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Effect of Core Stability Training on the Endurance and Strength of Core in Basketball Players with Trunk Dysfunction

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ABSTRACT

Background: Core stability is predominantly provided by the dynamic function of musculature. Although poor core stability ultimately leads to injury, a proper training can reduce injury. The purpose of this study was to investigate the effects of core stability training on the endurance and strength of core muscles among basketball players with trunk dysfunction.

Methods: The present research was a semi-experimental study. 28 basketball players with trunk dysfunction were voluntarily participated in this study, who were then divided into two groups randomly as experimental (n=14) and control (n=14) groups. At the onset of the study, core strength and endurance were measured using some field-based tests. Dynamometer was utilized for strength and the Sorensen, trunk flexion, right and left bridge, and Prone Bridge were used for endurance measurements as pre-test. Experimental group performed the exercise training in terms of the protocol, three days per week, for a 6week period. By the end of the sixth week, the subjects performed the same core tests as post-test.

Results: Some significant differences were observed in Sorensen (P=0.003), trunk flexion (P=0.001), prone bridge (P=0.001), right bridge (P=0.001), left bridge (P=0.001), total score of endurance (P=0.001), hip abduction strength (P=0.001), hip external rotation strength (P=0.001), trunk extension strength (P=0.001), and trunk flexion strength (P=0.001) between these two groups.

Conclusion: According to the results, it can be concluded that six weeks of core stability training improved core muscle strength and endurance, which are known as two components that being weak in people with trunk dysfunction. Overall, strength and conditioning coaches and basketball players with trunk dysfunction can incorporate the present study's core training as a viable strategy to induce a significant improvement in the core suggesting a better trunk function.

Introduction

The "core" also referred to lumbo-pelvic-hip complex, include diaphragm muscle (superior), abdominal and oblique muscles (anterior-lateral), paraspinal and gluteal muscles (posterior), and pelvic floor and pelvic girdle (inferior). Moreover, core stability is a concept discussed as an essential need for muscle balance [1]. Any weakness or incoordination in this area, as core, can lead to inefficiency of proper movement patters and/or to compensatory movement patterns, muscle strain, and muscle hyperactivity, which all result in muscle injury [2]. Accordingly, it seems important that building a stable core requires well-developed lumbo-pelvic muscles in terms of strength and endurance [2]. In addition, core

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acts as a cylinder at the center of the body composing of 29 pairs of muscles that not only support lumbo-pelvic-hip complex, but also are related to some other parts such as upper and lower extremities. Accordingly, it has been noted that changes in core's mechanics would probably lead to some changes in the neuromuscular pattern recruitment. Thus, upper and lower extremities can be greatly affected by the mechanical and neuromuscular properties of core stability [1].

On the one hand, evidences suggest that core stability decrement may predispose individuals to injury, and on the other hand, performing appropriate training programs can reduce the injuries [3]. Due to the simultaneous movements of the vertebral column in three dimensions, many loads act on passive structures (e.g. bones and ligaments), which make the spine more susceptible to injuries. So, these movements should be controlled by the lumbar and abdominal muscles that provide optimal stiffness against the loads imposed on the lumbar spine and also prevent injuries resulted from overload [4]. Also, the main objective of stability training of vertebral column is to create a physical capacity and maintain neutral position of the spine during doing daily activities by increasing the tolerance and coordination of stabilizer muscles [5]. *In this regard,* many studies have shown the relationship between core stability and musculoskeletal injuries [3]. Neuromuscular control deficits are defined as inappropriate patterns of activation, low level of muscle strength, and power of trunk as well as lower limb leading to the increased loads on the anterior cruciate ligament (ACL) and knee joint during movements. Notably, trunk dysfunction is considered as one of the deficiencies in neuromuscular control. In addition, trunk deficiency can simply be defined as an incoordination of trunk control in three dimensions [6]. Core weakness results in an inefficient energy transmission, thereby reducing sport performance as well as increasing the risk of injury. Accordingly, these definitions suggest that core stability in athletes can dynamically control and transfer large forces between upper and lower extremities through the core to maximize performance and promote a movement to be dynamic and efficient [7].

Moreover, it was demonstrated that individuals with trunk dysfunction have inability in controlling trunk flexion (the increased flexion angle between the hip and trunks) as well as inability in controlling trunk lateral flexion while testing, which are known as predictive factors for this disorder. Moreover, strength ratio impairment among flexor/extensor muscles as well as lateral muscles is considered as risk factor for such a condition [8]. Various studies have also reported the influence of each of these factors on lower extremity injury. In this regard, Read et al. found that the increased trunk lateral flexion is associated with the increased risk of ACL injury in adolescent soccer players [9]. In addition, some researchers have reported that athletes suffering from hip abduction and external rotation weakness are more exposed to lower extremities injury during the season compared to the healthy individuals [3]. Notably, different mechanisms have been proposed for ACL injury such as lower extremity muscle weakness (e.g. gluteus medius, gluteus maximus and tensor fasciae latae), hip external rotator weakness [10], and trunk neuromuscular dysfunction, which cause an uncontrolled lateral movement of the trunk during jumping/landing maneuvers [11].

In this regard, implementing trunk neuromuscular exercises can reduce knee abductor torque and hip adductor torque, which consequently, reduce the risk of injury [12]. As mentioned earlier, core muscle weakness has a direct relationship with the occurrence of lower extremity's injuries in some sports involving maneuvers such as jumping, landing, and cuttings [13]. In another word, it seems reasonable that core stability has many benefits for musculoskeletal structure, from maintaining body alignments to prevent knee injury [14]. Although Carps et al. [15], Mills et al. [16] and Haddadnezhad et al. [17] investigated the effectiveness of core stability exercises on sports performance, skills, and sports injury's prevention, up to the author's knowledge, this is one of the preliminary studies performed to investigate the effects of core stability exercises on core strength and endurance among basketball players with trunk dysfunction selected by s creening tests to fill the gap in this area.

Methods

The present study was a semi-experimental research conducted as a field trial. The statistical population of this study consisted of 186 basketball players. A total of 104 people were examined using the tuck jump test. Finally, 28 individuals with trunk dysfunction were selected to participate in the study, which was consistent with previous studies. Afterward, the tuck jump test was utilized to identify individuals with trunk neuromuscular dysfunction and/or any imbalances. Accordingly, this test requires a high-level effort from the athlete and to perform the tuck jump, athletes stood in athletic position with feet approximately placed as shoulder width apart. Subsequently, they initiated the jump with a slight crouch downward while extending their arms behind them. Next, they swung their arms forward as they simultaneously jumped straight up and brought both thighs as close to parallel with the ground as possible. When landing, the athletes should have immediately started the next tuck jump again for 10 seconds [18]. A subject was considered as a person with trunk control dysfunction if he would show the following items: 1- Inability to land in the same foot print, 2- unparalleled thigh with the ground at the highest point of the jump, and 3- interrupted jumps with pauses during 10 seconds [7]. To ensure that there is a trunk dysfunction in men, before initiation of the study, a pilot test was performed and trunk dysfunction was confirmed in the subjects. In addition, the subjects were then examined for other neuromuscular dysfunctions but only those with trunk dysfunction were allowed to participate in this study. Prior to participation in this study, all the procedures were explained to the participants and they signed a consent form and also completed the pre-participation questionnaire including personal information and injury background. In addition, the dominant leg was determined by asking the participants that which leg they would use to kick a ball. The research method was approved in terms of ethical considerations and the inclusion and exclusion criteria was as follows: at least 3 years of regular basketball playing, age ranged between 18 and 25 years old and having trunk neuromuscular dysfunction for inclusion criteria; and any history and background of surgery, pre-existing injury in lower limbs (e.g. ACL, DJD, ankle instability etc.) or sever postural abnormalities such as scoliosis and kyphosis for exclusion criteria.

Core Muscles Endurance Measurement Test

For this task, the reliable McGill protocol was used to determine the endurance of trunk stabilizer muscles. Correspondingly, this protocol is comprised of 5 tests exploring the endurance of all trunk muscles. Prone bridge, right-side bridge, left-side bridge, biering-sorensen test, and trunk flexion test were also performed at an angle of 60 degrees in terms of the previous references [19, 20]. A stopwatch was used to record the duration of subject's isometric contraction maintenance. After each test, subjects had five minutes rest time. The results of the previous studies indicated that these tests have great validity coefficients [20].

Trunk Flexion Test

The flexion endurance test was firstly described in an article by McGill in 1999 [20]. This test required subjects to sit on the test bench and then place the upper body against a support with an angle of 60 degrees from the test bed. Both the knees and hips should be flexed to 90 degrees. The arms should be folded across the chest with the hands placed on the opposite shoulder and toes must be placed under the toe strap. The subjects were then instructed to maintain the body position while the supporting wedge was pulled back 10 centimeters to begin the test. Finally, the test ended when the upper body fell below the 60 degree angle. Test re-test reliability was found to have ICC scores of 0.95-0.98, which is considered as an excellent reliability [19, 20] (Figure 1).

Figure 1: Core endurance Tests. McGill protocol was used to determine the endurance of trunk stabilizer muscles.

Biering-Sorensen Test

For the trunk extension test, also known as the biering-sorensen test, the participants were instructed to lie prone off the edge of a plinth with all body parts above their anterior superior iliac spines hanging off the table. Three straps were then performed to hold lower extremities onto the table as follows: one at gluteal fold, one just above the knee joints, and one just above the ankles. Afterward, the participants were allowed to rest their upper extremities on a chair prior to start. They were then instructed to cross their arms in front of their chest and to lift their upper body up until their trunk was horizontal with the ground. Time was started when the subject achieved the starting position. Accordingly, this position was held until fatigue or until their body deviated from horizontal, and the test was then ended. The biering-sorensen test has been found to have a good reliability with ICC scores greater than or equal to 0.77 [19, 20] (Figure 1).

Prone and Side Bridge Tests

Before beginning the timed prone bridge, a picture of proper technique was shown to the participants. This test required the participant to be in a side-lying position with her body in a straight line. The lower foot should be positioned behind the top foot for support. The participant was then directed to elevate the hips above the mat to uphold a straight line along the entire body length, and to hold the position on one elbow as well as both feet. The top arm was placed along the chest with hand located on the opposing shoulder. This test was terminated when the subjects were no longer able to hold their hips in line with the trunk. (Figure 1). The subjects were shown how to position themselves prone with only their forearms and toes in contact with a table's surface. Afterward, they were told that, after the command "go" they should perform a position with their head, neck, back, and hips in neutral position and to hold the position for as long as possible. If they deviated from this neutral posture they were warned up to 3 times. Timing with a stopwatch commenced when the position was firstly assumed and ended when the participants voluntarily stopped that, or when they were not able to maintain the required neutral position in spite of three warnings [19, 20] (Figure 1).

Core Muscles Strength Measurement Test

Trunk Flexion and Extension Strength

To measure the isometric strength of trunk flexors, the subject flats on his back, while the knee was in the 90° flexion. Also, legs were tight on examination bed by straps. Then, handheld dynamometer was placed on the sternum and the center of the chest for each person, and afterward, isometric strength was measured three times and the average of these measurements were recorded as isometric strength of the trunk flexors. For trunk extensors isometric strength measurement, the subjects laid prone and legs was fixed by strap to the examination bed. Handheld dynamometer was placed on the inferior angle of the scapula and between the shoulder blades, also, similar to trunk flexors, isometric strength was measured three times for each individual and the average of these measurements was recorded as an isometric strength of the trunk extensors [7] (Figure 2).

Hip Abduction

This measurement was performed in terms of the Bohannon protocol [7]. The subjects were in side-lying position on the examination bed, and handheld dynamometer (Nicholas, Lafayette, US) was also placed

Figure 2: Core Strength Tests. Dynamometer was used to determine the Strength of core muscles.

on the lateral side of femur, 5 cm proximal to lateral articular line of knee. Afterward, a large pillow was placed between subject's legs, so that both hips were fixed in 0° abduction related to the line connecting right and left anterior superior iliac spine. A strap was tied in the region proximal to iliac crest and fixed the trunk to the test table. The center of dynamometer's surface was directly placed on the point marked over the knee. Dynamometer was then tied to the bed using another strap. The subject was asked to move his leg upward with maximal effort. Test-retest reliability of this method was determined to be 0.95 (Figure 2) [21].

Hip External Rotation

This measurement was performed based on the procedure suggested by Cahalan et al. in 1989. Subject sat on the table with his hips and knees in 90° flexion. A strap was tied around subject's hip and the table. A rolled towel was placed between his knees to maintain their position and minimize rotation generated by hip adductors. Dynamometer was placed in a way that the center of its surface was directly fixed on the point of 5 cm proximal to medial malleolus of the testing leg. Dynamometer was then fixed to the table using a strap. The subject was asked to rotate his leg toward dynamometer with a maximal effort. Test-retest reliability of this protocol was determined as 0.83 (Figure 2) [21].

Core Stability Training Protocol

This protocol was performed three times per week for a 6week period. According to the specificity principle of training, the training program was combined with basketball-specific core stability exercises [17, 22]. The subjects of the training group performed the core stability exercises for 6 consecutive weeks.

The exercise and control groups were allowed to do their normal daily activities. Also, training sessions were conducted by the researcher. Each one of the subjects had to participate in three training sessions per week. The subjects of the training group also had to participate in at least 16/18 training session. Those who were absent in two consecutive training sessions were excluded from the study. At the beginning of each training session, 10 minutes general warm-up training was performed including running, upper extremities, trunk, and lower extremity (Table 1).

Statistical Method

In order to analyze differences of the pre- and post-test averages between core strength and endurance in the subjects who performed exercise protocols, analysis of covariance (ANCOVA) was used. The obtained data was analyzed using SPSS version 22. It is also worth noting that the significance level was considered as $P \leq 0.05$.

Results

Descriptive statistics of each group including age, weight, height, and body mass index were measured prior to the test, and its results are summarized in Table 2:

Firstly, distribution of the data set was evaluated using statistical testing including the Shapiro–Wilk test. Accordingly, the results of the analysis indicated that the data were normal in these two groups, which are not presented in the findings section may be due to the extensiveness of the results. In addition, the ANCOVA test results of the core strength and endurance with the excluded pre-test effect are reported in Table 3.

The results of the covariance analysis test showed that there were significant differences among the mean score of biering-sorensen test [$F(1,28)=10.43$, $P=0.003$], trunk flexion endurance [$F(1,28)= 55.06$, $P=0.001$], prone bridge [$F(1,28)=77.14$, $P=0.001$], right-side bridge [$F(1,28)=25.79$, $P=0.001$], left-side bridge [$F(1,28)=27.34$, $P=0.001$], total endurance score [$F(1,28)=74.28$, $P=0.001$], hip abduction strength

Table 1: Core training protocol

Exercise	First and second week	Third and fourth weeks	Exercise	Fifth and Sixth weeks
Basic Plank	3 repetitions of 30 seconds	3 repetitions of 45 seconds	One Arm Plank	3 repetitions of 45 seconds (each side)
Side Plank	3 repetitions of 30 seconds (each side)	3 repetitions of 45 seconds	One Arm Side Plank	3 repetitions of 45 seconds (each side)
Supine Bridge	3 repetitions of 30 seconds	3 repetitions of 45 seconds	Single leg supine bridge	3 repetitions of 45 seconds (each side)
Medicine ball pullover pass	2 times, Each time with 20 repetitions	2 times, Each time with 30 repetitions	Medicine ball pullover pass	2 times, Each time with 45 repetitions
Russian twister	3 times, Each time with 20 repetitions	3 times, Each time with 30 repetitions	Russian twister	3 times, Each time with 45 repetitions
Spilt Legs Scissors	3 times, Each time with 20 repetitions	3 times, Each time with 30 repetitions	Spilt Legs Scissors	3 times, Each time with 45 repetitions
Side double-leg lift	3 times, Each time with 20 repetitions	3 times, Each time with 30 repetitions	Side double-leg lift	2 times, Each time with 45 repetitions
Medicine ball overhead throw	2 times, Each time with 20 repetitions	2 times, Each time with 30 repetitions	Medicine ball overhead throw	2 times, Each time with 45 repetitions

Table 2: Descriptive statistics of research variables

Variables	Group	Number	Mean±SD	P
Age (year old)	Control	14	22.78 ± 2.60	0.175
	Experimental	14	22.71 ± 1.20	
Weight (kg)	Control	14	72.07± 6.59	0.052
	Experimental	14	66.58± 6.78	
Height (meter)	Control	14	1.83 ± 0.07	0.755
	Experimental	14	1.82 ± 0.05	
Body mass index (kg / m 2)	Control	14	21.52+1.67	0.054
	Experimental	14	20.14± 1.93	

Table 3: The ANCOVA test results of the core strength and endurance with the excluded pre-test effect

Factor	Variable	Sum of squares	Degrees of freedom	*Mean square*	F ratio	The significance level	The effect size
Trunk flexion strength (kg)	Groups	17.90	1	17.90	88.14	0.001**	0.859
Trunk extension strength (kg)	Groups	20.87	1	20.87	27.29	0.001**	0.744
Hip abduction strength (kg)	Groups	35.683	1	35.683	116.418	0.001**	0.911
Hip external rotation strength (kg)	Groups	22.35	1	22.35	24.96	0.001**	0.727
Trunk flexion endurance (second)	Groups	1508.91	1	1508.91	55.06	0.001**	0.948
Biering-sorensen (second)	Groups	3493.536	1	3493.536	10.43	0.003**	0.350
Prone bridge (second)	Groups	1406.86	1	77.14	77.14	0.001**	0.901
Right-side bridge (second)	Groups	449.29	1	449.29	25.79	0.001**	0.776
Left-side bridge (second)	Groups	1399.27	1	1399.27	27.34	0.001**	0.865
Total Endurance (second)	Groups	1679.803	1	1679.803	74.28	0.001**	0.871

[F(1,28)= 116.418, P=0.001], hip external rotation strength [F(1,28)= 24.96, P=0.001], trunk flexion strength [F(1,28)= 88.14, P=0.001], and trunk extension strength [F(1,28)= 27.29, P=0.001] between the experimental and control groups in post-test.

Discussion

The aim of this study was to evaluate the effect of a core training program on the improvement of the strength and endurance of the core in basketball players with trunk neuromuscular dysfunction. Although there were many studies regarding the effectiveness of core stability exercises in sports performance as well as the sports injury prevention, to the best of author's knowledge, this is the first study implementing functional tests to select basketball players with neuromuscular dysfunction. This study has also examined the effects of core exercises on endurance and strength of people with trunk dysfunction. Thus, the primary finding of this study was that, the core stability training for six weeks in male basketball players with trunk dysfunction have significantly improved the core strength and endurance.

Our results demonstrate that, implementing a core stability training to basketball players, can enhance core strength, which can be seen from the tests including trunk flexion strength, trunk extension strength, hip abduction strength, and hip external rotation strength, which showed several significant improvements. Our results allow us to speculate that implementation of core stability exercises improved the strength and recruitment of trunk muscles, which may help individuals to overcome muscle imbalances, because most of the people with trunk dysfunction have some problems with strength and endurance trunk muscles [23]. Therefore, facilitating the simultaneous contraction of the muscles around the lumbar vertebrae such as abdominal and oblique muscles, transverse abdominis, multifidus, and erector spinae muscles may increase the stability of the trunk, which can be valuable for those people, and more specifically for athletes [1, 24].

This finding, the improved core strength, is consistent with that of previous studies conducted by Haddadnezhad et al. [17], Kumar et al. [25] and Sahebozamani et al. [26]. In another study, Abdullah and Beltagi [27] examined the effect of core stability training on the maximum torque of the trunk's flexors and extensors. Accordingly, they reported that there was a significant increase in the maximum torque of the flexors and extensors of the trunk in the experimental group, while no changes were observed in the control group. In this regard, it has been noted that the activation of core musculature in patterns with extremity movements, the common movement performed in basketball, helps the improvement of postural control, which is a phenomenon that may have been improved in the group that completed Core Stability exercises [23].

In addition, hip abductor muscles strength improvement observed in this study, is in agreement with Ekstrom et al. [28] who examined the effect of side bridge training on electromyographic activity of the glutes medius and external oblique muscles. The result of this study is also consistent with the study by Gaig et al. [29]. Moreover, it is worth mentioning that landing biomechanics and postural control are not unrelated to neuromuscular control as previous studies showed some improvements in neuromuscular control after doing core exercises, which all resulted in the enhanced landing biomechanics [30]. Despite the fact that we measured no biomechanical factors in this study, it is reasonable that the improved core strength and endurance can be advantageous to landings, which are included in the main maneuvers performed in basketball. Moreover, larger muscles of the core developed by our core training program act as a solid cylinder generating more inertia against body instability, and thus, they provide stronger base of support for lower extremities movement [31]. Also, it is important to bear in mind that, any dysfunction in neuromuscular control of the core during sports activities can lead to an uncontrolled displacement of the trunk, which would consequently cause asymmetry in the distal joints [12, 13]. It can be said that core stability has many benefits for musculoskeletal structure, from maintaining body health to preventing injuries [15, 16]. Haddadnezhad et al. investigated the effect of core stability exercises on trunk muscle activity among women with the impaired trunk control. The outcomes showed that core exercises improved the neuromuscular control, in which a person can perform the same task with less energy [17]. The present study also proved that athletes (basketball players) with trunk dysfunction examined by the tuck jump test prior to study, can benefit from core exercises compared to previous studies conducted in general population.

Moreover, the outcomes of this study demonstrated muscle endurance improvements. In this regard, trunk muscles endurance is more important than strength [32]. Although there is no linear relationship between the endurance and strength, the increased strength may result in endurance increase to a certain extent and then endurance remains constant. Therefore, if these capacities are related, it could be expected that training one capacity should also improve another. Also, in other way, it may be possible that trunk muscle strength reduction lead to muscle endurance decrement [33]. Muscular endurance is an essential element to indicate physical fitness level of human's body. In addition, muscle endurance reduction can also cause abnormal movement or displacement in various parts of the body. Moreover, it has been evaluated in some studies that trunk muscle endurance plays a crucial role in protecting the spinal column. Since muscles around the spine are postural, they help in keeping the body stable while standing, which also control the body when forward/backward bending. Hence, they should be fatigue-resistant, since the endurance capacity of the muscles is an indication of their fatigue capacity [34]. Therefore, the results of muscle endurance enhancement in this study might be beneficial in this context.

Core exercises are vital for all athletes. When athletes ignore the core exercises, the level of their sport performance reduces and the risk of injuries increases for them [1]. On the other hand, the study results have shown that neuromuscular dysfunction of trunk control or trunk dominance causes dysfunction of the trunk and inability in the accurate control of the trunk in three dimensions [34]. It seems that the results of this study indicate the effect of the core training on trunk strength and endurance, which is effective on reducing these disabilities by improving these factors. The results of this research can lead to the idea that Potential improvements in the core stability training group are related to the level of activation of the muscles of core region. Whenever it is inferred that participating in the core stability exercises leads to the development of strength and endurance of the trunk muscles, it cannot be concluded that, no changes are experienced in the pattern of muscle activation.

This study has also some limitations. In this regard, although the core stability training showed some significant improvements in core strength and endurance which, can only lead to supposition that these improvements might be related to the level of activation in the targeted musculature, we cannot conclude what, if any, changes in muscle activation patterns were experienced. While difficult to perform, it will be important to quantify with electromyography of the changes in core stability muscle activation patterns (strength vs. endurance measures) during the basketball-related skills performance before and after the intervention program in future. Finally, we are not sure whether there is any study examining the effect of sex and playing experience on core stability of basketball players; therefore, we suggest that future investigators should consider potential influences of sex and levels of expertise (professionals vs. amateurs) on core stability.

Conclusion

According to the outcomes of the present study, basketball players with trunk dysfunction benefited from this core training regimen in terms of muscle strength and endurance, which are known as two factors to be weak in people with trunk dysfunction. Thus, strength and conditioning coaches and allied health professionals could potentially use core stability exercises as a viable strategy to increase the trunk core muscle strength and endurance.

Conflict of Interest: None declared.

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