

Comparison of the effects of core stability exercises on the static and dynamic balance of female athletes with trunk deficiency on the stable and unstable surfaces

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ABSTRACT

Introduction: Weakness in core stabilizer muscles can have a negative effect on the balance. Accordingly, this study was designed to compare the effect of core stability exercises in the stable and unstable surface on the balance of female athletes with trunk deficiency. **Methods:** The statistical population of the study consisted of 30 female athletes from Gilan province who were intentionally entered into the study. They were divided into two groups of 15, and stable and unstable training exercises were implemented for 6 weeks and 3 sessions per week). Static balance was evaluated using BESS test and the dynamic balance was measured using WI balance test. To analyze the difference in balance between athletes of the two groups, statistical analysis of covariance and t-correlation analysis was used. **Findings:** The results of the study showed a significant effect of both exercise protocols on static and dynamic balance ($P = 0.01$). In addition, the results of covariance analysis showed that exercises at the unstable surface have more effect on static and dynamic balance in compare to exercises at the stable surface ($P < 0.05$). **Discussion:** Considering the difference between the two types of exercises in affecting the balance component, the results of the study suggest that both types of core stability exercises of the body are beneficial to improve the balance, by strengthening the muscles associated with controlling the spinal cord and the pelvis. In addition, coaches and athletes can take advantage of unstable surfaces of core stability exercises to improve balance.

Keywords: Athletes, body core, stable surface, unstable surface, static balance, dynamic balance.

Introduction

Increasing number of athletes and sports enthusiasts has led to an increase in the number of sports-related injuries. Damage may occur due to a simple accident, or because of complex interactions between internal and external risk factors [1]. On average, more than 10,000 Americans need medical treatment due to injuries from sports and recreational activities every day [2]. According to researchers, about 50% to 80% of these

injuries are due to overuse and non-contact damages [3]. These injuries can be a result of weakness, muscular imbalance and previous injuries [4]. One of the reasons for athletic injuries is the lack of balance. Balance is an indispensable and a key component of almost everyday activities for athletes.

Balance is the most important part of an athlete's ability and is involved in almost every form of activity. Balance is a complex motor skill that describes the dynamic state of the body in preventing falling [5]. Maintaining balance is considered as an important advantage for sports activities in the field. State of weakness in balance is considered as one of the most important causes of injury in athletes and an important clinical variable. Physicians of sports teams have to assess the balance and postural control when ordering an athlete to return to sports field following an injury [6]. The results of researches show that weakness of balance is one of the most important risk factors in falling and consequently occurring injury in people [6]. On the other hand, the balance between power and stability in the lower limb's motion chain is vital to prevent sports injuries. The

Access this article online

Website: www.japer.in

E-ISSN: 2249-3379

How to cite this article: Elham Mirdjamali, Hooman Minoonedjad, Foa'd Seydi, Hadi Samadi. Comparison of the effects of core stability exercises on the static and dynamic balance of female athletes with trunk deficiency on the stable and unstable surfaces. *J Adv Pharm Edu Res* 2019;9(S2):63-69.

Source of Support: Nil, Conflict of Interest: None declared.

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stability of body core plays an important role in the prevention of sports injury ^[7]. The stability of body core is described by movement control and muscular capacity of the waist, hip, and thigh complex ^[8]. Maintaining positional alignment and dynamic balance during functional activities is one of the tasks of the body core that helps preventing false patterns ^[9]. Position and movement asymmetry do not allow the core region to have stability ^[9]. Present limitations to the power and stability of deep muscles result in inappropriate sports techniques that can potentially harm the athlete ^[10]. A favorable core region maintains the natural length-tension relationship of agonist and antagonistic muscles, which results in the favorable kinematics of joints in the waist, hip and thigh complex in functional motion chain movements and maximizes the stability for the lower body movements ^[11].

As an interface, the stability of body core effectively transfers the force produced in the lower limbs to the upper limb through the trunk, which leads to a more efficient exercise ^[12]. The results of the researches show that the stabilizing muscles contract before the lower limb movers and through all of the motion plates, which increases the hardness of the spinal cord in creating a stable support. The researchers also stated that athletes must have sufficient strength in the thigh and trunk muscles to maintain the stability in different motion plates ^[13]. Reducing the proximal muscles strength (hip and thigh) creates a weak and unstable foundation for the development and application of force in the lower limbs. This body core instability can be a predictor of lower limbs damage ^[14]. In addition, the weakness of core body muscles is directly related to the occurrence of lower limb damage, especially in sports that require jumps, leaps, and fast running ^[15]. On the other hand, increasing the stability of core body increases neuromuscular summation in order to reduce the pain of the lower body and back, as well as preventing damage to the lower limb ^[15]. The results of the researches indicate that the strength and endurance of the core body stabilizing muscles in individuals with lower limb injuries is lower than those without a history of injury ^[16]. These findings are consistent with the closed motion chain theory. Based on this theory, the strength and stability of the upper segments are necessary for controlling the lower segments and preventing damage, and if one of the upper joints does not function properly, the other joints will be involved as well ^[17]. Researches have shown that the loss of strength in core body muscles increases the oscillations of the body, and therefore may cause a deficiency in body balance ^[18]. Carpes et al. (2006) showed improvement in balance by strengthening the muscles of the core body ^[19]. Petrofsky et al. (2005) concluded that one month of core body muscle strengthening training program has a significant effect on increasing the balance and stability and reducing tremor in the elderly ^[20]. The various exercises in core body are carried out on stable and unstable surfaces, and a swiss ball is used to perform unstable core body exercises. Comparing the effect of exercises in stable and unstable surface, Ehsani et al. (2015) examined the effect of training at unstable surfaces on pain

and disability variables and muscular activity patterns in patients with back pain during a systematic study. The results of the study showed that exercises at unstable surfaces have a positive and significant effect on pain and disability control, as well as increased activity of trunk muscles, especially abdominal muscles compared to stable surfaces ^[21]. In another study, Sekendiz et al. (2010) examined the effects of 12 weeks of core body strength training with Swiss ball on dynamic balance in 21 non-active females. The results showed that strength exercises of the core body on the Swiss ball could promote dynamic balance in non-active females ^[22]. Comparing the effect of stable and unstable training, Cosiol- Lima et al. (2003) compared the effects of core body stability training programs with Swiss ball and exercises on the surface on women's balance, and showed that training with a Swiss ball significantly increases the balance ^[23]. In another study, Sato and Mukha (2009) did not observe any significant improvement in the balance after performing six weeks of core body stability training on runners ^[24].

Each sport may require different surfaces of sensory and motor processes to execute skills and protect the neuromuscular system from injury. Volleyball and basketball players need a high surface of neuromuscular and balance coordination in many of the motor skills performed by the lower limbs. These sports have different movement patterns, all of which are done dynamically. Therefore, balance is necessary for volleyball and basketball exercises for better performance of the skills, and on the other hand, to prevent musculoskeletal injuries. Considering the importance of balance as a key factor in sports activities, and since it is important to study the difference of the exercises results in balance at stable and unstable surfaces, further investigation of this issue is needed. Furthermore, considering the need to maintain balance and application of exercise program to improve balance, a good solution helping to reduce injury during exercises and competitions. The purpose of this study was to compare the effect of 6 weeks of core body stability training in stable and unstable surface on the static and dynamic balance of academic female athletes.

Methods

The statistical population of the study consisted of all volleyball and basketball players in Gilan province. According to the literature and similar researches in this field, athletes with at least 3 years and maximum 8 years of sports experience, training at least 3 sessions per week, as well as participating in the province's league were qualified to enter the study. Among these, 30 athletes with trunk deficiency (15 in stable surface training group and 15 in the unstable surface group) were selected. Prior to the beginning of the study, all participants signed the consent form of the research, and then the process of the tests was explained during a session for all participants. The participants were healthy and had no history of back pain. In addition, only athletes with trunk deficiencies were entered the study. To begin the dynamic balance test, the actual length of the foot -from the cranial anterior pelvis crest to the proximal

ankle- was measured to normalize the data and compare the participants. For each participant, two repeats were done and the mean was calculated, then the calculated mean was used as foot length. In addition, the superior leg in shooting saloon football was determined by using the information obtained from participants that which lower limbs is tended to be used more.

Participants were evaluated using talk jump test to identify individuals with a neuromuscular deficiency in trunk control. To perform talk jump, the athlete should have been standing with open legs as wide as the shoulder, and started jumping vertically, raising her knees as much as possible. At the highest point of the jump, the thighs were parallel to the surface. At the point of landing, the athlete should have started the next jumping. The test was performed for 10 seconds [25]. Two camcorders were used to improve the accuracy of the evaluation. The cameras were adjusted according to the height of the participant and in coordination with transverse and parity plates of the participant. After performing the test, KINOVEA software was used to analyze jump sequences [25]. A person who was unable to land at her jump's starting position, or did not have parallel thighs with the ground at the peak of the jump, or had interrupted jumps during the 10 seconds, was considered as a person with trunk control deficiency. To ensure trunk deficiencies in men, a pilot test was performed before implementing the study, and trunk deficiencies were confirmed in the athletes [25].

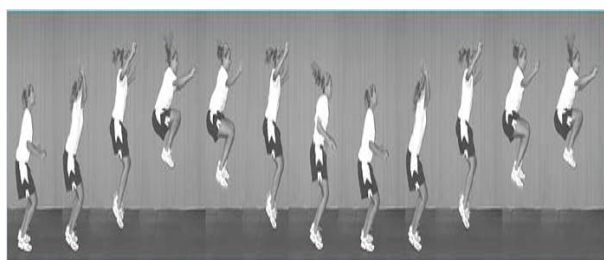


Figure 1. Talk jump

Star balance test was used to assess dynamic postural control. This test is a valid and reliable tool for quantifying the dynamic balance [26]. In this test, eight directions drawn as stars on the ground are aligned with a 45-degree angle. Due to the similarity of the results between the Y balance test and the star balance test, the Y balance test was used in this study [26]. Participants were standing at the center of the directions, then stood on one leg, and with the other foot, performed the achievement and returned to the normal position on two legs. The participant touched the furthest possible point in each of the directions with her toe. the distance from the contact point to the center is the achievement distance which is measured in cm. In order to minimize the learning effects of each participant, she was trained six times in three directions.

To obtain a dynamic balance score in each direction, we used the following equation separately:

$$\text{Score} = \text{achievement distance} / \text{length of the limb} \times 100$$

Static balance was evaluated by the balance error evaluation test. In this test, six different positions were considered, including three standing positions (standing on two legs, standing as one leg in the front and the other in rear, and standing on one leg) on soft and hard surfaces. In each position, the eyes of the participants were closed and their hands were on their back. The participants performed each position for 20 seconds, and the total number of errors committed in these six positions was calculated as the score of the participant. Errors included: Hands getting off the back, eyes getting open or loss balance for any reason. Before the test, the participant performed a training three times to be acquainted with the test levels [27].

The practice protocol in stable surface included six weeks of training, as well as three sessions of exercise each week, conducted at a stable surface on the ground [28, 29]. Based on the intensity of exercise and the amount of time spent for each exercise, resting between sets and end of sets varied from 1 to 2 minutes and 2 to 4 minutes, which could be altered according to the individual's ability. In addition, the total volume of exercise began from 50 minutes in the first week to 70 minutes in the sixth week of training. The training protocol at the unstable surface included six-week training on the swiss ball, as well as three sessions per week [30, 31].

Table 1: Practice protocol for core body stability on the stable surface

Training	First and the second week	Third and fourth week	Training	Fifth and sixth week
Bridge to abdomen	30 seconds, 3 repeats (rest 1 minute between sets and 3 minutes in the end)	45 seconds, 3 repeats (rest 1 minute between sets and 3 minutes in the end)	Bridge to the abdomen, one-handed	45 seconds, 3 repeats (both sides) (rest 1 minute between sets and 3 minutes in the end)
Plunk to sides	30 seconds, 3 repeats (rest 1 minute between sets and 3 minutes in the end)	45 seconds, 3 repeats (rest 1 minute between sets and 3 minutes in the end)	Bridge to sides with straight hand	45 seconds, 3 repeats (both sides) (rest 1 minute between sets and 3 minutes in the end)
Bridge to back	30 seconds, 3 repeats (rest 1 minute between sets and 3 minutes in the end)	45 seconds, 3 repeats (rest 1 minute between sets and 3 minutes in the end)	Bridge to back with one leg straight	45 seconds, 3 repeats (both sides) (rest 1 minute between sets and 3 minutes in the end)
Russian twist	30 pushes, 3 repeats (rest 2 minutes between sets and 4 minutes in the end)	30 pushes, 3 repeats (rest 2 minutes between sets and 4 minutes in the end)	Russian twist	45 pushes, 3 repeats (rest 2 minutes between sets and 4 minutes in the end)
Leg scissors	30 pushes, 3 repeats (rest 2 minutes between sets and 4 minutes in the end)	30 pushes, 3 repeats (rest 2 minutes between sets and 4 minutes in the end)	Leg scissors	45 pushes, 3 repeats (rest 1 minute between sets and 2 minutes in the end)

Table 2: Practice protocol for core body stability on the unstable surface

Fifth and sixth week	Third and fourth week	First and the second week	Training
25 seconds, 3 repeats (rest 1 minute between sets and 2 minutes in the end)	20 seconds, 3 repeats (rest 1 minute between sets and 2 minutes in the end)	15 seconds, 3 repeats (rest 45 seconds between sets and 2 minutes in the end)	Opening opposite legs and hands-on the swiss ball
3 sets, 20 repeats (rest 90 seconds between sets and 3 minutes in the end)	3 sets, 15 repeats (rest 90 seconds between sets and 3 minutes in the end)	3 sets, 10 repeats (rest 1 minute between sets and 3 minutes in the end)	Bridge with marsh
3 sets, 20 repeats (rest 90 seconds between sets and 3 minutes in the end)	3 sets, 15 repeats (rest 90 seconds between sets and 3 minutes in the end)	3 sets, 10 repeats (rest 1 minute between sets and 3 minutes in the end)	Situp with stretch hands
3 sets, 20 repeats (rest 90 seconds between sets and 3 minutes in the end)	3 sets, 15 repeats (rest 90 seconds between sets and 3 minutes in the end)	3 sets, 10 repeats (rest 1 minute between sets and 3 minutes in the end)	Body twist with weight
3 sets, 20 repeats (rest 90 seconds between sets and 3 minutes in the end)	3 sets, 15 repeats (rest 90 seconds between sets and 3 minutes in the end)	3 sets, 10 repeats (rest 1 minute between sets and 3 minutes in the end)	Shoulder bridge on swiss ball

Descriptive and interpretive statistical methods were used to analyze the collected data. Shapiro-Wilk test was used to investigate the normalization of data distribution. In order to investigate the difference in balance between athletes in both groups, the covariance analysis test was used, and the correlated t-test test was used to examine the intra-group changes at a significance level of 05.0. All statistical operations were performed using SPSS software version 22.

Findings

The mean and standard deviation of specific characteristics of participants including age, height, weight, and body mass index were presented in Table 1. Each group included 15 athletes in the field of basketball and 15 athletes in the field of volleyball. Demographic information is presented in Table 3.

Table 3. Anthropometric indices related to the two groups

Measuring index	Group	Standard deviation ± Mean	T	P
Age (years)	Stable surface	25.33±3.22	1.007	0.32

Height (cm)	Unstable surface	24.20±2.93	-0.57	0.57
	Stable surface	1.77±0.03		
Weight (kg)	Unstable surface	1.78±0.03	-0.78	0.44
	Stable surface	63.40±3.54		
Body mass index (Kilograms per square meter)	Unstable surface	64.53±4.34	-0.39	0.69
	Stable surface	20.18±1.18		
Sport history (years)	Unstable surface	21.38±0.56	-0.44	0.66
	Stable surface	6.00±1.92		
	Unstable surface	6.33±2.19		

Regarding the normality of the data, which was determined by the Shapiro-Wilk test, covariance analysis and t-correlated tests were used to examine the effect of exercises and compare them.

In order to compare the amount of static and dynamic balance between the two groups in the pre-test, the covariance analysis test was used for considering the pre-test of Curtis. Results are presented in Table 4.

Table 4. The results of covariance analysis of the effect of independent variable and predictor on post-test

Variable	Test stage	Group	Mean *	F	df	P	Eta squared
BESS	Post-test	Stable surface	13.06	32.39	1	0.001	0.54
	post-test	Unstable surface	9.93				
Y test anterior direction (% of lower limb length)	Post-test	Stable surface	84.48	34.80	1	0.001	0.56
	Post-test	Unstable surface	90.73				
Y test posterior internal direction (% of lower limb length)	Post-test	Stable surface	90.13	32.85	1	0.001	0.54
	Post-test	Unstable surface	95.51				
Y test posterior external direction (% of lower limb length)	Post-test	Stable surface	82.83	21.46	1	0.001	0.44
	Post-test	Unstable surface	87.17				
Y test overall score (% of lower limb length)	Post-test	Stable surface	99.81	52.03	1	0.001	0.65
	Post-test	Unstable surface	102.05				

The results of covariance analysis showed that there is a significant difference between the two training groups in static and dynamic balance tests (P <05.0). Examining the mean scores showed that participants in the unstable surface group showed better performance in static and dynamic balance in compare to the stable surface training group.

To compare the static and dynamic balance between the study groups, and between the pre-test and post-test data, a correlated t-test was used. Results are presented in Table 5.

Table 5. The difference in mean of factors in participants before and after implementing the exercise protocols

Group	Stable surface (15 persons)				Unstable surface (15 persons)			
	Pre-test	Post-test	T	P	Pre-test	Post-test	T	P
BESS	20.2	13.2	11.	0.	21.2	9.1	16.	0.

	±40.61	±06.12	64	001	±40.94	±93.38	98	001
Y test anterior direction (% of lower limb length)	81.5	84.6	-10.	0.	82.7	90.8	-9.	0.
	±74.58	±48.08	62	001	±59.87	±73.30	47	001
Y test posterior direction (% of lower limb length)	86.3	90.4	-9.	0.	88.6	95.5	-9.	0.
	±59.97	±13.66	44	001	±61.60	±51.17	89	001
Y test posterior external direction (% of lower limb length)	79.5	82.5	-7.	0.	80.2	87.3	-8.	0.
	±93.03	±83.24	74	001	±17.89	±17.83	89	001
Y test overall score (% of lower limb length)	96.6	99.6	-21.	0.	95.6	102.6	-12.	0.
	±28.70	±81.51	70	001	±55.29	±05.09	39	001

The results of Table 4 indicate that both stable and unstable surface stability exercises of the core body have a significant effect on static and dynamic balance ($P \leq 0.05$). The static and dynamic balance were significantly improved in both groups after the test and after 6 weeks of training.

Discussion

The results of this study showed that both types of exercises in stable and unstable surfaces have an effect on the static and dynamic balance of athletes with trunk deficiency. Comparing the two types of exercises showed that exercising at the unstable surface has more effect on balance. The results of the present study comparing the two types of exercises are consistent with the results of Cosiol-Lima et al. (2003), who compared the effects of core stability between exercise programs with Swiss ball and exercise on the surface on the balance of females [23]. In addition, in the context of the impact of Swiss ball exercises on balance, our study results are in line with the results of, Skendiz et al. (2010). They examined the effects of 12 weeks of core strength exercises with Swiss ball on dynamic balance in 21 non-active females [22]. The results of the study were also consistent with the results of the research conducted by Arjoo et al. (2015) [28], which examined the effect of these exercises on performance. The results of this study are contrary to the results of Sato and Mokha (2009) on the effect of core stability exercises [24]. They did not achieve any significant improvements in the balance of participants after six weeks of core stability training among runners. The reason for this could be the type of sport or gender of participants because the participants of Sato and Mokha research were male runners while the participants of our study were female athletes in volleyball and basketball fields.

Wilson et al. (2005) showed that there is a clear correlation between core muscle stability and lower limb injury as well as lower limb function [32]. Stronger core muscles create more stability in the trunk, which facilitates the mobility in the lower limb. The abdominal muscles complex including transverse abdominal muscle, the internal and external oblique muscles, and rectus abdominis muscle, provide stability to the spinal cord with their contraction and provide a stronger support for

the movements of the lower limbs [33]. When the transverse abdominal muscle contracts, intra-abdominal pressure and thoracic-lumbar fascia tension increase, and these contractions lead to the establishment of a hard support for movement and activation of the muscles before moving the limbs [34]. The rectus abdominis, and internal and external oblique muscles are also activated in a specific motor pattern based on limb movement and control the posture [34]. According to Kibler's findings, activation of core muscles in the movement pattern of lower limbs improves postural control, and the body uses core stabilizing muscles to produce rotational force torque around the body and create limb movement [34].

The coordination between all trunk and hip muscles is essential for controlling the normal position of the spinal cord, and there is no specific muscle playing a unique role in increasing core stability [35]. In addition, the balance between the muscles on the four sides of the spinal cord is the most important factor in maintaining the balance [36]. The hip and thigh stabilizing muscles are responsible for maintaining the correct alignment of the lower body during dynamic movements. [37] Therefore, any weakness and loss of endurance in posterior, anterior, and lateral stabilizing muscles lead to a decrease in the strength and function of the thigh-surrounding muscles. The thigh muscles play an important role in transferring force from the lower limbs to the upper body, and the spinal cord. As well, it has a role in performing vertical or standing activities [37]. Consequently, the weakness of the core stabilizing muscles defects the alignment of the lower limbs during dynamic movements and interrupts the motor pattern in the lower body [37]. The lumbar spinal cord is firmly associated with gluteus maximus and triceps muscles through the thoracolumbar fascia and sacrotuberous ligament [38]. Therefore, poor core posterior muscles weaken the strength and endurance of the gluteus medius and gluteus maximus muscles.

Since the gluteus medius and gluteus maximus muscles are connected to the iliotibial strip [39], any weakness in the muscular structure of core body can reduce the effect of correct movement patterns, incidence of compensative patterns, muscle tension, labor-intensiveness and ultimately damage to the muscle. [7]. Muscular endurance is also an essential element in demonstrating the level of physical readiness and the ability of the human body to function. Hence, reducing muscle tensile strength can cause abnormal movement or displacement in various parts of the body. The role of trunk muscles in protecting the spinal cord from harmful tensions is often evaluated in researches. The muscles surrounding the spinal cord are positional muscles that help to maintain the body posture directly when standing. They also facilitate body control during bending and straightening. There is a theory indicating that reducing the endurance of trunk muscles causes muscle tiredness and increased pressure on soft tissue and inactive structures of the lumbar spinal cord. In addition, since muscle endurance capacity is an indication of fatigue capacity as well, people with lower muscular endurance in trunk muscles are more vulnerable to structural pressures, which may lead to

inappropriate stresses on the spinal cord and back pain. ^[40]. Therefore, using stabilizing exercises in core body –considering their effectiveness in improving the endurance of the trunk muscles- can be important in the prevention and rehabilitation of spinal problems. Researches have shown that there is probably no other area of the body that deserves more attention than the body core ^[39].

The results of this study could lead to the perception that potential improvements in the groups of core body stabilizing exercises are related to the level of activation of the muscular structures of the core body. When it can be inferred that participation in the core body stabilizing exercises leads to an improvement in the function and endurance of the trunk muscles, it cannot be concluded that no change occurs in the pattern of muscular activation. Although more research is needed about these exercises, the results of the study suggest that, considering the difference between the two types of exercises in affecting the components of balance, unstable surface training can be used to better improve the static and dynamic balance in compare to an unstable surface. This is achieved through strengthening of muscles that are often associated with controlling the spinal cord and pelvis. Since exercises on the swiss ball focus more on motion control and require more power to perform exercises, it can be concluded that the difference in the measured tests is related to the training characteristics.

Acknowledgment

The authors would like to thank all the athletes and coaches of Gilan province, who collaborated with researchers in this research

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