.69±22.25	Within Group	64553.581	138	467.780	11.02	0.01	0.13	1>2.3
	Obese³	62.25±14.15	Total	74864.184	140					
	Normal Weight¹	87.32±15.20	Between Groups	2623.979	2	1311.989				
TMQ	Overweight²	79.69±13.95	Within Group	28066.206	138	203.378	6.45	0.02	0.08	1>2.3
	Obese³	75.25±9.71	Total	30690.184	140					

M: Mean, SD: Standard deviation, 1 MQ1: Motor values/backstepping, MQ2: Motor values/one-foot jump, MQ3: Motor values/sideways jump, MQ4: Motor values/sideways stepping, TMQ: Total motor values

MQ3 values show a statistically significant difference according to BMI classes [$F(2,138)=9.75$ $p<0.05$]. According to the Bonferroni multiple comparison tests used to determine which BMI classes differ, people with normal weights have significantly higher MQ3 values than those who are overweight or obese

MQ4 values show a statistically significant difference according to BMI classes [$F(2,138)=11.02$ $p<0.05$]. According to the Bonferroni multiple comparison tests used to determine which BMI classes differ, people with normal weights have significantly higher MQ4 values than those who are overweight or obese.

TMQ values show a statistically significant difference according to BMI classes [$F(2,138)=6.45$ $p<0.05$]. According to the Bonferroni multiple comparison tests used to determine which BMI classes differ, people with normal weights have significantly higher TMQ values than those who are overweight or obese.

Discussion

The aim of the study was to compare the general gross motor performance levels of children diagnosed with ASD and children showing typical developing in the elementary school-age bracket through KTK, which has been evaluated as a test that is very easy to apply, with very low activity cost and simple precautions. It was seen that children diagnosed with ASD had higher BMI values after KTK, and that in all of the applied tests (backstepping, one-foot jump, sideways jump, sideways stepping), children diagnosed with ASD displayed lower motor performance compared to their peers showing typical developing. It was concluded from the obtained data that the girls participating in the study had lower overall body coordination than boys, on average.

Studies have reported that children and adolescents with ASD lead a sedentary lifestyle and, as a result, they are more affected by health problems such as being overweight and obese [10-11], and that the probability of being overweight and obese was higher in children diagnosed with ASD compared to their peers showing typical developing [12-13, 43]. Moreover, the results reported in the limited number of studies in which the BMI values of children with ASD are determined, differ from each other. In a study Takeuchi [44] conducted with a group of 13 people diagnosed with ASD, it was stated that the BMI values of the participants were low. However, in their study conducted with a group of 17 people, Tyler et al. [45] reported that the BMI values were normal. In a study conducted with a larger sample group, Egan et al. [46] evaluated 273 children with ASD and stated that 17% of the participants were overweight and approximately 22% of them were obese. Similarly, in a study they conducted with 429 children with ASD in the age group 6–11, Xiong et al. [47] stated that 51% of the participants were overweight or obese. Curtin et al. [48] also examined obesity in children with ASD and found that the probability of being obese was 40% higher in children with ASD as compared to children showing typical developing. In this study, it was observed that 78% of children with ASD and 32.9% of the children showing typical developing were overweight and obese, while the results strengthen the assumption that children with ASD have a higher risk of obesity and being overweight. Thus, the data obtained support the results of other studies [48-51].

Further, in general, it has been reported that children and adolescents diagnosed with ASD participate in physical activity to a limited extent [4, 52-53]. In studies investigating the relationship between physical activity, motor proficiency [4, 13, 15-17, 33, 49, 52, 54] and gross motor performance [7, 24], it was found that the gross motor performance of adolescents with ASD, who are affected by a sedentary lifestyle, were lower than their peers showing typical developing and the reported results are parallel to those in this study [55-56]. In their study, Kiphard and Schilling [37] obtained a general (gender and all age groups) 100±15 TMQ value. While results close to the Germany-based sample were reported in similar studies [57-60], lower TMQ values were reported in some studies [61-62] and higher values were reported in others [63-64]. In this study, it is seen that the TMQ values of the ASD and TD groups differ from other studies as they remain below the KTK norm values reported by Kiphard and Schilling [37]. Staples and Reid [34] observed in their study, with 25 children diagnosed with ASD in the 9–12 age group, that the diagnosed children attained lower values compared to their age. In a similar study, Freitag et al. [65] stated that individuals who were diagnosed with Asperger syndrome had low gross motor performance and reported results parallel to this current study.

Performance differences between genders were observed in some of the conducted studies. Antunes et al. [66], stated that boys displayed higher performance compared to girls in the backwards balancing and stepping sideways tests. In a study they conducted, Fransen et al. [67] and Hardman et al. [60] obtained higher values in girls compared to boys in the backwards balancing test; however, they stated that boys displayed overall higher performance compared to girls in other parts of the test. In this study, it was also determined that boys attained higher TMQ values as compared to girls and results similar to other studies were obtained.

In a study where an eight-week traditional dance program was given to 10 adolescents diagnosed with ASD, Arzoglou et al. [68] tried to determine the gross motor performance of the participants with KTK. They reported that the TMQ values were lower than the standard norm values. The TMQ values in this study were also determined to be lower, which is consistent with the results of other such studies.

Conclusion and Suggestions

This study was designed about an important area such as ASD, which has increasingly become the subject of research in recent years. It aims to shed light on future research and support the existing database by comparing the gross motor performance of children with an ASD diagnosis and children showing typical developing. As a result of this study, it was determined that children with ASD were overweight and obese when compared to their peers showing typical developing. From these results, it is thought that children with ASD are at a higher risk for obesity and being overweight. The obtained data show that the gross motor performance of children with ASD is lower than their peers showing typical developing, and that girls had lower TMQ scores compared to boys in both groups. However, although it was found that children with ASD had lower TMQ scores, this result should not be interpreted as children showing typical developing do not have gross motor performance problems. It was found that children showing typical developing also had TMQ scores under the standard norm values, suggesting that the gross motor performance problem is not solely caused by ASD.

It should be noted that the conducted study was limited to a relatively small sample and only focused on children living in Germany. As such, future studies that study international, more ethnically diverse and more comprehensive samples are needed alongside experimental studies to recommend KTK in determining gross motor performance in children with ASD, following which the current study's results can be verifiable. Simultaneously, it is recommended that clinicians diagnosing and treating children with ASD additionally evaluate motor coordination deficits and take early intervention precautions for motor problems to contribute towards eliminating these problems.

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Conflicting interest

The author declares no conflict of interest.

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ORIGINAL ARTICLE

An insight into Short-sprint coaches' knowledge and use of periodisation models and training methods - Sri Lankan context

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

Abstract

Background and Study Aim Periodised training strategies, due to their demonstrated success in improving athletic performance, have become increasingly utilised by coaches, athletes, and strength and conditioning practitioners as a key training methodology. As a consequence, a coach's knowledge of periodisation and training methods have become increasingly important for improvement of sport-sprint performance. Despite their importance of performance at the elite level, it was suspected that little is known about the Sri Lankan context. As a result, the purpose of this formative exploratory study was to examine knowledge about, and application of, periodisation and training methods by Sri Lankan elite-level coaches working with short-sprint athletes.

Material and Methods With institutional ethics approval, ten (n=10) expert short-sprint coaches volunteered to participate in the study, with data collected via semi-structured interviews. Data were analysed inductively, to identify 'patterns', 'themes' and 'categories' using the NVivo 12 qualitative software.

Results Four primary themes emerged from the interview data. These included "*Periodisation models*", "*Monitoring training*", "*Strength development*", and "*Speed development"*. Findings revealed that coaches reported minimal or inadequate knowledge of periodised training and consequently, there did appear to be a gap between coach knowledge of periodised training, but additionally in regard to general training methodology; including aspect such as prescribing strength and speed training loads and, monitoring of training loads. The coaches believed that their knowledge was inadequate to support athletes with Olympic level potential.

Conclusions The findings identified a potential knowledge gap in coach education and development for elite sprint coaches in Sri Lanka.

Keywords: coaches' knowledge, periodised training, sprint training, sports performance, elite level

Introduction

A significant challenge in sports training is to effectively manipulate training loads [intensity and volume] to maximise athletes' physical performance while avoiding overtraining and injury over the competitive season [1]. Periodisation was developed as a systematic manipulation of training variables [load, sets, and repetitions] with the goal of maximising training adaptations and avoiding overtraining syndrome [2–5]. There appears to be common agreement regarding the importance of appropriate periodisation for achieving optimal performance outcomes [1, 6, 7]. Therefore, the concept of periodisation continues to gain increased popularity across different parts of the world to enable athletes to perform their very best when it comes to competition. The use of periodisation models in the planning of training programmes for athletes has enabled feasible in enabling coaches to effectively manage the training variables during each phase [8, 9]. Periodized training is essential in high-performance sports to achieve high levels of maximum strength, power and speed [10]. Track and field coaches have access to a range of training planning models [11]; they must fully understand these and choose the best approach based on the athlete's event, age, level of training maturity, and competition needs [12]. Therefore, sprinters use periodized programmes that include strength training, plyometrics, and sprint practice in order to improve performance [8, 13–15].

The distance, athletes cover in short-sprint competitions in track and field athletics, ranges from 60 to 200 metres [16]. Dynamic interaction of technical and physiological variables is the factor responsible for the determination of sprint performance [17]. Other factors to consider include starting strategy, stride length, stride frequency, physiological demands, biomechanics, neurological impacts, muscle composition, anthropometrics, as well as track and ambient conditions [18]. It is possible to employ numerous training modalities

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to increase sprint performance. However, strength and conditioning coaches should choose the most effective model for their athletes, considering the competition distance. The analysis of relevant literature sources indicates that sprint training should be specific [free sprinting, resisted sprinting with bands, sleds, or incline running, assisted sprinting with towing devices or a downhill slope], nonspecific [resistance and plyometric training], or combined [a combination of specific and nonspecific] methods on various sprint distances (0–10, 0–20, 0–30, and 31+ m) [8,19,20]. The speed development methods are usually classified into primary (performing proper movement technique of a specific motor ability), secondary (sprint resistance and sprint assistance), and tertiary (flexibility, strength, and speed-endurance) [21]. Although the training methods for the sprint are highly variable, they are not the same [22]. The coach must apply the knowledge of training methods, matching them to the individual needs of an athlete.

In high-performance sport, coaches play a critical role in the development of elite athletes and their engagement in sport [23]. Sprint coaches look at sprinting performance through different lenses based on their own experiences; they combine a wide range of knowledge to increase performance [24]. Planning is a crucial and fundamental part of the coaching process [25]. The effectiveness of the coaching process directly depends on knowledge and abilities of a coach who must be aware of the training philosophy [26], pedagogical strategies [27] and ways to enhance the improvement and development of athletes [28]. It assists in helping athletes to reach their potential and gain specific knowledge of their sport. Moreover, the ability to respond to changing circumstances requires from coaches to develop a solid knowledge base [29]. Consequently, many individuals involved in coaching have expressed their interest to expand their experience and skills on how to prepare sprinters. Finally, knowledge and understanding of periodized training and training methods, which are vital for the effective short-sprint performance, may help athletes to improve their overall sporting outcomes.

Scientific literature shows that researchers dedicate their studies to the coaches' knowledge of sport-specific themes, including verbal feedback [27], growth, maturation, and training load [30], resistance training principles and methods [31], eccentric resistance training [32], and sport volume [33]. Furthermore, special attention is paid to technical knowledge [34], nutrition [35], maximum velocity sprinting technique [24] and talent identification [36]. However, it remains unknown whether the knowledge of coaches and their application of periodization models and training methods assists in improving optimum short-sprint performance, either in Sri Lanka or elsewhere.

Recent developments in training theory and methodology for short-sprint athletes have likely seen significant improvement in performance for short-sprint athletes [37]. It is possible, however, perhaps due to the lack of a formal coach education system, that these improvements have not been widely adopted by coaches in Sri Lanka. As a result, Sri Lankan athletes may be at a disadvantage because of their preparation for the competition, when compared with international competitors. Therefore, the *purpose* of this study was to qualitatively examine the knowledge and use of periodised training and training methods made by Sri Lankan short-sprint coaches. These findings may contribute to the development of future coach education programmes and make practical recommendations to assist other coaches in critically evaluating and exploring the use of contemporary best practices in their practise.

Material and Methods

Participants

Following institutional ethics approval, ten (n=10) expert short-sprint coaches were stratified and selected representatively from eight different provinces who are located throughout the country using criterion-based sampling [38]. They were identified as the most knowledgeable and respected coaches in Sri Lanka by the Sri Lanka Track and Field Coaches Association, having produced athletes at the national and international levels in past years. The average age of the coaches' age was 47.5 years and had coaching experience for an average of 18.7 years. Out of ten, nine were male participants. Demographic information of the participant coaches is provided in Table 1. Most of the coaches that were involved in the study were male genders. This was because the country possessed more experienced male coaches than female coaches. In line with previous studies [34, 39, 40], the coaches were classified as an expert or elite level based on three criteria related to experience, achievement, and qualification. First, a minimum of 10 years' sprint coaching experience was considered necessary. Second, each coach was required to hold a valid IAAF Athletics coaching certificate; the recognised IAAF coaching award available in the athletics, or a national sprint coaching position [either currently or previously]. Finally, each coach was required to have coached at least two international-level athletes.

Data collection

Interview guide: An interview guide approach was adopted where topics and issues were specified in advance to ensure that the same basic lines of inquiry were followed by each of the interviewed coaches [41]. An interview was developed, by an experienced T&F coach with a background in qualitative research, in order to provide a basic structure for the interviews. A list of potential research questions linked to the research topic was gathered using relevant literature and personal experience. During the interview, the researcher determined the order and wording of the questions. The first section of the schedule includes a brief description of the coaches to assist the researcher in keeping track of who responded to what during the interviewing process. This methodology has already been used in qualitative research studies on the use of training periodization models by professional judo coaches [42].

Prior to the start of the data collection period, the guide was pilot tested with two short-sprint coaches who met the criteria for full study participation. The pilot interviews allowed minor changes to the clarity of some questions and highlighted the need for further explanation and clarification probes to be included.

The final interview guide consisted of three sections: periodisation models [e.g., "Do you plan your athlete's season? If yes, can you describe the type of periodisation model that you use to plan an athlete's season?", "How do you monitor training loads (volume and intensity] across different phases of the season?"), training methods for strength development (e.g., " Can you describe the variety of training methods you use to develop strength and power? "), and, training methods for speed development (e.g., "Can you describe the variety of training methods you use to develop speed?"). A social validation process was also used to assess the interview process to see whether participants felt they could completely tell their story, whether their responses were affected, and whether they had the opportunity to provide comments or suggestions on the process and format [43].

Procedure.

After receiving consent from the Sri Lanka Track and Field Coaches Association invitations were sent to the short-sprint coaches who met the criteria. Coaches were given a detailed explanation of the study and asked to give their consent to participate before starting each interview.

Coaches who accepted to be interviewed expressed their consent through the return of a signed reply form. This included a section providing the interviewer permission to use the coaches' contact details in confidence. Each coach, who returned the signed consent form, were contacted three days prior to the interview by phone as a courtesy reminder or to reschedule, if necessary, in the event the participant needed to change the date, time, or place of the interview [38]. Prior to the actual interviews, participants received the interview guide to familiarize themselves with it and have time to reflect on their responses to the questions [44]. The interview took place at a time and location convenient to the respondents, in a comfortable setting free of any disturbances and noise. [45].

Face-to-face semi-structured interviews were conducted with each coach to elicit information about their various knowledge domains and insights [46], concerning the periodisation models and training methods used by short-sprint coaches.

Table 1. Demographic profile of the short-sprint coaches interviewed

Name of the coach	Gender	Years of experience	Highest level of education	Highest level of coaching certificate	Training frequency
C1	Male	12	Diploma in Sports	IAAF Level 1	10x/week/90 min *
C2	Male	14	Higher Diploma in Sports	IAAF Level 1	09x/week/90 min
C3	Male	18	Diploma in Sports	IAAF Level 1	10x/week/90 min
C4	Male	32	Diploma in Sports	IAAF Level 4	08x/week/90 min
C5	Male	22	Diploma in Sports	IAAF Level 1	09x/week/90 min
C6	Female	13	Diploma in Sports	IAAF Level 2	09x/week/90 min
C7	Male	19	Higher Diploma in Sports	IAAF Level 1	10x/week/90 min
C8	Male	14	Diploma in Sports	IAAF Level 2	10x/week/90 min
C9	Male	26	Diploma in Sports	IAAF Level 1	09x/week/90 min
C10	Male	17	Diploma in Sports	IAAF Level 2	10x/week/90 min

* Each training session

The principal investigator, who has familiarity with qualitative research and interviewing techniques and an in-depth understanding of periodisation models and training methods with the coaches' history and the nature and terminology, conducted all of the interviews. This method ensured the trustworthiness of the data collection [47]. The semi-structured nature of the interviews enabled for a more flexible approach to data gathering, allowing researchers to explore deeper into the coaches' experiences [48]. Interviews have been already used to explore elite coaches' knowledge used in training [49]. The number of interviews was continued until no new analytical information emerged – the study provides maximum information on the phenomenon known as 'data saturation' [50].

The methods of data collection were semi-structured interviews of short-sprint coaches, gym/field observations, and documentation [Training schedules and dairies]. The respondents' data were handled with the strictly confidential, since their identities were anonymized and made private. Interviews, which lasted 60 to 90 minutes, were transcribed verbatim resulted in over 210 pages. Interviews were transcribed immediately after completion in order to find analytical frameworks that connected the experiences of different interviewees [45]. Transcripts were returned to participants for member checking in order to determine the quality and accuracy of their experiences [51]. Minor changes were made to the statements to ensure confidentiality and increase transparency. Finally, participants' confidentiality was safeguarded by a coding scheme that substituted each name with a number [for example, coach © 1 - 10]. Any possibly identifiable details [such as coaches' names, their athletes' name, hometown, and so on] was also de-identified to prevent coaches' identity being revealed.

Data analysis

The data collected during the interviews were then subjected to thematic analysis, a very simple and flexible method of qualitative analysis [38], in order to identify patterns of meaning across the dataset. Qualitative coding and theme development procedures were adapted from the use of the six-stage process by Braun and Clarke [52] which provides such a clear and usable framework for conducting thematic analysis. These stages include; idea familiarization, the generation of initial codes, theme identification, reviewing of the themes, and defining and theme naming. Key themes were identified concerning the various codes in the analysis using a qualitative analysis software (QSR NVivo 9). This allowed the researcher to come up with a thematic map (Figure 1) that would best examine the application of the periodization training approach for sprinters in the country.

Results

Overview

This study is the first to assess the knowledge and use of periodised training made by Sri Lankan short-sprint coaches. Themes and sub-categories emerged following the process of thematic analysis can be seen in Figure 1. Four higher-order constructs emerged: ''*Periodisation models*'', ''*Monitoring training*'', ''*Strength development*'', and ''*Speed development*". Each of these constructs will now be explored in greater depth as to their precise meaning while being simultaneously located, where appropriate, within the existing body of knowledge. The following section will detail the major findings within each category and sub-theme concerning the range of knowledge on periodisation and training methods held by the expert short-sprint coaches interviewed. Where relevant, quotes from interviewees are included with the pseudonyms C1 through to C10. The gender-neutral pronoun "they" has been used throughout to hide the gender of the coach.

Periodisation models

Periodisation models included the use of type of periodised training they employed and the knowledge about it. Eight of the ten coaches are unaware of the model. "As a coach, I feel not prepared to use the periodisation models in my training even though heard about it" (C2). "We do not do periodisation because we do not have proper knowledge" (C5). Another coach (C1), who produced South Asian junior gold medallist, said the following:

"I do have athletes who can qualify for the Olympics. They can qualify. Nevertheless, my knowledge of periodization and strength and conditioning is not perfect. In addition, the microcycle knowledge also is not enough. Those areas all should be developed. Nevertheless, we do not have the facilities and opportunities to develop that knowledge".

Monitoring training

Monitoring training included knowledge about monitoring and the facilities for it. All the coaches mentioned that they do not have sufficient knowledge about monitoring. "I do not perform monitoring or testing properly as I do not have depth idea about it" (C6). "I do not use anything because our science side is weak" (C5). "No, I do not do that because I do not have knowledge" (C1). Another coach (C3), said the following:

"I have some idea about monitoring, but I do not have a big idea about this. Just a normal level idea".

Strength development

Strength development included training plan, training method and the load they used. Nine of the ten coaches use non-periodized training. Seven

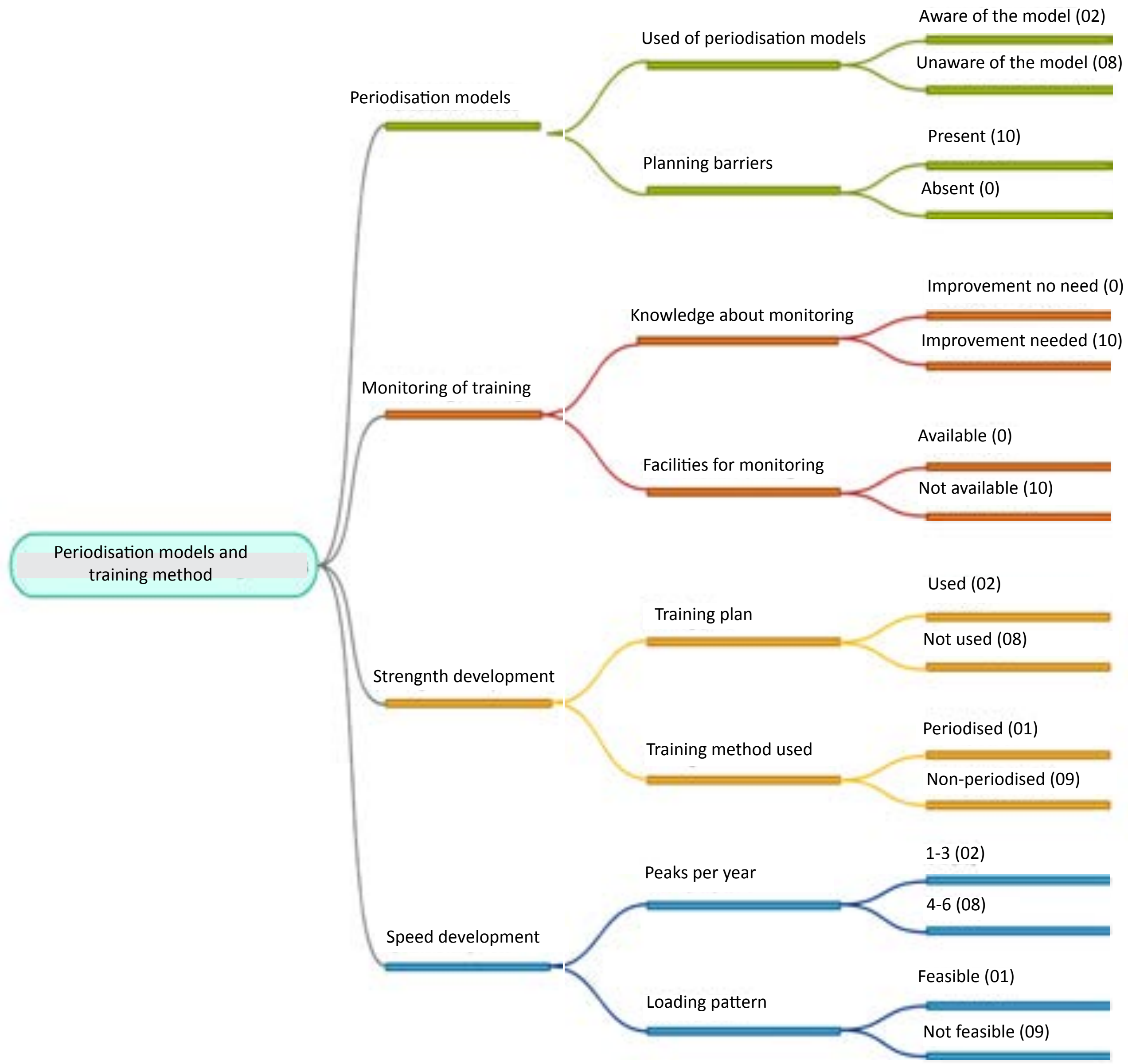

Figure 1. Thematic mind map of semi-structured interview.

of the ten do not have a clear plan for strength development. "I do not plan my training as I do not have a big idea about intensity and volume for developing strength. I do the way I know" (C3). "During special preparation, the percentage is 80%, repetition is 8 and 2 sets. For pre-competition, the load is 95% with 3 reps and 1 - 2 sets. During the competition period, 98%" (C4). Another coach (C9), who produced Asian junior gold medallist, said the following:

> *"I start with about 35-40% with 10 to 12 reps and 3-4 sets in general preparation. In special preparation, 60- 65% with 8 – 10 reps and 3 sets. In pre-competition intensity is about 80 – 85% with 6 reps and 2 sets. Intensity during the competition, we do not use 100%. Maybe 98%. This is during competition training 95% – 98% with 1- 4 reps and 1 to 2 sets"*

Discussion

The purpose of this formative exploratory study was to examine knowledge about, and application of, periodisation and training methods employed by Sri Lankan elite-level coaches working with short-sprint athletes.

The majority of participants in this study did not possess the minimal knowledge necessary to design, implement, and supervise periodized strength and conditioning programmes for short-sprint athletes based on the findings of this study. The results of this study indicate that coaches need further training and continuing education specific to periodisation training. Periodised training is more effective than non-periodised training in trained subjects, according to scientific research and training practice [53–55]. According to the findings of the study, despite the fact that a few coaches confirmed that they had adopted periodization approaches to training athletes, they believed that they lack the necessary knowledge to translate their athletes to the Olympics. Even though coaches believed that knowledge about periodisation and training methods are very essential, they reported that their knowledge is inadequate to transfer their athletes to Olympics. The main reason for this was that they bore inadequate resources in terms of expertise. In this case, the coaches' knowledge was derived from their extensive personal experiences. Due to this, Sri Lanka has experienced significant challenges associated with training its top athletes over the years. This problem has made it particularly difficult for these competitors to win in the international arena. For this reason, it is essential to ensure that the country bears a suitable means of training coaches on enabling them to gain relevant knowledge and skills.

Coaches were able to recognize the importance of periodization of training as opposed to using non-periodization, which had little impact on athletes' physical well-being due to a lack of adequate monitoring techniques [37, 56] including for youth athletes [57]. This also goes to show that athletes should be able to understand what is required of them at any particular time of the training process to ensure that they experience overall growth in terms of fitness development. Sri Lankan short-sprint coaches often deal with an increasingly large number of competitions throughout the year, which also subsequently reduces the use of periodisation.

On the other hand, most coaches in Sri Lanka lacked relevant expertise concerning advanced knowledge and skills on matters of training in general. Although a considerable percentage of the respondents proved they had sufficient experience concerning having been part of a training team in their past experiences, it was evident that they were unaware of how to go about to effecting essential periodized techniques in training [58]. Such being the case, this has often made it difficult for them to effectively guide athletes on essential means of enabling them to be competitive enough not only in the Olympics but also in the Asian Games. Therefore, relevant stakeholders need to find logical solutions concerning rectifying this problem. One of how this can be made possible is by enrolling them in proper and advanced learning in the field of sports and, more specifically, what to do when it comes to ensuring that they are capable of conducting effective training sessions for their athletes.

The results also highlighted that a majority of coaches lacked proper training plans. Although quite a number of the respondents confirmed that they had proper ways of conducting their training programs, it was evident that most of their plans were not probable and feasible. The plans were not in any way, capable of meeting the requirements of coming up with informed periodization models. A majority of coaches, therefore, need to be guided on how to come up with plans that may allow their athletes to be in a position of training under similar conditions as their competitors in other countries.

Despite the fact that most coaches work with groups of athletes, it is important to focus on each athlete's responses to training rather than the group's overall performance [59]. Monitoring training load during a macrocycle is an important strategy to increase physical performance and reduce possible risks of overtraining. Even though monitoring the progress of athletes is a vital component of the training process [15, 60], coaches neglect monitoring due to lack of knowledge and facilities. All the coaches, who are not implementing monitoring methods, reported knowledge or financial constraints. Athletes should be closely monitored during preparation to ensure that the desired results on athlete's performance and well-being are achieved [61]. Monitoring of training leads to improved sports skill, which results in increased sports performance. Therefore, coaches should include strategies to monitor the training load in order to improve the accuracy of training periodization and reduce the risk of over- or under-training [62].

Most of the coaches apply inadequate intensities and volume for their athletes. According to most experts, advanced athletes should perform 2 to 6 repetitions of 85% 1RM (of 1 repetition maximum [RM]) for strength gains and 6 to 12 repetitions at higher loads [75% -85% 1RM] for power conversion [63–66]. However, when beginning strength training with boys and girls start with a mild to moderate weight (60 percent of 1RM).

Conclusions

As a foundation for further research, the current exploratory study aimed to examine the knowledge and use of periodised training made by Sri Lankan short-sprint coaches who are considered as being expert coaches. The coaches sampled in the study believed that they lack adequate knowledge to translate their athletes to the Olympics suggesting that our study is heuristically significant. Future research should investigate the potential of coach education for short-sprint coaches in Sri Lanka. Additionally, research should be conducted with Sri Lankan short-sprint athletes to investigate the benefit of periodised strength and conditioning on their performance. Government should aim to optimize social and economic resources to provide learning opportunities for Sri Lankan coaches in order to develop a coaching education system in Sri Lanka. This requires collaboration from international experts and a commitment to research in order to produce knowledge firmly grounded in the specific needs of Sri Lankan coaches.

Limitations

This study had a Sri Lanka sample and only considered the knowledge of elite short-sprint coaches. Therefore, the findings cannot be generalised to other countries, coaching cultures, sports, contexts, or novice coaches.

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Conflict of interest statement

The authors declare no conflict of interest regarding this manuscript.

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ORIGINAL ARTICLE

The effect of TRX suspension trainer and BOSU platform after reconstruction of anterior cruciate ligament of the knee joint

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Abstract

Background and Study Aim The tear of the anterior cruciate ligament of the knee joint is experienced by people of all ages for a variety of reasons. The physiotherapy procedures with different equipment help recover lost functions. The aim of this research was to determine the effect of 'TRX' (Total body Resistance eXercise) suspension trainer and platform 'BOSU' (Both Sides Utilized) after anterior cruciate ligament of knee joint reconstruction.

Material and Methods The study included 20 patients after anterior cruciate ligament reconstruction surgery, 13 women, age (31.7 ± 3.4) and 7 men, age (31.7 ± 3.5) participated in the assessment. The strength of the calf flexors and extensors muscles was assessed by Lovett scale. The range of motion of the knee joint was assessed by goniometer. The static and dynamic body balance was assessed by Fullerton Advanced Balance Scale. The stability of the knee joint was assessed by Lachman test. The statistical data reliability was evaluated using Student's T criterion.

Results The data obtained showed that stabilization exercises with 'TRX' suspension trainer ant platform 'BOSU' have positive effect on knee joint after reconstruction. In the first and second group strength of the calf flexors and extensors muscles, amplitude of knee joint, static and dynamic balance significantly increased ($p<0.05$). Knee joint stability increased. Comparing both groups' results, there are no statistically significant difference ($p>0.05$).

Conclusions Physiotherapy exercises with TRX suspension trainer and platform 'BOSU' can help patients to return lost muscles strength, knee joint amplitude, static and dynamic balance and knee joint stability.

Keywords: rehabilitation, physical therapy, injury, fitness, joint stability, muscle

Introduction

Functions of the anterior cruciate ligaments and the mechanism of injury. The main function of the anterior cruciate ligament is to prevent the anterior tibia from slipping relative to the femur. Anterior crucial ligament provides 85 percent. Resistance forces to prevent the front tibia from slipping when the knee joint is bent at 30 ° and 90 °. The anterior cruciate ligament also performs other functions: it limits the hyperextension of the knee joint, it limits the internal and external rotation of the tibia relative to the femur, and it limits the slip of the femur back during weight transfer [1]. Cross ligaments are damaged during direct and indirect contact. Direct contact or stroke - this type of injury usually occurs in contact sports such as football, rugby or basketball. The knee joint is in a forced position subjected to a strong impact. Non-contact injuries: sudden stopping, changing the direction of running when the pavement surface is uneven, jumping on one leg, suddenly twisting the leg through the knee joint, when the ankle joint is fixed, knee joint hyperextension [2]. Treatment of the anterior cruciate ligament should be individualized and tailored to the needs of each patient. In case of anterior crucial ligament trauma, patients can be treated in two ways: conservatively and surgically. Older people who are not physically active are usually treated conservatively. In young patients, active athletes, surgical treatment during anterior crucial ligament reconstruction is most common. The younger and more active the patient, the earlier the surgery is performed. The choice of the most effective treatment must take into account the symptoms experienced by the patient, the clinical examination, the time elapsed since the injury, and the needs for daily physical activity [3].

Physiotherapy is one of the most important rehabilitation methods used in cases of anterior crucial ligament disorders. Rupture of the anterior crucial ligament decreases the muscle strength

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of the injured leg and the amplitude of active movements through the knee joint [4]. Therefore, the scientific literature recommends starting physiotherapy before surgery. Complete restoration of the amplitude of motion through the knee joint in the preoperative period reduces the risk of arthrofibrosis. It has been established that proper preoperative rehabilitation determines the positive course of postoperative rehabilitation and treatment and faster recovery of the patient's physical activity [5]. Various studies are being conducted in many parts of the world to find and adapt the most effective means of rehabilitation and to restore lost knee joint function as quickly as possible and to safely restore a patient to pre-traumatic physical activity levels [6]. The overall goal after anterior cruciate ligament reconstruction surgery is to restore normal knee joint biomechanics and stability, return the patient to preoperative activity levels, and improve health-related quality of life. However, many factors such as fear of re-trauma, persistent pain, knee instability, and weakness can affect a patient's condition after anterior crucial ligament reconstructive surgery [7].

TRX (Total body Resistance eXercise) functional belts are now widely used in gyms and during rehabilitation. [8]. The term "functional belts" was coined by TRX. Due to its versatility, the TRX functional belt system is used in rehabilitation and various sports exercises. The TRX sports system consists of a variety of exercises that use body weight as resistance. By choosing a point of contact with the floor, athletes can increase or decrease body weight and resistance through special exercises [9]. TRX functional belts are suitable for people with any level of physical fitness. With their help, muscle strength, joint stability, balance and endurance are developed 10]. U.S. General Surgeon fact sheets state that moderate-intensity exercises with TRX functional belts promote weight loss and reduce the risk of disease. In addition, TRX functional belts have been used effectively in rehabilitation exercises to restore impaired patient function. During testing, it was shown that exercises with TRX functional belts improved the height of vertical jumps by 9%, hockey players improved skating speed, and 5,000-meter runs accelerated by 47 seconds [9].

The TRX functional belt system allows you to perform many exercises of different intensities depending on the load and stability. Using TRX functional belts creates a constant force that, together with body weight, acquires resistance [10]. Such functional systems use certain principles to perform various exercises, to increase or decrease their intensity. The basic idea of this type of exercise is the principle of stability, which states that the size and position of the support base relative to the center of gravity determine the stability of the exercise [9]. The wider base allows for greater stability depending on the position of the feet: feet together or standing on one foot. Physiotherapy sessions on an unstable balancing platform BOSU (Both Sides Utilized) are gaining more and more popularity [11]. BOSU is an unstable balancing platform that consists of a rubber balance attached to a rigid plastic base. Its name is translated as "Two Sides Up," i.e. "Use of both sides". This means that during the session there is an opportunity to perform exercises based on balance and on a flat surface [12]. Exercises on the platform develop almost all physical qualities: endurance, strength, flexibility, coordination. During the exercises, not only the target muscle groups work, but the straight muscles of the back work actively, which stabilizes the proper position of the body in space, whether it be different static positions or dynamic work. Thus, a proper balance of muscle work is observed, the support-movement system is strengthened, the asymmetry of movement is smoothed, and a proper relationship between the upper and lower torso at the fascia level emerges [12]. In addition, exercises with BOSU are necessary for injury prevention after injuries. Proper selection of exercises can correct various functional disorders of the musculoskeletal system [11].

Purpose. The aim of this research was to determine the effect of 'TRX' suspension trainer and platform 'BOSU' after anterior cruciate ligament of knee joint reconstruction.

Material and Methods

Participants

The study included 20 patients after anterior cruciate ligament reconstruction surgery, all of whom gave voluntary consent to participate in the study and signed the individual's consent. Those who agreed to participate in the study were explained in detail the course of the study and introduced to the possible inconveniences of the study. The study included 20 patients after anterior cruciate ligament reconstruction surgery. A total of 13 women, mean age (31.7 ± 3.4) and 7 men, mean age (31.7 ± 3.5) participated in the assessment of gender distribution. All subjects in the study were randomly divided into two groups. Group I consisted of 10 patients. A total of 7 women and 3 men participated in the study to assess the gender distribution of group I (TRX) patients. Group II (TRX and BOSU) also consisted of 10 patients. A total of 6 women and 4 men participated in the gender distribution of this group.

The study included individuals who met the following criteria:

1. Diagnosed knee anterior crucial ligament rupture;
2. Reconstructive operation of the anterior cruciate ligament of the knee was performed;
3. 25-35 years of age;

4. Non-athletes;
5. Secondary rehabilitation;
6. 6 weeks must elapse after surgery;
7. Women and men participate in the study;
8. Patients without bone tumors, osteoporosis, joint diseases, arthrosis, joint prostheses, chronic kidney disorders, ankle joint instability, neurological diseases are included in the study.

Research ethics

The research was approved by the Bioethics Commission of the Department of Rehabilitation of Klaipeda University (No. 46 Sv - HMRK - 01) and the director of the physiotherapy center of UAB "Jurando". Study participants confirmed their participation by signing the informed consent form. The research protocol carried out according to the Helsinki Declaration.

Research Instruments

For the subjects, the muscle strength, the amplitude of the knee movement, the stability of the knee joint, and the static and dynamic balance of the body were assessed. All tools and methods used in the study were applied without infringing copyright, as their descriptions are open access texts on the Internet. The following instruments were used in the study:

Evaluation of thigh muscle strength

Was assessed with Lovett Scale [13] At the beginning and end of the study, the leg force of all patients undergoing leg flexion and leg extension through the knee joint was measured and the change in muscle strength was assessed. When measuring thigh muscle strength, the muscle strength of healthy and injured leg was also compared. The results obtained for healthy leg muscle strength were not recorded because they were insignificant to achieve the purpose of the study. The strength of the flexor muscles of the knee joint is assessed while the patient is lying on his stomach. The physiotherapist fixes the back of the patient's thigh with one hand and places the other hand on the back of the lower leg. The patient is asked to bend the calf through the knee joint. At that point, the physiotherapist provides resistance to this movement. The strength of the extensor muscles of the knee joint is assessed while the patient is sitting on the edge of the couch. The physiotherapist fixes the patient's thigh with one hand and places the other hand at the middle of the calf, below the knee joint. The patient is asked to place the lower limb through the knee joint. At that point, the physiotherapist provides resistance to this movement. Lovett scale rated: 0 points - No contraction; 1 point - Flicker or trace of contraction; 2 points - Active movement, with gravity eliminated; 3 points - Active movement against gravity; 4 points - Active movement against gravity and resistance; 5 points - Normal power. Max score - 5 points.

Knee joint range of Motion

Assess with Goniometry [14, 15]. In the study "Effect of TRX functional belts and unstable platform BOSU after rupture of the anterior cruciate ligament rupture of the knee joint", the amplitude of active movements through the knee joint was assessed by goniometer. The flexion of the leg joint and the construction of the leg joint were evaluated in all patients. Evaluation was performed at the beginning and end of the study. Bending through the knee joint. The patient is asked to lie on his stomach on the couch. The rear surface of the knee is then inspected for swelling. The patient is asked to actively bend the leg across the knee joint to extract the greatest possible amplitude of movement. During the test, the physiotherapist places the stationary part of the goniometer at the midline of the thigh and the moving part along the midline of the lower leg. The center of the goniometer must coincide with the center of motion in the joint. Maximum Knee flexion -140° degrees; Knee Extension - 0° degrees. It is important to compare the amplitude of the extension of the calf of a healthy and damaged leg through the knee joint. Construction through the knee joint. The patient is asked to lie on his stomach. It is then examined for swelling. The patient is asked to actively bend the leg across the knee joint and stretch. When evaluating the extension of the tibia of the leg operated by the patients through the knee joint, the number of degrees is missing before the complete extension of the tibia through the knee joint, i.e. to 0°. It is important to compare the amplitudes of the calf of a healthy and damaged leg through the knee joint.

Assessment of static and dynamic body balance.

Was performed with Fullerton Advanced Balance Scale (FAB) [16]. In the study "Effects of TRX functional belts and unstable platform BOSU after knee anterior cruciate ligament reconstruction surgery", the assessment of static and dynamic equilibrium was performed using the Fullerton Advanced Balance Scale (FAB). This test assesses both static and dynamic equilibrium [17]. 10 performance based activities in both static and dynamic phases. Items scored on a 5 point ordinal scale (0-4). 0 points - the patient is unable to perform an attack, 1- movements are arrhythmic, oscillation, tremor, extraneous movements, unwilling or unable to close, 2 - increasing the speed of performance decreases the accuracy of movements, balance is maintained for a very short time, 3 points - small inaccuracies, 4 points - normal movement and body position control (maintained balance for a period of time or while walking a set distance). The test is administered for 10-12 mins. Score of 0-40 / 40 points possible (higher scores are better).

Assessment of knee instability.

Was performed with Lachman test [18]. In the study "Effect of TRX functional belts and unstable platform BOSU after knee joint anterior cruciate ligament rupture reconstruction", knee instability was assessed using the Lachman test. Performance: Lying on your back, legs bent at an angle of 30°. The researcher stabilizes the thigh with one hand and covers the proximal inner part of the lower leg with the other hand. The proximal inner end of the tibia is gently pulled forward. If the front displacement is more than 5 mm, the Lachman test is positive.

Research progress.

The study was performed at UAB "Jurando" Physiotherapy Center. Duration of the study: 19/11/2011 - 19/19/2019. The aim of this study was to identify and compare the effects of two different physiotherapy measures on the restoration of knee joint function in patients after anterior crucial ligament reconstructive surgery. To achieve the goal, the subjects were divided into two groups by random sampling. Group I patients underwent stabilization and strength exercises with TRX functional belts, 3 times per week, duration of one session 1 hour (60 min), group II patients received exercises with TRX functional belts and Bosu unstable platform 3 times per week, one session duration 1 h [60 min). Rehabilitation treatment was started on average 6 weeks after anterior crucial ligament reconstructive surgery. Testing was performed twice: before the study and at the end, which lasted 8 weeks and was performed in 14 physiotherapy sessions. The results are summarized and compared. All subjects underwent 14 visits to the outpatient rehabilitation unit after anterior cruciate ligament reconstruction surgery. During outpatient rehabilitation, patients underwent 14 physiotherapy procedures in the gym, 14 physiotherapy procedures in water, as well as 7 massage procedures and 14 RES procedures. Other procedures were prescribed based on each patient's current medical condition. For example, magnet therapy is used in patients with swelling of the knee joint of the operated leg. Continuous passive motion therapy is used in patients with a bending amplitude across the knee joint <90 degrees. The procedures are applied individually after 30 minutes.

Physiotherapy program

Physiotherapy is one of the most important rehabilitation methods used in patients after anterior cruciate ligament reconstruction surgery. Although the first (TRX) and second (TRX and BOSU) groups had different methods of performing physiotherapy procedures, the main goals of rehabilitation were the same: to increase flexor and extensor muscle strength and reduced range of motion in the knee joint, to restore knee stability and balance, and activity. In the study "Effect of TRX functional belts and unstable platform BOSU after knee anterior cruciate ligament reconstruction surgery" to increase the reduced range of motion through the knee joint and muscle strength, all subjects in the physiotherapy program included exercises on TRX functional belts in various directions. As patients' functional status improved, heavier exercises were used during physiotherapy procedures, increasing the speed of exercise and the number of repetitions. For patients after anterior crucial ligament reconstructive surgery, it is especially important to include balance and coordination exercises in the physiotherapy program. To develop balance and coordination, exercises were performed while standing on an unstable boss BOSU on two legs, one leg, standing with his eyes closed.

Statistical analysis

The study data were processed by IBM SPSS 17.0 (Statistical Package for the Social sciences, version 17.0) program. The software used to calculate arithmetic means, rates, standard deviations, and mean errors. The statistical data reliability was evaluated using Student's T criterion (where $p > 0.05$ means the difference is statistically insignificant and $p < 0.05$ means the difference is statistically significant).

Results

Changes in tibial flexor and extensor muscle strength (fig. 1).

At the beginning of the study and after the study, calf flexor and extensor muscle strength was measured in patients who underwent anterior crucial ligament reconstruction surgery. The mean tibial flexor muscle strength of the group I (TRX) subjects was 2.4 ± 0.51 points at the beginning of the study, and the average score after physiotherapy sessions was 3.9 ± 0.56. Thus, the strength of the tibial flexor muscles increased statistically significantly in the TRX group ($p < 0.05$). The mean tibial flexor muscle strength was 2.6 ± 0.51 points before the study in group II (TRX and BOSU), and 4.3 ± 0.67 after the study. After analyzing the obtained results, it can be stated that in the course of the study, in the TRX and BOSU group, a significant change in the strength of the lower leg flexor muscles was also found ($p < 0.05$). Mean estimates of calf flexor muscle strength between the TRX group and the TRX and BOSU group before and after sessions measured in patients undergoing anterior crucial ligament reconstructive surgery. During the study, a significant change in the strength of the extensor muscles of the leg operated on the patients was observed ($p < 0.05$). In group I (TRX) subjects, the mean tibial extensor strength was 2.4 ± 0.51 points before the study, and the average score after physical therapy sessions was 4.4 ± 0.51. The obtained results show that in group I (TRX) the strength of the extensor muscles of the knee joint increased statistically significantly ($p < 0.05$). At the beginning of the study, in group II (TRX and BOSU), the mean force of the extensor muscles of the knee joint was 2.3 ± 0.48 points, after the study the mean score was 4.6 ± 0.51. Thus, in group II (TRX and BOSU), the strength of the extensor muscles of the knee joint was also significantly increased (p <0.05). Mean estimates of knee extensor muscle strength did not differ statistically significantly between group I and group II before and after physical therapy sessions (p> 0.05), a better change was found in the second group.

Research groups joint range of motion assessment results (fig. 2).

The amplitude of knee flexion movements was measured in patients after anterior crucial ligament reconstructive surgery. After reviewing the obtained results, it can be stated that a significant change

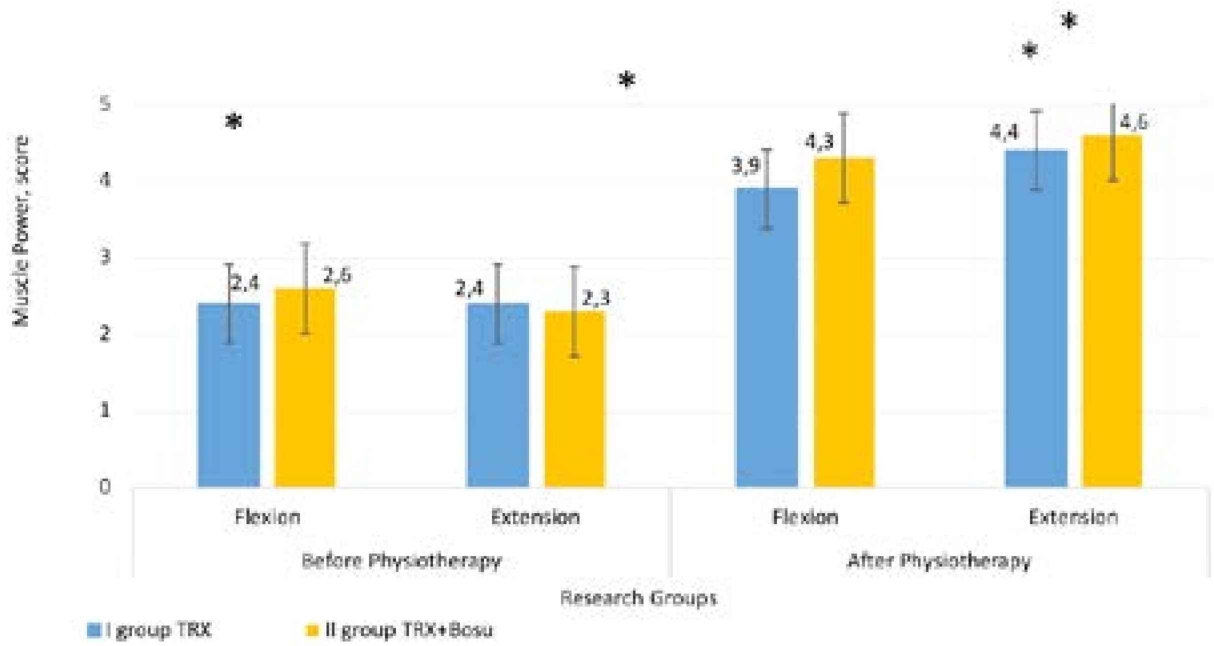

Fig. 1. Research subjects' knee flexor and extensor muscles power. Statistical significance, p<0.05 (*).

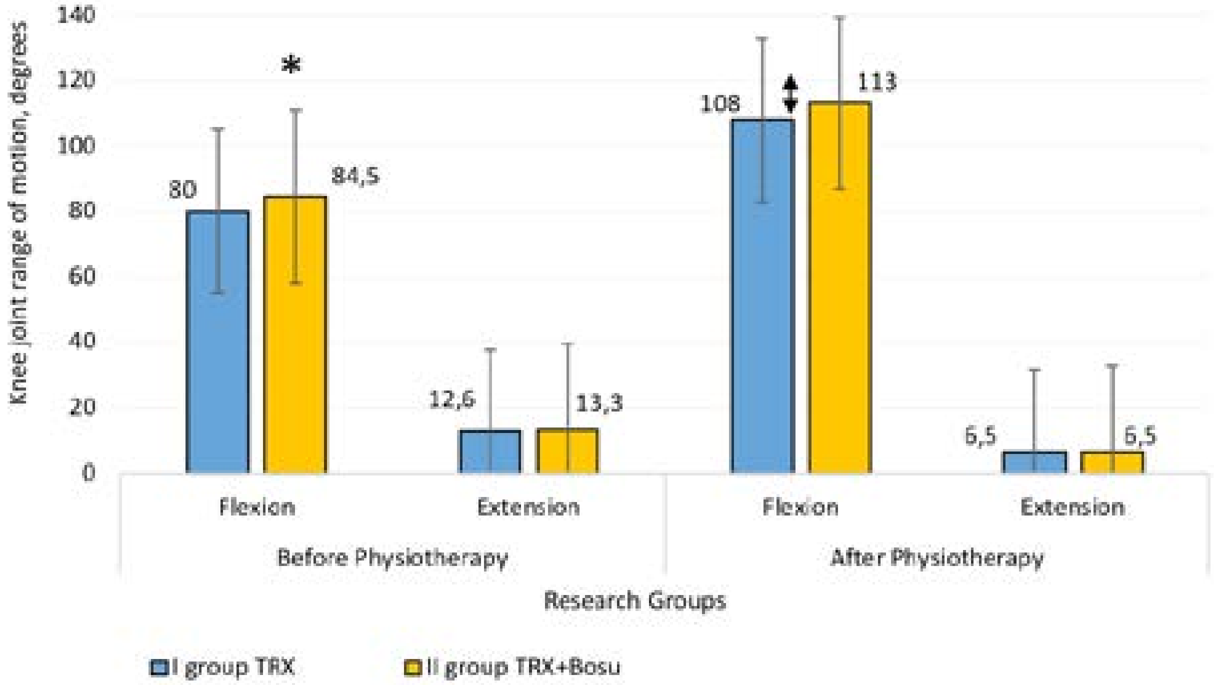

Fig. 2. Research subjects' knee joint flexion and extension range of motion assessment. Statistical significance, p<0.05 (*).

in the amplitude of the flexion movements of the lower leg of the operated leg was observed ($p < 0.05$). The mean amplitude of the knee joint flexion movements of the group I (TRX) subjects was 80 ± 14.9 degrees at the beginning of the study and 108 ± 12.06 after the study. Reviewing the results of group I, it can be stated that the amplitude of knee bending movements increased statistically significantly during the study ($p < 0.05$). At the beginning of the study, the mean amplitude of the leg flexor movements of group II (TRX and BOSU) was 84.5 ± 16.4 degrees, and at the end of the study, the mean degrees were 113 ± 14.56. Thus, at the end of the study, a significant change in the amplitude of the bending movements of the knee joint was also observed in group II ($p < 0.05$). Mean estimates of the amplitude of knee flexion movements between group I (TRX) and group II (TRX and BOSU) before and after physical therapy sessions did not differ statistically significantly ($p > 0.05$), a better change was found in the second group (TRX and BOSU). The amplitude of knee joint movement movements was measured in patients after anterior crucial ligament reconstructive surgery. Thus, in the course of the study a significant change in the amplitude of the movements of the operated leg calf was observed ($p < 0.05$). At the beginning of the study, the mean amplitude of the knee joint movement movements of the group I (TRX) subjects was 12.6 ± 4.35 degrees. After the examination - 6.5 ± 2.59 degrees. Thus, in group I, a positive change in the amplitude of the examined knee joint movement movements was found ($p < 0.05$). At baseline, in group II (TRX and BOSU), the mean amplitude of knee joint movement was 13.3 ± 4.87 degrees. After the examination - 6.5 ± 2.32 degrees. Thus, in group II, a significant change in the amplitude of knee joint movement movements was also found ($p < 0.05$). The mean estimates of the amplitude of knee joint movement movements between group I (TRX) and group II (TRX and BOSU) before and after physical therapy sessions did not differ statistically significantly ($p > 0.05$), the same change was found in both groups.

Static and dynamic equilibrium change (fig. 3).

The static and dynamic equilibrium of the subjects was assessed by the Fullerton Equilibrium Test (FPT). The mean score of this test in group I (TRX) before physiotherapy sessions procedures was 23.4 ± 4.45 points, after physiotherapy sessions procedures it increased statistically significantly ($p < 0.05$) and reached 33.2 ± 2.1 points. After calculating the mean score of the group II (TRX and BOSU) FTP test before physical therapy sessions it was 25.2 ± 4.94 points, and after physiotherapy sessions (36.6 ± 1.71) points. Group II (TRX and BOSU) also showed a statistically significant change ($p < 0.05$) after physiotherapy sessions. FPT mean estimates between group I (TRX) and group II (TRX and BOSU) before physical therapy sessions did not differ statistically significantly ($p > 0.05$), and after physical therapy sessions there was a statistically significant difference ($p < 0.05$), better change was found Study group II (TRX and BOSU).

Change in knee instability (tabl. 1).

The subjects' knee instability was assessed by the Lachman's test. When evaluating individual patient outcomes, it was observed that in both groups of 20 subjects, the Lachman test was positive before physiotherapy sessions procedures (in group I TRX 3 subjects and in group II TRX and BOSU 4 subjects). After the study, the stability of the knee joint improved, a positive test remained in 3 subjects (TRX for 2 patients in group I and TRX and BOSU for only 1 patient in group II).

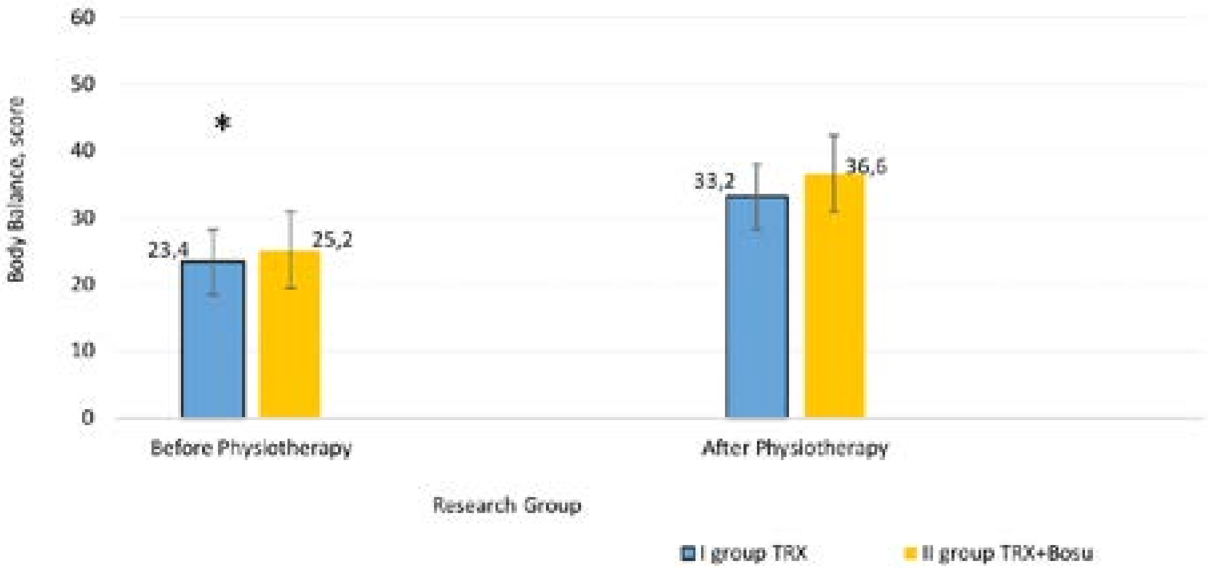

Fig. 3. Research subjects' static and dynamic body balance assessment. Statistical significance, p<0.05 (*).

Table 1. Knee joint stability assessment.

Research groups	Test before Physiotherapy (positive/negative)	Test After Physiotherapy (positive/ negative)
I (TRX)	3 patients positive 7 patients negative	2 patients positive 8 patients negative
II (TRX ir BOSU)	4 patients positive 6 patients negative	1 patient positive 9 patients negative

Discussion

This paper analyzes the impact of TRX functional belts and the unstable platform BOSU on those who underwent reconstructive surgery for anterior cruciate ligament rupture. After reviewing the scientific literature, it has been observed that anterior crucial ligament reconstruction surgery often results in a decrease in the amplitude of movements through the knee joint, weakened knee flexor and extensor muscle strength, imbalance and marked knee instability [19]. The data obtained from the study showed that the use of exercises with TRX functional belts and the unstable platform BOSU had a positive effect on all subjects. Thigh muscle strength increased, amplitude across the knee joint, static and dynamic balance improved, knee joint stability was restored. In the study “Effect of TRX functional belts and unstable platform BOSU after reconstruction of the anterior cruciate ligament rupture of the knee joint”, two research groups were formed, which differed in the rehabilitation methodology. Group I subjects underwent exercises only on TRX functional belts, and group II subjects underwent exercises on both TRX functional belts and the unstable BOSU platform. Unfortunately, in Lithuania, such studies that would confirm the effect of TRX functional belts and unstable platform BOSU on patients after reconstruction of the anterior cruciate ligament rupture of the knee joint could not be found.

Strength of flexor and extensor muscles of the knee joint.

Many authors point out that anterior crucial ligament reconstruction surgery significantly reduces the strength of the flexor and extensor muscles of the thigh [20]. In the study “Effect of TRX functional belts and unstable platform BOSU after knee joint anterior cruciate ligament reconstruction surgery”, knee flexor and extensor muscle strength was assessed by manual knee flexor and extensor muscle strength testing according to Lovett R. W., Martin E. G. [13]. After reviewing the results, the strength of the calf flexor muscles of the I (TRX) group increased statistically significantly ($p < 0.05$). In group II (TRX and BOSU), the strength of the flexor muscles after physical therapy sessions also increased statistically significantly ($p < 0.05$). A better result was found in group II (TRX and BOSU). Similar results were obtained by reviewing the extensor muscle strength of the knee joint. Based on the estimates of the results after the physical therapy sessions with TRX functional belts and unstable platform BOSU, we found that there was a statistically significant ($p < 0.05$) improvement in both group I (TRX) and group II (TRX and BOSU) thigh extensor muscle strength. In summary, it can be stated that in both groups the strength of the flexor and extensor muscles of the knee joint improved statistically significantly ($p < 0.05$). Tugolukov A.V. [10] concluded that physical therapy sessions with TRX functional belts are an additional means to increase muscle strength. Istomin A. G. [8] also recognize the positive effects of using TRX functional belts in rehabilitation to develop knee flexor and extensor muscle strength.

Amplitude of knee joint movements.

Research shows that the amplitude of patient-operated leg movements across the knee joint also decreases after anterior crucial ligament reconstruction. In our conducted study, knee flexion and extension through the knee joint were evaluated with a goniometer. The amplitude of knee joint bending movements in group I (TRX) subjects increased statistically significantly ($p < 0.05$). In group II (TRX and BOSU), the amplitude of calf bending movements also increased statistically significantly ($p < 0.05$). After reviewing the amplitude of the knee joint construction in the subjects, the amplitude of the group I (TRX) construction increased statistically significantly ($p < 0.05$). Regarding group II (TRX and BOSU), the amplitude of knee joint movement movements also increased statistically significantly ($p < 0.05$). In summary, it can be stated that the amplitude of bending and stretching of the knee joint through the knee joint significantly improved in both groups ($p < 0.05$). Ucar M. et al. [21] conducted a similar study to estimate the amplitude of movements across the knee joint. A total of 58 patients participated in the study, who were randomly divided into two groups. Tests were performed 2 times, before and after the study. The first group performed exercises on an unstable platform 3 times a week, and the second group performed exercises without a platform 3 times a week. After reviewing the obtained results, it can be stated that the higher result was found in the first group.

Static and dynamic body balance.

The literature provides many standardized scales and tests for assessing equilibrium. The Fullerton Equilibrium Test was chosen for the study. The static and dynamic balance of group I (TRX) after physical therapy sessions increased statistically significantly ($p < 0.05$). After reviewing the results obtained in group II (TRX and BOSU), a statistically significant change ($p < 0.05$) was also found after physical therapy sessions. Tikhilov R.M.and colleagues [22] conducted a similar study with unstable platforms after reconstructive surgery. Our results are similar. Akbari A. et al. [23] also conducted a similar study to assess static and dynamic equilibrium using unstable platforms. A total of 60 subjects participated in the study. Subjects underwent balance exercises on unstable platforms 6 times per week for 30 min. Akbari argues that unstable platforms have a positive effect on static and dynamic equilibrium.

Knee instability.

The subjects' knee instability was assessed by the Lachman's test. When evaluating individual patient outcomes, it was observed that before physiotherapy sessions in both groups of 20 subjects, the Lachman test was positive in 7 subjects (TRX group 3 subjects and in the second group TRX and BOSU 4 subjects). After the study, the stability of the knee joint improved, a positive test remained in 3 subjects (2 patients in the first TRX group, and only 1 patient in the second group TRX and BOSU). Comparing the results of both groups, it can be stated that TRX and BOSU are effective methods for training knee joint stability, but in the second group (TRX and BOSU) the results are better. Bettendorf B., [9] agrees that TRX functional belts develop stability. The author has the same opinion Zemkova [11], which states that a BOSU unstable platform can cultivate knee joint stability.

Conclusions

1. In the first and second groups, the strength of the extensor and flexor muscles of the lower leg was significantly increased ($p < 0.05$) by using TRX functional belts and the unstable platform BOSU. However, the results before and after physical therapy sessions did not differ statistically significantly between the groups ($p > 0.05$).
2. In the first and second groups, the amplitude of movements across the knee joint was significantly increased ($p < 0.05$) using TRX functional belts and the unstable BOSU platform. However, the results before and after physical therapy sessions did not differ statistically significantly between the groups ($p > 0.05$).
3. In the first and second groups, the static and dynamic equilibrium was significantly increased ($p < 0.05$) by using TRX functional belts and the unstable BOSU platform. However, the results before and after physical therapy sessions did not differ statistically significantly between the groups ($p > 0.05$).
4. In the first and second groups, knee joint stability was improved by the use of TRX functional belts and the unstable platform BOSU. But the results before and after the physical therapy sessions did not differ significantly between the groups.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding this research.

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ORIGINAL ARTICLE

The effect of ankle strengthening exercise on balance in youth basketball players

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

Abstract

Background and Study Aim Balance is an important factor in basketball, so the level of balance that is still low needs to be improved to support future achievements, especially for youth basketball players. This study aims to improve the right and the left balance of adolescent basketball players aged 16 and 18 years old and determine the difference in the effect of theraband exercise and bosu ball exercise. The study was conducted to determine the effect of ankle strengthening exercise using bosu ball exercise and theraband exercise on the balance of male basketball players aged 16 years and 18 years is a type of quantitative research.

Material and Methods The research design used is experimental research with 2x2 factorial analysis, and the level of significance was set a 0.05 for all samples. The sample in this study amounted to 64 men's basketball players, with details of 32 players in the age group 16 and 32 players in the age group 18. Players in the age group 16 and age 18 were each divided into 4 sample groups using the ABBA formula, so that the number in each sample group consists of 8 players.

Results Pre-test left theraband exercise and post-test left theraband exercise = 5% (0.05) > sig. (2-tailed) 0.000, it can be interpreted that there is a significant change in left balance for basketball players aged 16 years after being given theraband exercise treatment. Pre-test left bosu ball exercise and post-test left bosu ball exercise on left balance the value of = 5% (0.05) > sig. (2-tailed) 0.001, then it can be interpreted that there is a significant change in left balance for basketball players aged 16 years after being given bosu ball exercise treatment. Pre-test left theraband exercise and post-test left theraband exercise = 5% (0.05) > sig. (2-tailed) 0.005, it can be interpreted that there is a significant change in left balance for basketball players aged 18 years after being given the theraband exercise treatment. Pre-test left theraband exercise and post-test left theraband exercise = 5% (0.05) > sig. (2-tailed) 0.005, it can be interpreted that there is a significant change in left balance for basketball players aged 18 years after being given the theraband exercise treatment.

Conclusions Characteristics of the age group of 16 years and 18 years are not much different. Bosu ball exercises give a better effect than theraband exercise. Although statistically not too significant, there is a difference in the average. That condition is because the motor system works more, starting from the legs, back, and abdomen muscles. The motor system that works when doing theraband exercise tends to be on the muscles in the legs.

Keywords: ankle strengthening exercise, theraband exercise, bosu ball exercise, balance.

Introduction

Basketball is a dynamic sport. The movement relies heavily on the feet to rest and serves as the center of mass (COM) so that the movement is very active [1, 2]. The foot that acts as the center of support is very dependent on the condition of the ankle in maintaining body balance, so if the body balance is good, it can be concluded that the condition of the ankle and the ankle propulsion muscles are also in good condition [2, 3]. Exercises and treatments that can help improve the condition of the moving muscles in the ankle are needed so that the balance of basketball players is not disturbed. Balance training for basketball players in Boyolali Regency has not been well controlled, and this is because there is no specific program to help improve the balance of basketball players. This condition is reinforced based on data findings in the field that the balance level of teenage basketball players in Boyolali Regency between the right and Left body balances has a significant difference, the average balance score of right is 94.87, and left is 100.41 with an average difference of 5 .53 points. Right balance details score 80-90: 13.33%, 91-99: 63.33%, and 100-110: 23.33%. Balance details left score 80-90: 16.66%, 91-99: 33.33%, 100-110: 43.33%, 111-120: 6.66%. Based on these data, the balance of right and left of teenage basketball players in Boyolali Regency is still quite low because

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the balance of right 76.66% is still below the score of 100 points, and the balance of left is 49.49% below the score of 100 points.

Poor balance conditions can certainly increase the percentage of lower extremity injuries. Foot and ankle injuries are very common in athletes and individuals who perform physical activities or sports [4]. Injuries to the ankle joint can occur when walking, running, and jumping, with the percentage of injuries reaching 50% of cases occurring in the ankle ligament [5]. Most injuries in basketball occur in the lower extremities, especially in the ankles and knees. Most injuries are orthopedic, namely ankle sprains, ACLs, and fractures [6]. Research data on observations of 12,960 injuries in basketball, 63.7% occurred in the lower extremities, with 2,832 (21.9%) ankle injuries and 2,305 (17.8%) knee injuries [7]. Based on the research data, it can be seen that the risk of injury to the lower extremities in basketball is high. There need to be actions that are focused on minimizing the risk of lower extremity injuries in basketball.

Research has been conducted by giving treatment using a bosu ball given to 18 women and 16 men with an average age of 21 years, showing an increase in balance and leg muscle strength [8]. Research on ankle strengthening conducted on students who had an ankle injury did not show significant results on balance growth. The exercise was given for six weeks after the student finished college [9]. Based on the results of these studies, of course, further research needs to be done regarding ankle strengthening exercises. Research on ankle strengthening exercise that is more specific is about the differences in the effect of theraband exercise and bosu ball exercise in improving the balance of male basketball players in the age group of 16 years and 18 years. Ankle strengthening exercise treatment is given after the players finish doing regular exercises in the field. The treatment given to the theraband exercise consists of four movements, namely: 1) Ankle Flexion Exercise, 2) ankle extension exercise, 3) ankle inversion exercise, and 4) ankle eversion exercise. The movement in the bosu ball exercise also consists of four movements: 1) single leg stand, 2) runner touch, 3) chest-passing in single-leg stance, and 4) forward-behind in single-leg stance. The research hypothesis is based on the existing theory that there is a balance between before and after training. There is a difference in balance between basketball players aged 12 and 18 years.

Materials and Methods

Participants

The population is a subject in an area and meets certain requirements related to the problem or object of research [9]. The population in this study were male basketball players aged 16 and 18 years (U-16 and U-18) in the Boyolali Regency who participated in the selection as members of the Boyolali Regency basketball team.

The sampling technique used is purposive sampling. Purposive sampling is sampling based on the researcher's assessment of anyone who deserves to meet the requirements to be sampled [10]. The requirements used to select the sample are by selecting players to take part in the Regional Student Sports Week and players prepared for the Regional Championship. Selection participants who pass to take part in the training center are taken as sample members. The sample in this study amounted to 32 male basketball players in Boyolali Regency, with details of 16 players aged 16 years and 16 players aged 18 years. Players in the age group of 16 and age group of 18 were each divided into 4 sample groups using the ABBA formula, with a total of 8 players in each sample group.

Study Design

The research conducted to determine the effect of ankle strengthening exercise using bosu ball exercise and theraband exercise on the balance of male basketball players aged 16 and 18 years is quantitative research. The research design used is experimental research with 2x2 factorial analysis. The research was conducted by providing an ankle strengthening exercise program consisting of two exercises: 1) theraband exercise and 2) bosu ball exercise given to male basketball players aged 16 years and 18 years. The purpose of this study was to determine the effect of the given exercise on the balance of male basketball players aged 16 and 18 years and to compare which exercise was better for improving the balance of male youth basketball players.

Table 1. Research Factorial Design [9)]

Ankle Strengthening Exercise (A) / Age Group (B)	Theraband Exercise (A1)	Bosu Ball Exercise (A2)
Age 16 years old (B1)	A1B1	A2B1
Age 18 years old (B2)	A1B2	A2B2

Instrumentation

The type of data in this study is primary data, so that data collection is carried out by testing [11]. Data were collected twice, namely pre-test and post-test. The pre-test and post-test data were carried out to determine the balance of KU-16 and KU-18 in Boyolali Regency before and after being treated. The data used in this study are the initial data (pre-test) and the final data (post-test).

Leg length measurements need to be done before doing the test using a predetermined instrument. The instrument used for data collection is the Y balance test (YBT) because the instrument has a high level of relevance and is efficient for analyzing the condition of the lower extremities, especially the ankle condition [12]. Leg length data is used to calculate the level of balance, which will be included in the Y Balance Test formula.

Y balance test is a balance test instrument whose validity is recognized by doctors and scientists. The instrument was developed from the Star Excursion Balance Test (SEBT) instrument. The difference lies in the direction of movement that must be carried out, namely YBT consists of 3 directions of movement, and SEBT consists of 8 directions of movement [13]. The direction of movement of the Y balance test is: a) AD: anterior, b) PMD: posteromedial, c) PLD: posterolateral (fig. 1, fig. 2) [14]. Y balance test is a balanced instrument with a 95% confidence level and a validity value of 0.89 – 0.97 [15]. The right and left anterior direction is 135o while the angle between posteromedial and posterolateral is 90o [12].

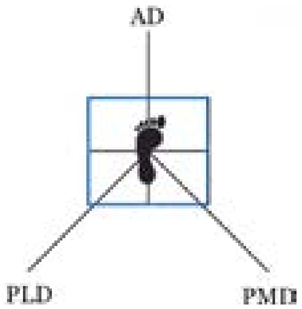

Figure 1. The direction of movement y balance test. [14]

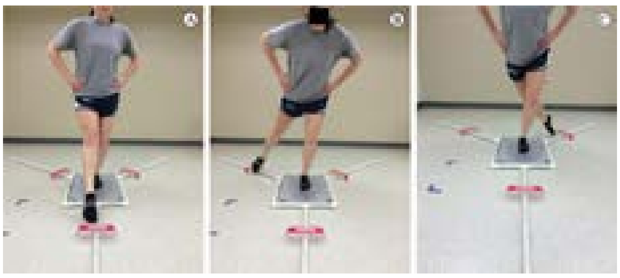

Figure 2. Y balance test. [16]

Information:
(A): anterior,
(B): posterior medial directions, and
(C): posterior lateral directions.

The Y balance test measurement tool can be modified using tape or a ruler attached to the floor according to a predetermined angle of 135o, while the angle between posteromedial and posterolateral is 90o [12, 17]. The value of the level of confidence and validity of the modification of the tool remains the same, namely 95% confidence and the validity value of 0.89 - 0.97 [17, 18]. Y Balance Test (YBT) is carried out to measure the balance on the right and left parts, measured alternately. Here is how to do the Y Balance Test (YBT):

1) The test taker stands on a point or platform with bare feet or wearing sports shoes.
2) Place both hands on the waist.
3) Test takers can try 3-6 times in each direction before taking the real test.
4) The actual test was carried out 3 times in each direction.
5) Participants are asked to move their legs to produce as far as possible and return their feet to the starting position.
6) The support leg must not be lifted or shifted when the other leg is moving.
7) The maximum coverage distance is then recorded in "cm" units.
8) Assessment of the Y Balance Test, the best achievement from each direction is then added and divided by three times the length of the leg (measured from the sias to the medial malleolus), multiplied by 100 as the normalized value.
9) The composite direction value is calculated by the formula: [(sum of the greatest reach in each direction) / (3 x limb length)] x 100

Exercise Protocol

Players selected as sample members were first examined regarding the condition of the muscles, ligaments, tendons, and joints in the lower extremities in general and specifically in the ankles. A team of physiotherapists carried out the examination, and the examination was carried out to ensure that basketball players aged 16 and 18 were allowed to perform ankle strengthening exercises with theraband exercises or bosu ball exercises. If the examination has been completed and the player is declared worthy of taking the exercise, the next step is to measure the balance using the Y balance test instrument. Balance measurements were carried out before and after the balance training program was completed.

The sample was divided into 4 groups consisting: 1) The age group of 16 years with theraband exercise, 2) The age group of 16 years with the bosu ball exercise, 3) The age group of 18 years with the theraband exercise, and 4) The age group of 18 years with the bosu ball. Exercise. The sample members gave the treatment after they finished doing regular exercises (skills and finishing) in the field. Ankle strengthening exercise treatment was given to each sample member for 16 meetings, with an exercise pattern of one day of exercise and one day of rest. Theraband exercise consists of four movements, namely: 1) plantarflexion (extension), 2) dorsiflexion (flexion), 3) inversion, 4) eversion. The Bosu ball exercise consists of four movements: 1) single-leg stance, 2) runner touch, 3) chest-passing in single-leg stance, 4) forward-behind in single-leg stance.

Statistical Analysis

Determining the statistical test used to process data needs to be determined precisely, using parametric or non-parametric statistics [19]. Data testing using parametric statistics can be done if the data is normally distributed and homogeneous. The following is a normality and homogeneity test, which was analyzed using SPSS 25. The normality test of the ankle strengthening, ice therapy, and age group research variables used the Liliefors (L) test, calculated using SPSS 25 software. The level of significance used in the normality test was = 5% (0.05). The homogeneity test of the research variables of ankle strengthening, ice therapy, and age group using Fisher's test (F) was processed using SPSS 25 software. The level of significance used in conducting the homogeneity test was = 5% (0.05).

The data analysis technique used in this study is a two-way analysis of variance (ANOVA) at a significance level of = 0.05. Furthermore, to compare the mean pairs of the given treatments used the Newman Keuls range test [20].

Results

The average score of the pre-test balance of male basketball players aged 16 years on the right balance is 97.76, and the left balance is 93.83 (fig. 3). The average value of the balance changed after being given the theraband exercise treatment. The post-test mean of the right balance was 102.05, and the left balance was 98.81.

Figure 4 shows that the theraband exercise treatment given to basketball players aged 16 years after regular training for 16 meetings with an exercise pattern of 1 training day and 1 day of rest showed a positive impact on improving right and left balance. The average increase in the right balance is 4.29, and the left is 4.98. Pre-test right theraband exercise and post-test right theraband exercise = 5% (0.05) > sig. (2-tailed) 0.000, then it can be interpreted that there is a significant change in

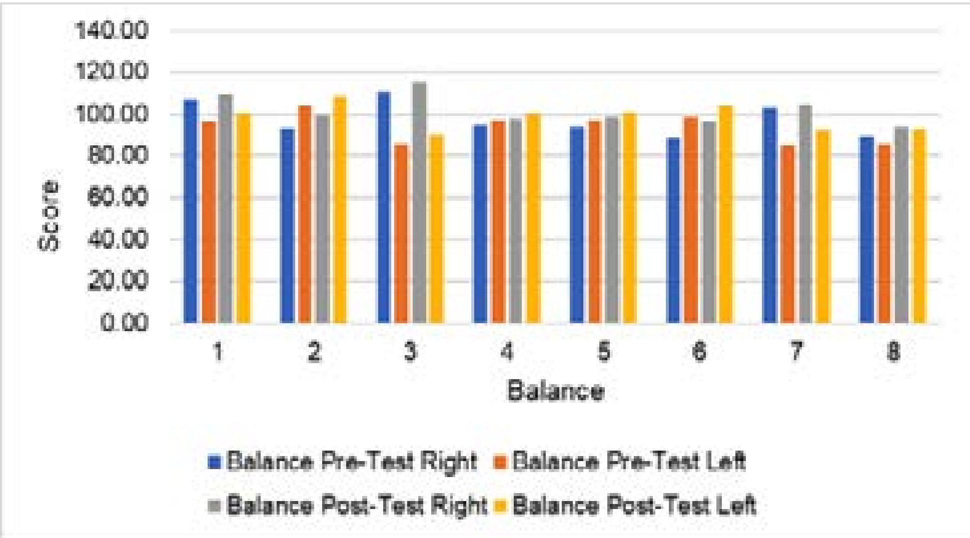

Figure 3. Data of balance theraband exercise 16 years old

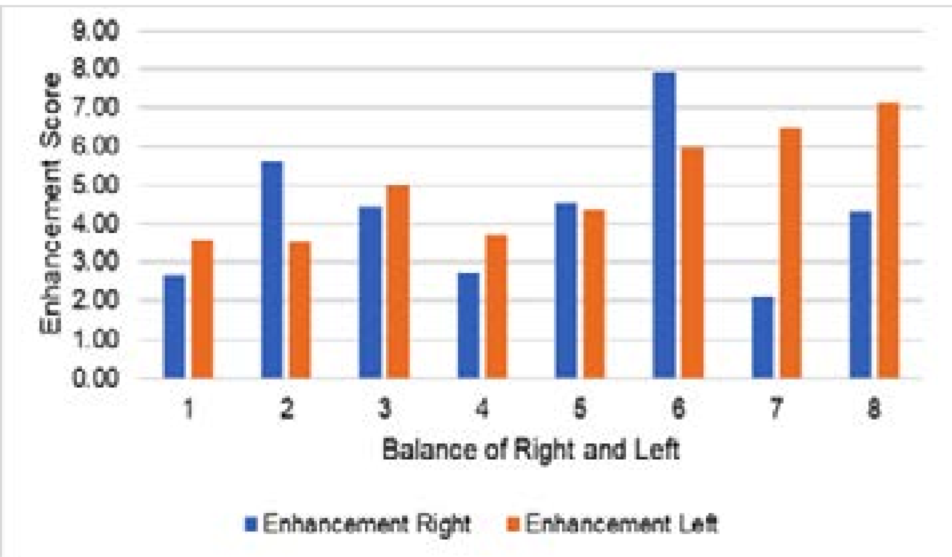

Figure 4. Enhancement of balance theraband exercise 16 years old

the right balance of basketball players aged 16 years after the theraband exercise treatment. Pre-test left theraband exercise and post-test left theraband exercise = 5% (0.05) > sig. (2-tailed) 0.000, then it can be interpreted that there is a significant change in left balance for basketball players aged 16 years after theraband exercise treatment.

The average score of the pre-test balance of male basketball players aged 16 years on the right balance is 98.27, and the left balance is 94.47 (fig. 5). The average value of the balance changed after being given the bosu ball exercise treatment. The post-test mean score for the right balance was 104.18, and the left balance was 100.64.

Figures 6 show that the bosu ball exercise treatment given to basketball players aged 16 years after regular training for 16 meetings with an exercise pattern of 1 day of training and 1 day of rest showed a positive impact on improving right and left balance. The average increase in the right balance is 5.91, and the left is 6.17. Pre-test right bosu ball and post-test right bosu ball exercise = 5% (0.05) > sig. (2-tailed) 0.000, then it can be interpreted that there is a significant change in the right balance of basketball players aged 16 years after being given bosu ball exercise treatment. Pre-test left bosu ball exercise and post-test left bosu ball exercise on left balance the value of = 5% (0.05) > sig. (2-tailed) 0.001, then it can be interpreted that there is a significant change in left balance for basketball players aged 16 years after being given bosu ball exercise treatment.

The average score of the pre-test balance of male basketball players aged 16 years on the right balance is 96.32, and the left balance is 104.10 (fig. 7). The average value of the balance changed after being given the theraband exercise treatment. The post-test mean score for the right balance was 100.34, and the left balance was 108.65.

Figures 8 show that the theraband exercise treatment given to basketball players aged 18 years after regular training for 16 meetings with an exercise pattern of 1 day of exercise and 1 day

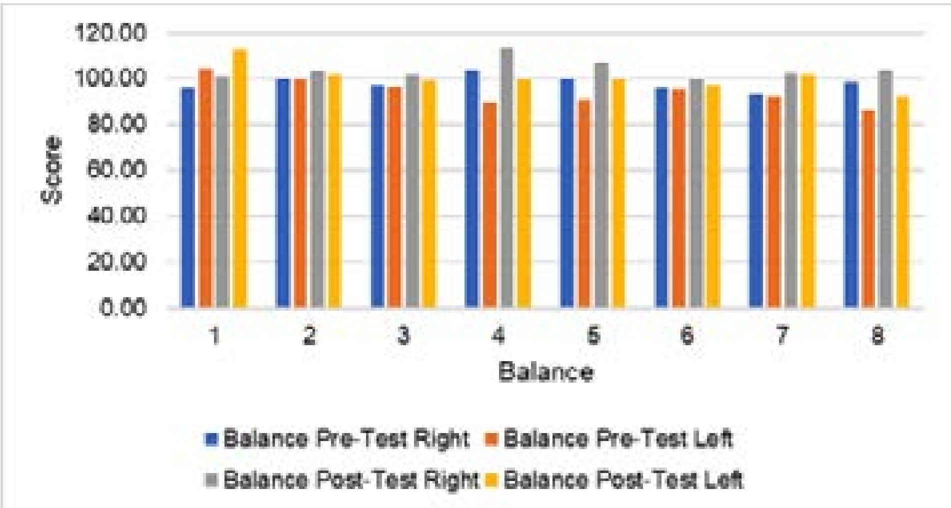

Figure 5. Data of balance bosu ball exercise 16 years old

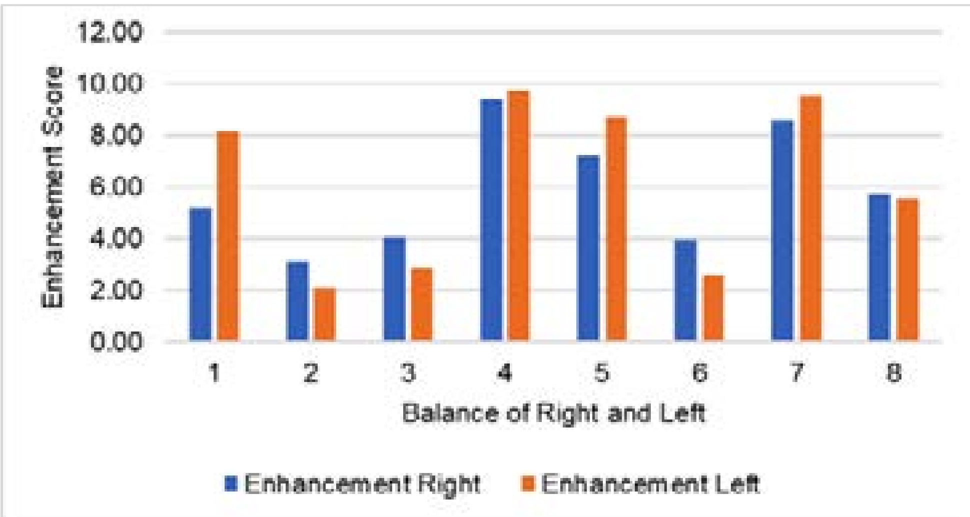

Figure 6. Enhancement of balance bosu ball exercise 16 years old

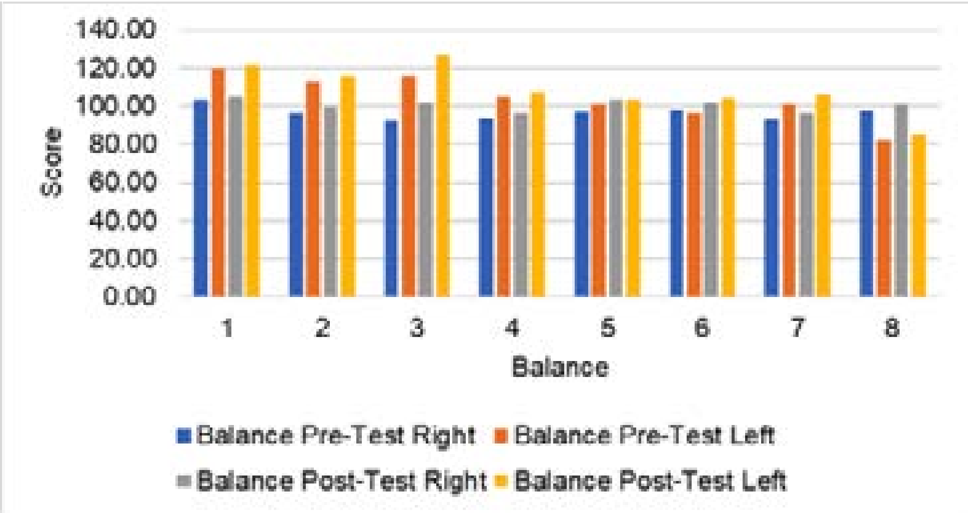

Figure 7. Data of balance theraband exercise 18 years old

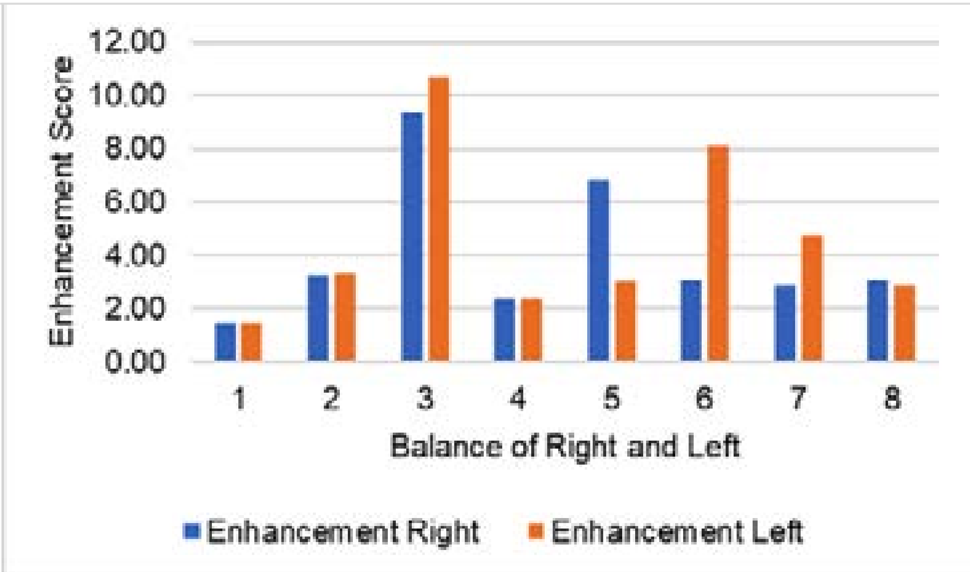

Figure 8. Enhancement of balance theraband exercise 18 years old

of rest showed a positive impact on improving right and left balance. The average increase in the right balance is 4.02, and the left is 4.55. Pre-test right theraband exercise and post-test right theraband exercise = 5% (0.05) > sig. (2-tailed) 0.004, then it can be interpreted that there is a significant change in the right balance of basketball players aged 18 years after the theraband exercise treatment. Pre-test left theraband exercise and post-test left theraband exercise = 5% (0.05) > sig. (2-tailed) 0.005, it can be interpreted that there is a significant change in left balance for basketball players aged 18 years after being given the theraband exercise treatment.

The average score of the pre-test balance of male basketball players aged 16 years on the right balance is 98.29, and the left balance is 102.16 (fig. 9). The average value of the balance changed after being given the theraband exercise treatment. The post-test mean score for the right balance was 103.57, and the left balance was 108.95.

Figures 10 show that the bosu ball exercise treatment given to basketball players aged 18 years after regular training for 16 meetings with a training pattern of 1 training day and 1 day of rest showed a positive impact on improving right and left balance. The average increase in the right balance is 5.29, and the left is 6.79. Pre-test right bosu ball and post-test right bosu ball exercise = 5% (0.05) > sig. (2-tailed) 0.000, then it can be interpreted that there is a significant change in the right balance of basketball players aged 18 years after being given bosu ball exercise treatment. Pre-test left bosu ball exercise and post-test left bosu ball exercise on left balance the value of = 5% (0.05) > sig. (2-tailed) 0.002, it can be interpreted that there is a significant change in left balance for basketball players aged 18 years after being given the bosu ball exercise treatment.

Figures 11 show no interaction between the treatment given to basketball players aged 16 and 18 years. The interaction did not occur because the

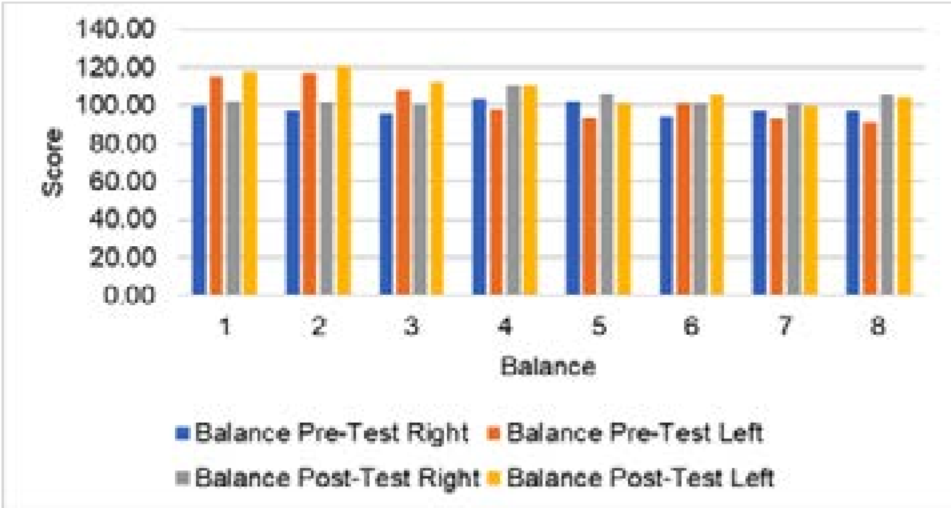

Figure 9. Data of balance bosu ball exercise 18 years old

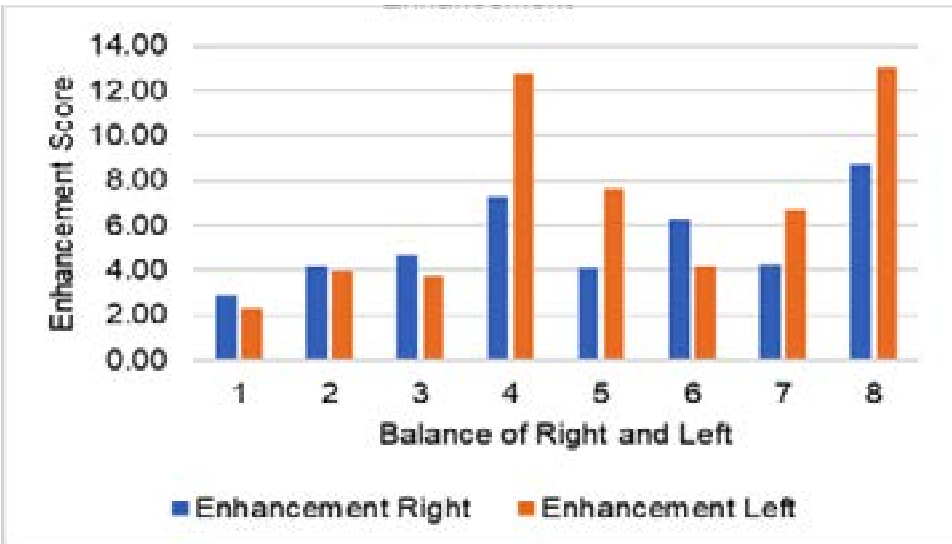

Figure 10. Enhancement of balance bosu ball exercise 18 years old

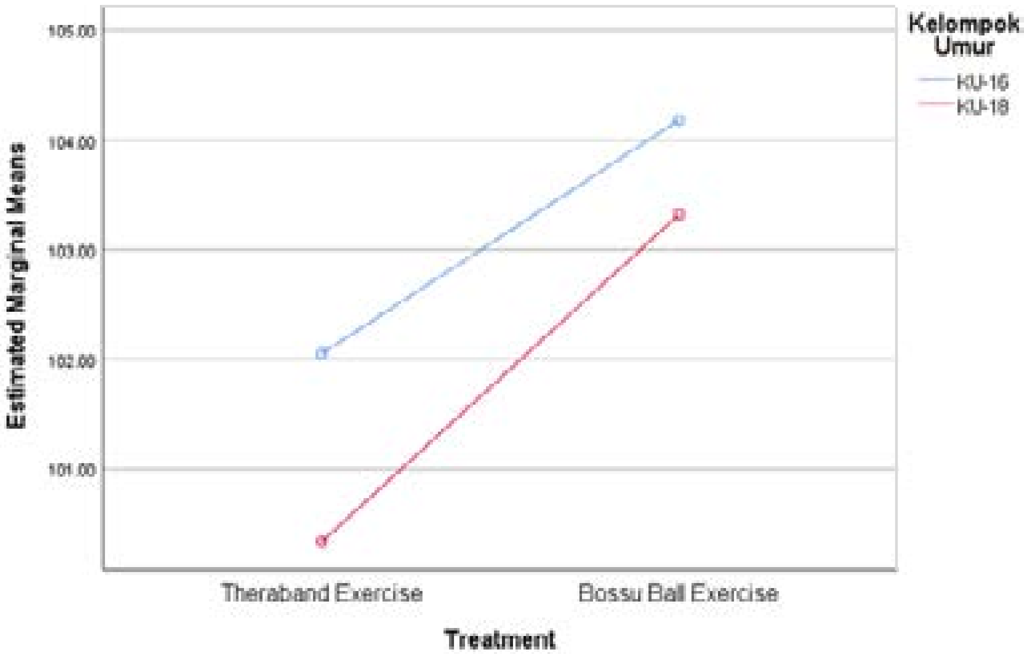

Figure 11. Raight balance

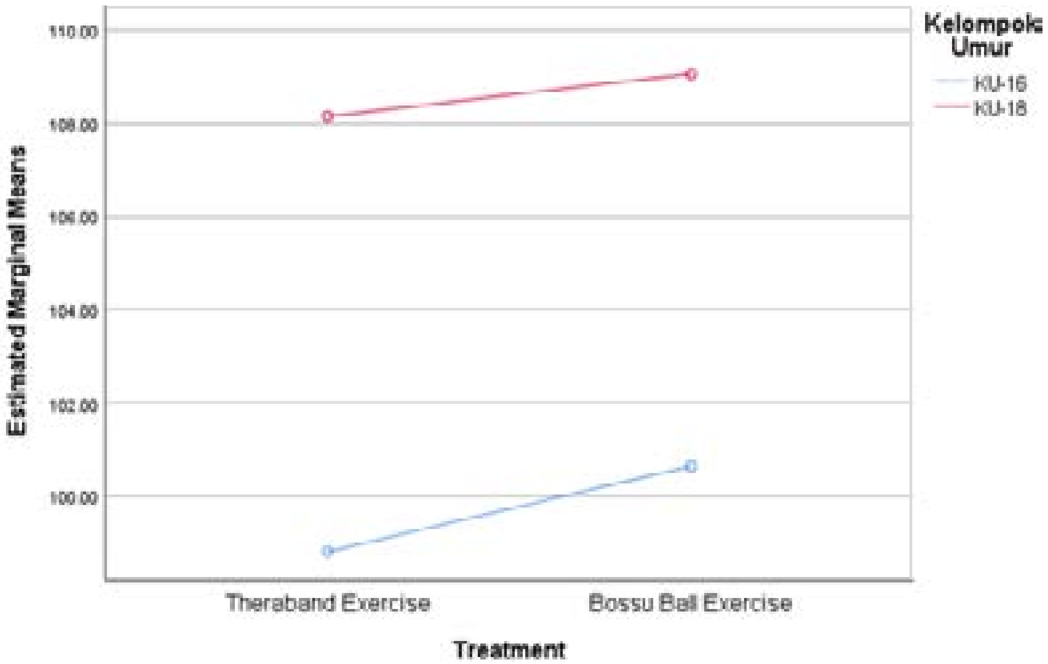

Figure 12. Left balance

growth and development phase of the 16-year-old and 18-year-old players were still in the adolescent phase. Characteristics of the age group of 16 years and 18 years are not much different.

Figures 12 show no interaction between the treatment given to basketball players aged 16 and 18 years. The interaction did not occur because the growth and development phase of the 16-year-old and 18-year-old players were still in the adolescent phase. Characteristics of the age group of 16 years and 18 years are not much different.

Discussion

Balance is divided into two, namely static balance and dynamic balance. Static balance (static balance) is the ability to maintain gravity in a stationary position such as standing and sitting. In contrast, dynamic balance can stabilize the body on an unstable surface or in moving conditions such as walking and running [21]. Balance can also be interpreted as an ability to control the center of the body (center of mass), the center of gravity (center of gravity), body position against the fulcrum (base of support) [22]. the law in biomechanics shows that the fulcrum is located on foot when standing, walking, and running, which shows that the ankle has a very large role in maintaining body balance [23]. The muscles that support the ankle when the foot is supported or moved will certainly contract so that the skin, muscles, tendons, and ligaments need to be given proprioceptive treatment in order to have a positive effect on balance [22, 24]. Joint and muscle movements are effectors that realize commands from the balance center [22, 24, 25].

The main system that functions as balance control in the human body consists of sensory, motor, and information processing centers [2, 3]:

1) Sensory
   a) Visual: the visual system is important in the sensory system because through vision, the body can make adjustments or adapt to environmental conditions, so that muscle responses respond synergistically to maintain body balance.
   b) Vestibular system: the vestibular system is located inside the ear, which has an important role in: 1) maintaining balance, 2) controlling head movement and position, and 3) controlling eye movement. Input received by the vestibular nucleus is via the receptor labyrinth, reticular formation, and the cerebellum. Output originating from the vestibular nucleus is transmitted to motor neurons through the spinal cord, especially motor neurons that innervate proximal muscles, neck muscles, and postural muscles (back muscles). The vestibular system works very quickly to control the postural muscles so that the body can adapt to the existing conditions to maintain balance.
   c) Somatosensory: the somatosensory system has an important role in maintaining body balance and motor control. The somatosensory system provides information related to body position and environmental conditions that can be received or responded to by: 1) the skin provides information about touch, 2) muscles are receptors that provide information about the position of the limbs and body. Movement control depends on constant and accurate information received through the somatosensory system.

2) Motor

Skeletal muscles and joints are motor movements that are part of the balance control system. Skeletal muscles and joints act as a movement system that can change the legs and body position. Muscles can respond appropriately so that the speed and strength produced can be adjusted to the activity or activity being carried out. The strength of the muscles of the legs, knees, and hips must be sufficient to maintain a balanced body position because muscle strength is directly related to its ability to resist gravity and other external loads. Joint range of motion or the breadth of joint motion also plays an important role in body movement so that the movements carried out can be directed properly so that the balance of the body can be maintained.

3) Information processing center

The central nervous system integrates inputs obtained from the sensory system, producing motor commands to control body position both in rest and in motion. The information process to control the balance is indeed controlled by the central system so that if there is damage to the unity of the system, the response given to control the balance will be disturbed. Disorders that occur can come from certain pathologies or decreased function of organs or the neuromuscular system.

Proprioceptive is the perception of stimuli on the balance of the body that is generated through the visual, vestibular, and sensory-motor systems [26]. Proprioceptive, locomotor exercise is needed to improve body balance because it can affect the performance of brain reflexes so that muscles and joints can provide an excellent locomotor response to maintain body position in stationary or moving conditions [26]. Basketball sports have complex biomotor component characteristics such as agility, speed, coordination, accuracy, endurance, and explosive power. The biomotor ability will be better if it is supported by good balance conditions [27]. A review of several articles recommended 10-20 minutes of balance training, but some were carried out 40-50 minutes. However, after research, it was recommended f two times per week for eight weeks with a training duration of 45 minutes [28]. Doing balance exercises for 30 minutes with a frequency of 2 times per week for 12 weeks can improve young basketball player's balance and vertical jump ability [29]. The average time to exercise using the theraband and bosu ball in this study ranged from 10-30 minutes per training session according to the number of repetitions that gradually increased.

The muscles in the legs are the muscles that support the ankle when the foot, when supporting or moving, will certainly contract so that the muscles, tendons, and ligaments need to be given proprioceptive treatment in order to have a positive effect on balance [24, 30]. Joint and muscle movements are effectors that realize commands from the balance centre [22, 24, 25].

Theraband exercise is an exercise that leads to movement-related strengthening. In contrast, the bosu ball exercise leads to balance training, which are ankle strengthening exercises that aim to improve the ankle's balance and functional capacity [5, 31]. Exercises using theraband and bosu balls for lower extremities given after regular training (drill skills) affect the proprioceptive system to help improve postural balance in the form of dynamic and static balance [29, 31, 32].

Ankle theraband exercise is an exercise that aims to increase strength, improve balance and proprioception, improve posture, reduce pain, increase leg muscle endurance, and restore ankle motion function [33]. The ankle theraband exercise consists of 4 movements, namely: 1) plantarflexion (extension), 2) dorsiflexion (flexion), 3) inversion, 4) eversion. Bosu ball is a sporting instrument in a hemispherical ball (half ball) with a bulging side like a dome with an unstable surface and a flat side made of hard rubber [34]. The Bosu ball is a multi-functional tool because various exercises can be done using the tool, such as exercises for fitness, core stability, balance, strength, and skills [35]. Bosu ball is a tool that can be used in functional training or exercises related to daily movements [35]. Based on this analysis, bosu ball exercise is better than theraband exercise because the muscle group responsible for maintaining balance in the training process is more complex, starting from the leg muscles to the back muscles [24, 35]. Whereas in theraband exercise, the balance guard muscles that are trained only focus on the muscles in the legs [36, 37].

Conclusions

The sample group that was given the theraband exercise treatment for ankle strengthening, which was given after regular exercise, could improve balance more significantly. A significant effect also occurred in the sample group that was given the bosu ball exercise treatment. The interaction between the treatment given to basketball players in the 16 and 18 years age group did not occur. The interaction between theraband exercise and bosu ball exercise did not occur because the growth and development phases of the 16-year-old and 18-year-old sample groups were still in the adolescent phase. Characteristics of the age group of 16 years and 18 years are not much different. Bosu ball exercises give a better effect than theraband exercise. Although statistically not too significant, there is a difference in the average. The motor system works more, starting from the legs, back, and abdomen muscles. The motor system that works when doing theraband exercise tends to be on the muscles in the legs.

Conflicts of interest

The authors do not have conflict interest with anyone about this writing and/or writing this article.

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ORIGINAL ARTICLE

Changes in joint kinematics and kinetics through the implementation of inter-repetition rest protocols in snatch training

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

Abstract

Background and Study Aim	Inter-repetition rest pertains to a short period of rest between repetitions during strength training. Manipulating inter-repetition rest may influence fatigue accumulation, manifesting alteration in lifting mechanics. This study aimed to examine the effects of different inter-repetition rest protocols on joint velocity and ground reaction force during snatch exercise.
Material and Methods	Fifteen male (n=15) athletes participated in this study (age = 23.0 ±2.31 years; body weight = 65.32 ± 1.37 kg; height = 168.80 ± 5.64 cm; snatch one repetition maximum (1RM)/bodyweight = 0.78 ± 0.12), performing three sets of 5 repetitions at 85% 1 Repetition Maximum snatch with 10, 30, or 50 seconds of inter-repetition rest implemented randomly across three sessions. Ankle, knee, and hip kinematics and ground reaction force in the three protocols were used for comparison. The participants visited the exercise science laboratory for four sessions between 0800-1700 hrs. These sessions were separated by 72 hours.
Results	One-way repeated measure analysis of variances (ANOVA) showed a significant effect of inter-repetition rest on the maintenance of kinematic and kinetic variables. The ground reaction force for 10 seconds inter-repetition rest protocol showed a significant drop in force output across repetition ($p = .037$, $p < 0.05$).
Conclusions	The utilization of inter-repetition rest in snatch exercise may reduce neuromuscular fatigue across repetitions, maintaining consistent performance output. Specifically, the 50 second inter-repetition rest protocol reduced the negative effect of neuromuscular fatigue in the kinematic and kinetic variables during snatch exercise.

Keywords: power, recovery, exercise, Olympic weightlifting, maximal strength, recovery

Introduction

Strength and conditioning coaches use a variety of resistance training [1] schemes for development of power, a physiological characteristic crucial to athletic performance. Among which is the utility of weightlifting exercises in RT programs. The mechanical stimuli from weightlifting exercises are believed to aid in enhancing neuromuscular adaptations related to power [2, 3].

Power, force output and velocity have been demonstrated to decrease with each repetition during high-intensity RT [4-8]. For example, Izquierdo et al. [9] posted decreased velocity across repetitions to failure in squat and bench press exercises. Duffey and Challis [10] also showed significant reduction in mean and peak velocity across repetition to failure during bench press. The attenuation in force and velocity output across repetitions are mainly linked to muscular fatigue [11, 12]. Thus, the employment of strategies to minimize fatigue during exercise repetitions may be beneficial to aid in training goals.

Recently, the inter-repetition rest (IRR) was suggested to reduce the effect of fatigue in RT. A study by Haff et al., [13] demonstrated higher clean pull barbell velocity with IRR compared to traditional set protocol that used no rest in between repetitions. Lawton et al. [7] also exhibited greater power output per repetition obtained during a bench press exercise from IRR protocols compared to the continuous repetition protocols. Garcia Ramos et. al. [4] posted more half squat repetitions with IRR that squat under continuous repetitions. Similarly, Mora-Custodio et al. [14] showed lower incidence of fatigue, percentage velocity loss, and lactate concentration during full squat with IRR than continuous repetitions. These studies suggest that employment of IRR may contribute to increased exercise efficiency.

While the previous studies involving IRR provide insight on kinematic and kinetic variables across repetitions, majority were executed using a single-set protocol. The effect of IRR across repetitions, involving multiple sets, remains unknown. Such information may be crucial for implementing exercises to aid in power development. Thus, this study aimed to examine the effects of IRR on lower body kinematic and kinetic parameters of snatch across multiple sets.

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Materials and Methods

Participants

Fifteen active male athletes (age: 23.0 ± 2.31 years, weight: 65.32 ± 1.37 kg, height: 168.80 ± 5.64 cm, 1RM of snatch relative to body mass: 0.78 ± 0.12 kg. kg^{-1}) volunteered to participate in this study. The sample size was based on a previous study with a similar design [5, 15]. The inclusion criteria were: (a) ability to lift at least 50% of their body weight during the snatch exercise; (b) at least six months of experience in a snatch training exercise; and, (c) non-use of drugs or dietary supplements that could affect physical performance. All participants were informed of the benefits and risks of the investigation before signing the informed consent. The experimental protocol adhered to the principles of the 1975 Helsinki Declaration and was approved by the ethical committee of Sultan Idris Education University Institutional Ethical Review Board.

Procedure

The participants visited the exercise science laboratory for four sessions between 0800-1700 hrs. These sessions were separated by 72 hours. To avoid diurnal variations, participants visited the facility at the same time across four sessions. In session one, anthropometrics (height and weight), equipment familiarization, and one-repetition maximum (1 RM) were administered. The 1RM testing was performed in the manner described by Baechle and Earle [9], facilitated by a certified strength and conditioning specialist. Sessions two to four were interspersed by 72 hours, with participants performing a general warm-up of five-minute jogging and five-minute stationary cycling. Participants then continued with dynamic upper body and lower body stretching using elastic bands, followed by five repetitions of snatch at 20-kg load. A five-minute active rest was implemented after warm-up. This was succeeded by three sets of five repetitions of snatch at 85% 1 RM, with a five-minute rest in between sets. The three protocols in this study included the 10s, 30s and 50s intervals, implemented as the rest duration in-between each snatch repetition.

The kinematic data of ankle, knee, and hip joint were captured at 100 Hz using 3D Vicon motion capture system with 6 Vicon T-10s cameras (Vicon Motion Systems Ltd UK, West Way, Oxford). The markers were placed on the left and right anterior superior iliac spine, left and right lateral thigh, left and right lateral epicondyle of the knee, left and right medial epicondyle of the knee, left and right lateral tibia, left and right lateral malleolus, left and right medial malleolus, left and right second metatarsal, and left and right heel. Only the data taken from the right leg were analyzed to be presented in this study. The first pull and second pull phases of snatch were analyzed in this study. The first pull refers to the barbell lift-off until the maximum knee extension, while the second pull occurs from the first maximum knee flexion until the second maximum knee extension [16]. The data is processed using VICON Polygon (Vicon Motion Systems Ltd UK, West Way, Oxford), filtered using 4th order Butterworth filter with cut-off frequency at 6 Hz [17, 18].

The vertical ground reaction force (GRF) of each snatch repetition was recorded using an AMTI force plate (Advanced Mechanical Technology, Inc, Watertown, MA) at 1000 Hz. The GRF was filtered using the 4th order Butterworth filter with a cut-off frequency of 25 Hz [17, 18]. The peak GRF at each snatch repetition was utilized for analysis.

Statistical analysis

The mean values of each repetition from the three sets across IRRs were utilized for analyses. A 3 (IRR) x 5 (repetition) repeated measure analysis of variance (ANOVA) was used to determine any significant main effect and interaction. The partial eta squared (partial η2) was utilized for estimating effect size. The Greenhouse-Geisser correction was employed for any violation on sphericity. Additionally, the Bonferroni post-hoc was utilized to determine any significant pairwise comparison. Statistical analysis was conducted in a commercial statistical package, SPSS version 25 (SPSS Inc., Chicago, IL.), with significance set at 0.05 level.

Results

First Pull

The 2 x 5 repeated measures ANOVA revealed non-significant main effect of intervention on ankle joint velocity, F(1.401, 19.62) = 2.268, p = 0.122, partial η2 = 0.139. There was a significant main effect of repetition on ankle joint velocity, F(4, 56) = 3.661, p = 0.010, partial η2 = 0.207. Bonferroni post-hoc posted significant reduction in angular velocity between 1^{st} (mean = 1.969 rad/s) repetition and 5^{th} repetition (mean = 1.617 rad/s) of the 10 s IRR (p = 0.023). The interaction in intervention and repetition on ankle joint velocity was not significant, F(8, 112) = 0.288, p = 0.969, partial η2 = 0.207.

The main effect of intervention on knee joint velocity was not significant, F(2,28) = 0.830, p = 0.447, partial η2 = 0.056. The main effect of repetition on knee joint velocity was significant, F(4, 56) = 4.895, p = 0.002, partial η2 = 0.259, with post-hoc demonstrating knee joint velocity difference between 1^{st} repetition (mean = 4.315 rad/s) and 5^{th} repetition (3.913 rad/s) of the 10 s IRR at p = 0.003.. There was no significant interaction between intervention and repetition on knee joint velocity, F(8, 112) = 0.237, p = 0.983, partial η2 = 0.017.

Non-main effect of intervention was found in hip joint velocity, F(2,28) = 0.447, p = 0.644, partial η2 = 0.031. There was a significant main effect of repetition on hip joint velocity, F(4, 56) = 3.536,

$p = 0.012$, partial $\eta 2 = 0.202$. Pairwise comparison showed significant difference between the 1st repetition (mean = 2.939 rad/s) and 5th repetition (mean = 2.632 rad/s) of the 10 s IRR.. There was no significant interaction between intervention and repetition on hip joint velocity, $F(8, 112) = 0.368$, $p = 0.935$, partial $\eta 2 = 0.026$. Figure 1 shows the peak ankle, knee, and hip joint kinematics during first pull of the snatch across repetitions.

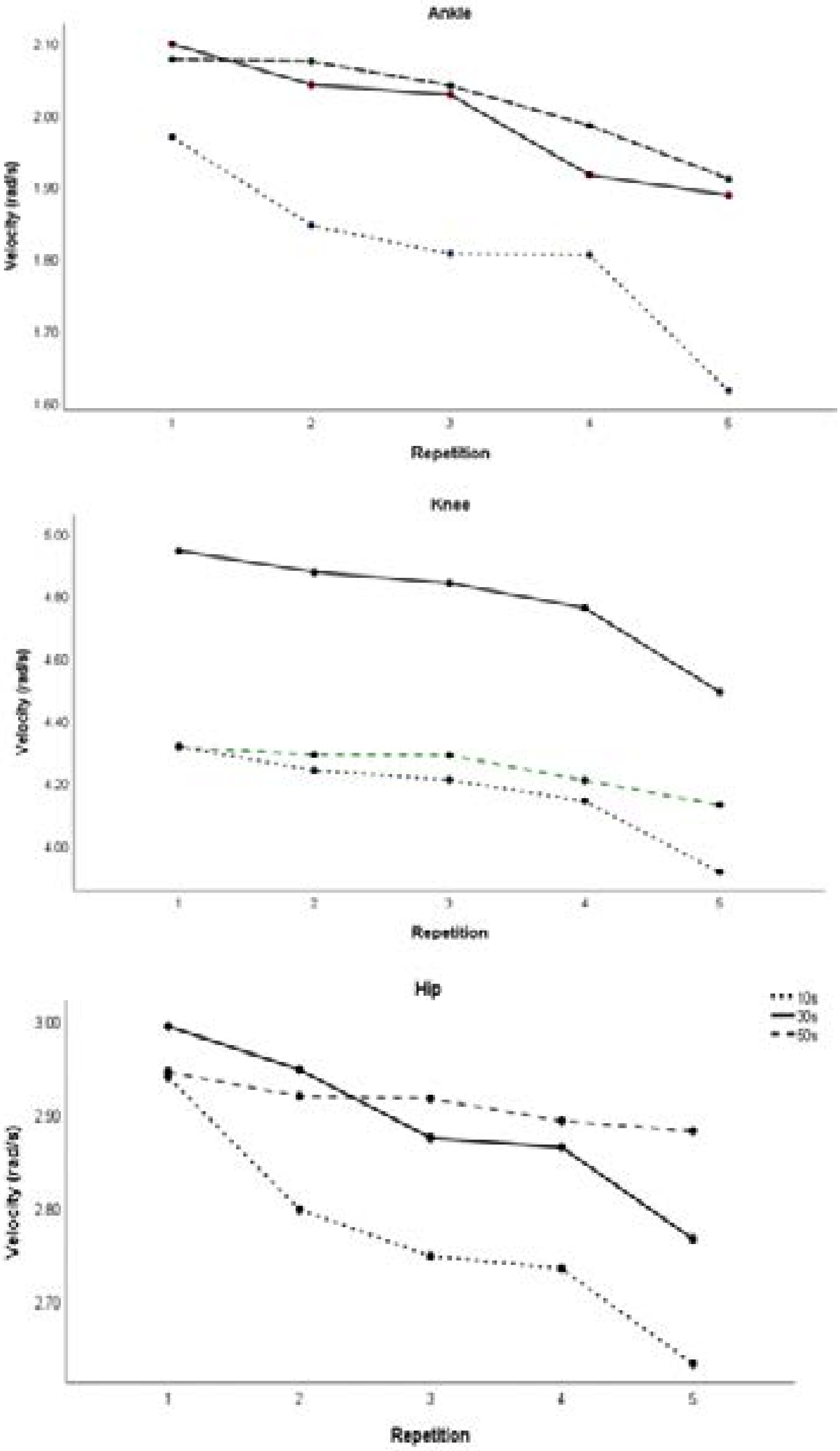

Figure 1. Peak Joint Kinematics at Snatch First Pull from Various Inter-repetition Rest Intervals

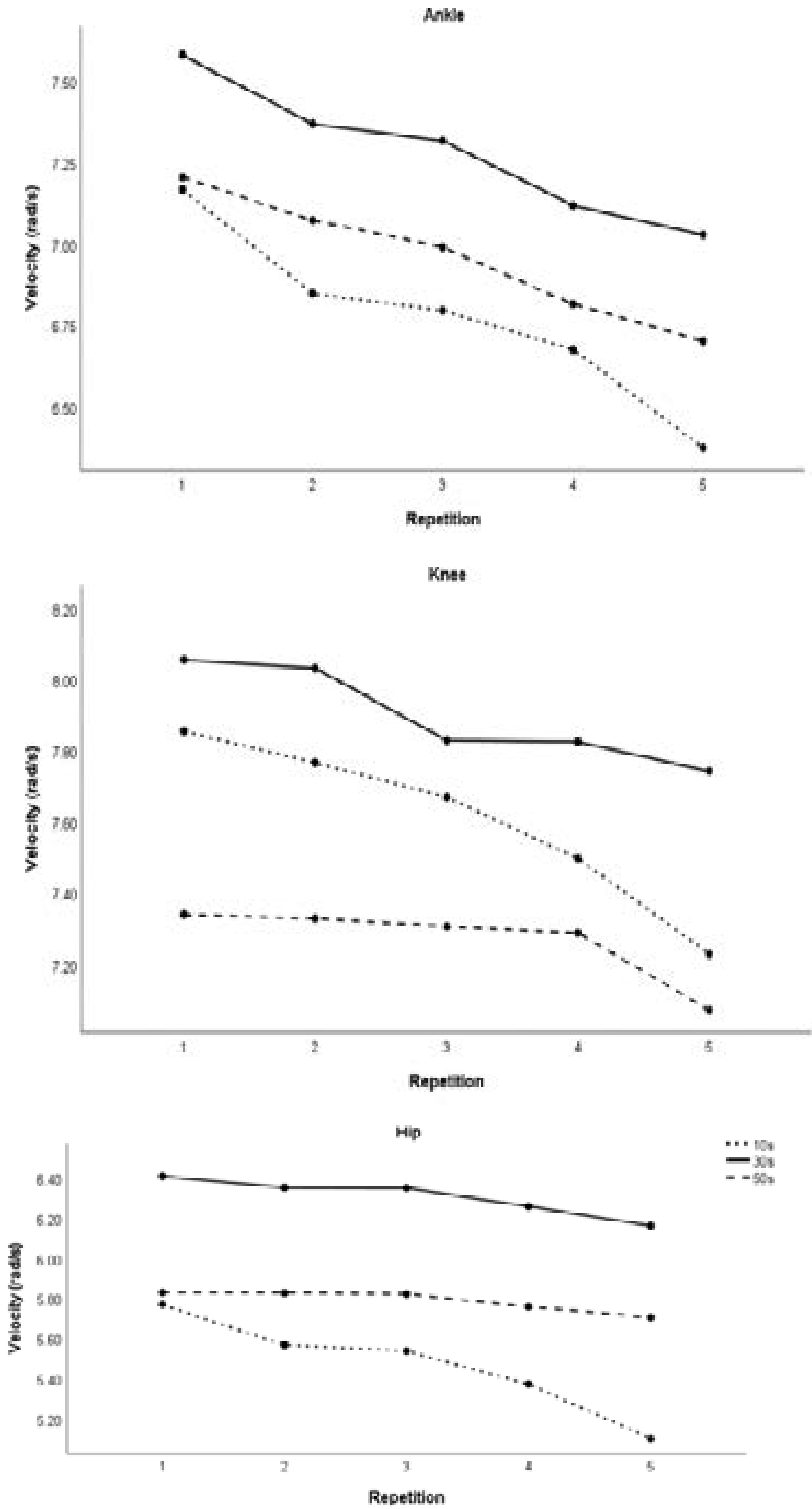

Figure 2. Peak Joint Kinematics at Snatch Second Pull from Various Inter-repetition Rest Intervals

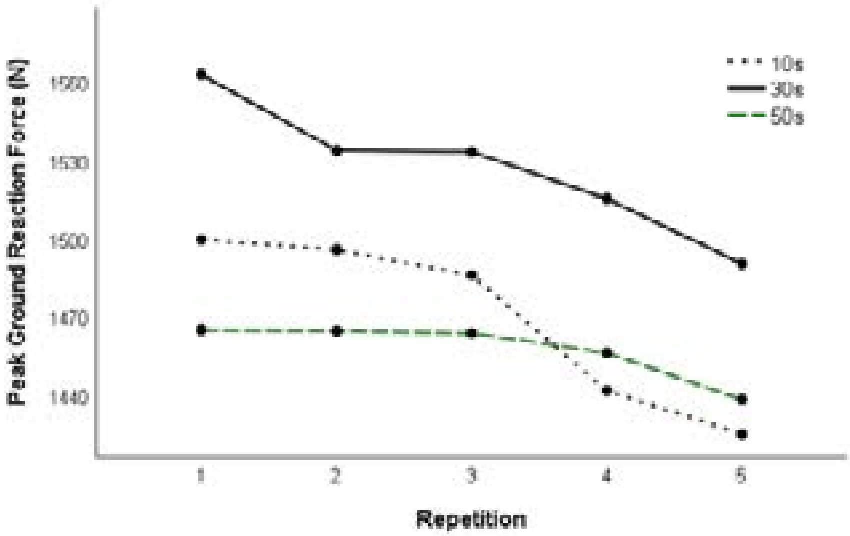

Figure 3. Peak GRF at each repetition from different IRRs.

Second Pull

Non-significant main effect of intervention on ankle joint velocity was identified, F(2,28) = 0.216, p = 0.807, partial η2 = 0.015. There was a significant main effect of repetition on ankle joint velocity, F(4, 56) = 4.912, p = 0.002, partial η2 = 0.260, and post-hoc exhibited ankle joint velocity difference between 1st repetition (mean = 7.167 rad/s) and 5th repetition (6.373 rad/s) of the 10 s IRR (p = 0.013). No significant interaction between intervention and repetition was found on knee joint velocity, F(8, 112) = 0.101, p = 0.999, partial η2 = 0.007.

There was no significant effect of intervention was found on knee joint velocity, F(2,28) = 0.155, p = 0.857, partial η2 = 0.011. There was also no significant main effect of repetition on knee joint velocity, F(4, 56) = 2.283, p = 0.072, partial η2 = 0.140. The interaction of intervention and repetition on knee joint velocity was non-significant, F(8, 112) = 0.204, p = 0.990, partial η2 = 0.014.

The main effect of intervention on hip joint velocity was not significant, F(2,28) = 1,969, p = 0.158, partial η2 = 0.123. There was a significant main effect of repetition on hip joint velocity, F(4, 56) = 3.766, p = 0.009, partial η2 = 0.212, with pairwise comparison revealing significant difference between the 1st repetition (mean = 5.768 rad/s) and 5th repetition (mean = 5.102 rad/s) of the 10 s IRR.. No significant intervention and repetition interaction was seen on hip joint velocity, F(3.757, 52.60) = 1.192, p = 0.310, partial η2 = 0.078. Figure 2 depicts the peak ankle, knee, and hip joint kinematics during the second pull of the snatch across repetitions.

Ground Reaction Force

There was no significant main effect of group on peak GRF, F(1.027, 14,38) = 0.649, p = 0.530, partial η2 = 0.044. On the other hand, the main effect of repetition was significantly different, F(4, 56) = 3.456, p = 0.014, partial η2 = 0.198. Post-hoc revealed significant reduction on peak GRF between 1st repetition (mean = 1500 N) and 5th repetition (mean = 1425 N) of the 10 s IRR at p = 0.045. No interaction effect was found between group and repetition on peak GRF, F(8, 112) = 0.502, p = 0.853 , partial η2 = 0.035. Figure 3 shows the peak GRF at each repetition from different IRRs.

Discussion

The purpose of this study was to examine the kinematics of snatch exercise from different IRRs. Specifically, the researchers investigated the ankle, knee, and hip joint kinematics from different IRRs during snatch exercise. Results revealed no significant snatch first pull joint kinematic differences between the 10s, 30s, and 50s IRRs. Similarly, there was also no significant snatch second pull joint kinematic differences between the 10s, 30s, and 50s IRRs. The secondary purpose of this study was to examine the snatch ground reaction force from the 10s, 30s, and 50s. It was found that no significant difference existed in the GRF during the 10s, 30s, and 50s.

In this study, no kinematic differences were observed from different IRRs. The snatch first pull plays a critical aspect for the generation of momentum in second pull. Further, the 1st pull sets the biomechanical stage for proper execution of the entire lift, needed for efficient and safe movement pattern [19]. Although no group differences were found, it should be noted that the 10s demonstrated the most notable trend in reduction of ankle, knee, and hip joint kinematics compared to the 30s and 50s IRR protocols. It may be possible that the 10s rest was not sufficient to facilitate replenishment of energy stores, that may help reduce fatigue from executing snatch repetitions [20, 21]. This is partially supported by previous studies that showed reduction in kinematic parameters from multiple exercise repetitions performed from short-duration IRRs [7, 15, 22-25]. While non-kinematic differences in snatch first pull were identified in this study, it appears that application of 10s IRR may contribute to a more pronounced attenuation in kinematics, that resulted from incomplete energy repletion. Thus, caution must be observed when implementing 10s IRR for snatch repetitions, as this may potentially reduce exercise efficiency and increase faulty movement patterns.

No second pull kinematic differences across IRRs were also demonstrated in this study. The second pull is considered as the most explosive phase of snatch, facilitating the upward acceleration of the bar [19]. While no group differences were identified, the 10s IRR displayed the greatest trend in reduction of ankle and hip kinematics compared to 30s and 50s protocols. It may seem that the snatch performed with 10s IRR exhibited more decrement trend on kinematic output which showed kinematic reduction across repetitions. The slower second pull kinematics in 10s IRR may have also resulted from the slower first pull kinematic output. Large reduction in velocity during the second pull movement may result to movement imbalance towards catch phase of snatch [26]. Thus, it seems that facilitation of longer IRR may help maintain velocity in snatch exercise repetitions, leading to favorable kinematic adaptations.

This study also posted no kinetic differences across IRRs. However, it should be noted 50s IRR demonstrated greater preservation of GRF across repetitions. The longer rest interval may have facilitated the partial recovery and reversal of fatigue [7, 13, 27]. Specifically, the longer rest allowed resynthesis of phosphocreatine, which is important in execution of explosive actions [28]. The results of this study somehow coincide with previous studies indicating the maintenance of kinetics from longer IRRs [7, 8, 13, 22, 23]. For example, Lawton, Cronin [7] demonstrated greater power output (21-25%) during bench press with longer IRR when compared with the continuous set protocols [7]. The longer IRR reduce neuromuscular fatigue [29], and may help maintain kinetic properties in exercise performance. Therefore, it shows that employment of 50s IRR may be helpful in maintaining similar force output during snatch repetitions.

While this study provided novel information on the contribution of IRR on phase kinematics of snatch, limitations are acknowledged. First, generalization of findings should be avoided as the results are only applicable to the participants of this study. Also, the study presented high inter-subject variability, which may have affected the results of this study. Lastly, only kinetic and kinematic parameters were evaluated from IRRs. Inclusion of psychological and physiological parameters in future studies may help explain the extent of IRRs in performance settings.

Conclusions

Implementation of IRR in snatch exercise may help in exercise, facilitating better adaptations in lower body kinematics and kinetics. In this study, no first pull kinematic differences were found after performing three sets of snatch using the 10s, 30s, 50s IRRs. Similarly, no second pull kinematic differences across IRRs were also identified. Lastly, kinetic non-differences were found across IRRs. More studies are needed to elucidate information on the phase kinematic contribution of IRR in snatch exercise.

Conflicts of Interest

The authors declare no conflicts of interest.

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