

Evaluation of Relationship between Trunk Muscle Endurance and Static Balance in Male Students

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Abstract

Purpose: Fatigue of trunk muscle contributes to spinal instability over strenuous and prolonged physical tasks and therefore may lead to injury, however from a performance perspective, relation between endurance efficient core muscles and optimal balance control has not been well-known. The purpose of this study was to examine the relationship of trunk muscle endurance and static balance.

Methods: Fifty male students inhabitant of Tehran university dormitory (age 23.9 ± 2.4 , height 173.0 ± 4.5 weight 70.7 ± 6.3) took part in the study. Trunk muscle endurance was assessed using Sørensen test of trunk extensor endurance, trunk flexor endurance test, side bridge endurance test and static balance was measured using single-limb stance test. A multiple linear regression analysis was applied to test if the trunk muscle endurance measures significantly predicted the static balance.

Results: There were positive correlations between static balance level and trunk flexor, extensor and lateral endurance measures (Pearson correlation test, $r=0.80$ and $P<0.001$; $r=0.71$ and $P<0.001$; $r=0.84$ and $P<0.001$, respectively). According to multiple regression analysis for variables predicting static balance, the linear combination of trunk muscle endurance measures was significantly related to the static balance ($F(3,46)=66.60$, $P<0.001$). Endurance of trunk flexor, extensor and lateral muscles were significantly associated with the static balance level. The regression model which included these factors had the sample multiple correlation coefficient of 0.902, indicating that approximately 81% of the variance of the static balance is explained by the model.

Conclusion: There is a significant relationship between trunk muscle endurance and static balance.

Key Words: Static Balance; Trunk Muscle Endurance; Sorensen Test; Trunk Flexor Endurance Test; Side Bridge Endurance Test; Single-Limb Stance Test

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INTRODUCTION

The core consists of many different muscles that stabilize the spine, pelvis and shoulder and provide a foundation for movement in the extremities. Core exercise programs need to address all these muscle groups to be effective. The muscles of the core help control movements, transfer energy, shift body weight and distribute the stresses of weight-bearing [1].

Functional movements are highly dependent on the core, and lack of core development can result in predisposition to injury [2]. The major muscles of the core are transversus abdominis in the anterior, multifidus in posterior pelvic floor in lower and the diaphragm in upper part. Minor core muscles include the latissimus dorsi, gluteus maximus, and trapezius [1,3]. Core exercises address the muscles of pelvis, lower back, hips and abdomen to work in a coordinated

manner that leads to better balance and stability. In fact, most sports and other physical activities depend on stable core muscles [4,5]. Core training programs are designed to optimize trunk muscle strength and endurance that is a fundamental demand during athletic performance. It is suggested that although core muscle strength is necessary for activity and sports, its endurance has a very important role in spinal stability during prolonged physical activity and protects from injury [5,6,7].

Balance is the ability to maintain the Center of Gravity (COG) of a body within the base of support with minimal postural sway. Maintaining balance is coordinated by three systems. The first input is from the vestibular system. The second balance coordinator is the proprioceptive system originating from somatosensory receptors in muscles, tendons, and joints for kinesthetic sense, body posture and spatial awareness. Finally, the visual system which sends visual signals about body's position [1,8,9]. Postural control necessitates interaction of nervous and musculoskeletal system. Components involving control include the motor system providing musculoskeletal synergistic response, somatosensory system obtaining visual, vestibular and proprioceptive information and central nervous integrating system for converting sensory inputs into muscle coordination and adaptation. There are three movement strategies the human body uses for re-establishment of stability in response to perturbation of balance and displacement in base of support, ankle strategy, hip strategy and stepping strategy [1,8,9].

Key stabilizing muscles are activated 50 milliseconds before the primary muscle and they are responsible for informing CNS proprioceptively and for inter and intrasegmental stabilization.

As mentioned before when an external perturbation disrupts one's balance, three movement strategies activate to return COG back to or maintain the COG in a balance position. Ankle strategy is the first one. Gastrocnemius contraction confronts anterior sway of body and tibialis anterior activates opposite posterior sway of body. The ankle strategy is followed by hip and lower trunk muscle contraction. After anterior sway of body, gastrocnemius muscle activation starts in 90-100 milliseconds, subsequently hamstring

muscles activate 20-30 milliseconds later and finally paraspinals contract. Gastrocnemius counteracts anterior sway and hamstrings and paraspinals maintain thigh and knees in erect posture. On the contrary in posterior sway, tibialis anterior counteracts and quadriceps and abdominalis muscles maintain the posture [1,8,9,10].

Theoretically balance has been defined as static and dynamic, while static balance is the body's ability to keep COG in base of support; dynamic balance is the active movement of center of pressure during standing, walking or execution of sports skill. From the functional view, balance has been categorized as static, dynamic and semi dynamic. There are several methods of balance assessment [11]. Objective or quantitative measurements have been preferred rather than subjective or qualitative ones. The single leg stance test is more sensitive for assessing normal balance [11,12].

As mentioned before, sufficient endurance of core muscles has an essential role in balance, coordination and sports specific tasks. A number of isometric tests of trunk muscle endurance have been described for extensors, flexors and lateral musculature of the trunk [13]. Reliability of Sørensen test for trunk extensor endurance assessment has been well established [14]. For testing the lateral trunk musculature, the side bridge exercise has been suggested that was first described by McGill et al. Trunk flexor endurance test has been employed for assessment of core flexors [13,14].

In literature, the aim of many studies describing the relationship between trunk muscle & balance has been therapeutic and rehabilitative intervention and core muscle strength has been emphasized [15]. Meanwhile, the role of trunk muscle endurance in balance & coordination has not been clear so in the study this relationship has been taken into consideration.

METHODS AND SUBJECTS

In this correlation study fifty subjects were evaluated. Male students inhabitant of Tehran university dormitory (age 23.9 ± 2.4 , height 173.0 ± 4.5 , weight 70.7 ± 6.3) took part voluntarily in the study. A session

was held at the dormitory to distribute consent forms and give an overview of the research. Exclusion criteria were BMI more than 25 and less than 18, professional sports activity, history of Low Back Pain, any fracture or history of lower limb surgery in lower limb, neurologic disease and, Meniere's disease, neuromuscular problems and any vestibular or balance disease and informed consent was obtained from all of them. Very tall or very short subjects were kept out of study. An informed consent was also taken for using photos from the subject.

In first phase, static balance was measured using a quantifiable clinical test called the single-limb stance test [12]. Trunk muscle endurance was assessed using Sørensen test of trunk extensor endurance, trunk flexor endurance test and side bridge endurance test [13,14]. All tests were performed by a 5th author to eliminate inter-rater reliability under supervision of first and second authors. To improve the internal consistency or intra-rater reliability all tests were taken two times (Spearman Brown formula).

In Single-leg stance Test, Subjects were asked to stand on dominant foot by placing their hands on the iliac crests with contra-lateral limb in hip flexion and knee flexion relying on medial side of dominant knee (Fig. 1). Subjects were told to; with observer command, lift the stance foot heel and keep the stance position motionless while time was then recorded. Errors include hands lifted off iliac crests and compensatory adjustment such as displacement of ball



Fig. 1: Single leg stance test

of non-dominant foot. The test was executed twice and the better result was recorded.

Sørensen test was performed for assessment of trunk extensor endurance. The subject lied in the prone position on the examining table with the upper edge of the iliac crests positioned on the upper edge of the table. The pelvis, knees, and ankles were fixed to the table by three straps and arms were bent (Fig. 2). The subject was asked to isometrically maintain the upper body in a horizontal position. A chair was placed in front of the subject to support him by holding it with hands in case of inability to keep the position. The time during which the patient keeps the upper body straight and horizontal was recorded by chronometer.



Fig. 2: Sorensen test

For testing the flexor trunk musculature, the trunk flexor endurance test was performed. The subject lied on a cushioned and flat surface with hip and knees flexed, both at 90 degrees with the arms crossed over the chest. The subject was asked to raise the trunk in a smooth motion, keeping the position as much as possible (Fig. 3). The time was recorded by chronometer.

And finally for testing the lateral trunk musculature, the side bridge exercise described by McGill was used



Fig. 3: Trunk flexor endurance test

to recruit quadratus lumborum and anterolateral trunk wall muscles. The subject lied on his right side. The upper body supported off the ground by the right elbow and forearm. The legs were straight, with the left foot in front of the right foot. The hip was lifted off the floor while the elbow and feet supported the body, creating a straight line from head to toe. The left hand was placed on the supporting shoulder. As soon as the subject was in correct position, the stopwatch was started. The test was over when subject was unable to hold the back straight and the hip was lowered. After 5-7 minutes rest, other side was tested (Fig. 4).

Statistical analysis:

A multiple linear regression analysis was conducted to determine if the trunk muscle endurance measures (independent variables) significantly predicted static balance (dependent variable). Regression diagnostics were performed to detect violations in regression modeling assumptions. The residual plot against the fitted values showed no evidence of curvature and non-constancy of error variance. In addition, no departure from normality was observed in the normal probability plot of the residuals. Multicollinearity was studied by calculating the variance inflation factors. Based on the results, multicollinearity among the three predictor variables was not a problem. For the fitted model, the influence of outlying cases did not appear to be influential. Statistical analysis was performed using the statistical software SPSS 16.0.0. (SPSS Inc. Chicago, IL, U.S.A.). *P* values less than 0.05 were considered statistically significant.

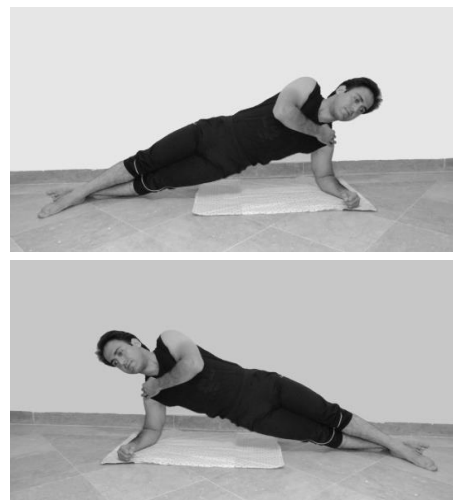


Fig. 4: Side Bridge Exercise Test

RESULTS

Table 1 shows the baseline characteristics of the participants. There were positive correlations between static balance level and trunk flexor, extensor and lateral endurance measures (Pearson correlation test, $r=0.80$ and $P<0.001$; $r=0.71$ and $P<0.001$; $r=0.84$ and $P<0.001$, respectively) relative to the static balance ($F(3,46)=66.60$, $P<0.001$). Endurance of trunk flexor, extensor and lateral muscles were significantly associated with the static balance level (table 2). The regression model which included these factors had the sample multiple correlation coefficient of 0.902, indicating that approximately 81% of the variance of the static balance is explained by the model.

Table 1: Baseline Characteristics of the Participants (n=50)

Characteristics	Mean (SD)	Median (range)
Age, years	23.88 (2.38)	24 (20-29)
Height, cm	173.04 (4.52)	172 (164-181)
Weight, kg	70.70 (6.27)	70 (60-85)
BMI	23.62 (2.05)	23.14 (19.23-28.37)
Trunk Flexor Endurance, sec.	32.68 (12.52)	31.5 (12-60)
Trunk Extensor Endurance, sec.	42.22 (13.51)	40 (19-78)
Trunk Lateral Endurance, sec.	30.60 (10.38)	30 (14-54)
Static balance	21.42 (10.15)	20 (7-47)

BMI, body mass index (calculated as weight in kilograms divided by height in meters squared)

Table 2: Summary of Multiple Regression Analysis for Variables Predicting Static Balance

Variables	<i>B</i>	SE (<i>B</i>)	<i>B</i> [*]	<i>t</i>	<i>P</i> . value
Trunk Flexor Endurance	0.29	0.08	0.36	3.56	0.001
Trunk Extensor Endurance	0.22	0.06	0.29	3.60	0.001
Trunk Lateral Endurance	0.37	0.11	0.38	3.51	0.001

B: Unstandardized Coefficients; SE(*B*): Standard error of the estimate;

B^{*}: Standardized Coefficients; *t*: t-value; R²=0.813; Adjusted R²=0.801

DISCUSSION

The primary purpose of this study was to determine the relationships between core muscle endurance and static balance that subsequently affect functional movement and performance. In the posture and balance context, lower limb has been the main focus for study and therapeutic intervention; whereas the role of strength and endurance deficits of core muscles has not been clear, so it is not surprising that core training was not the priority in training program design. In 2009, Suri et al evaluated the association of trunk muscle attributes and balance and mobility in elderly and found an average correlation (41%) between balance and trunk muscle endurance [15].

The literature unanimously shows negative effects of trunk muscle fatigue on balance. In 2010, Helbostad et al demonstrated the consequences of lower extremity and trunk muscle fatigue on balance and functional tasks [16]. They showed that muscle extensor fatigue has been correlated with somatosensory process dysfunction that leads to poor balance and coordination, but it is not established that resistance against muscle fatigue or endurance could improve balance. Therefore it will be hypothetically sensible that muscle endurance as an opposite of fatigue could alleviate this negative effect on balance.

Based on a literature review, trunk extensor fatigue has affected static balance through increased postural sway. Carpes described positive effects of trunk strength program on low back pain pelvis kinematics, and body balance [17]. The result of Felipe pilot study suggests the influence of trunk strength and stability on low back and pelvis pain and kinematics as well as on body balance that was consistent with our findings.

Our study is not in accordance with the Tomoko et al study about relationship between core stability, functional movement and performance. They found weak correlation between core stability and functional movement screen. The main reason for this

concordance is the sports specificity of dynamic functional movement compared with static balance assessed in our study.

We assessed core muscle endurance through tests that elicited isometric muscle contractions of the trunk musculature during the time. The single leg stance test was used to measure static balance quantitatively and a strong correlation was found between core muscle endurance and static balance. Due to the correlation type of study, we cannot conclude that there is a cause and effect relationship between two variables but it can be inferred that with improvement in one, we can expect the better result in another one. The fact that which variable is the priority to be worked on for improvement is not well known but regarding that the core is where the center of gravity is located and operates as integrated functional units where the kinetic chain begins from, it deems trunk muscle as our primary issue to work on it. On the other hand, the trunk area contains shoulder and pelvic girdles, therefore stabilizing muscles should be activated dynamically in the beginning of movement to provide a strong foundation from which force is produced and motion starts [18,19].

From a performance perspective, specific training aimed at improving trunk muscle endurance must be incorporated in balance training design and vice versa [20,21,22]. Additionally, in order to help interpret the results of trunk muscle endurance testing and assist in setting training targets, another study is required for female athletes to compare and evaluate the role of gender on trunk muscle endurance and static balance.

From an injury prevention perspective in athletes, further study for observation of correlation between upper and lower limb injury rate with strength and endurance of trunk muscle is warranted. Since the relationship between trunk muscle endurance and static balance may be sport-specific, further studies of athletes from different sports are recommended.

The limitations of study are inability of emotional and motivational status control of subjects during tests and inability of subject's daily activity control.

addressing trunk endurance is to apply our knowledge and skills to design exercise programs that improve endurance and subsequently balance as an integrated part in optimal performance of athletes.

CONCLUSION

There is a significant relationship between trunk muscle endurance and static balance. The challenge in

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Conflict of interests: None

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