Relationship between Trunk Stabilizer Muscle Strength and Frontal Hip and Knee Angles during Single-Leg Squat in Female Individuals

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Abstract

Objective: The purpose of this study was to investigate correlation between trunk stabilizer muscle strength and the frontal hip and knee angles during single-leg squat.

Method: Fifteen women (19-27 years old) participated in this study. All participants were right leg dominance. Trunk stabilizer muscle strength was measured. A Vicon™ Nexus system with 10 cameras were used to examine the frontal hip and knee angles. Single-leg squat test was used dominant leg. Spearman's rank correlation was used to determine the correlation between the level of lumbar stabilization exercise and the frontal hip and knee angles. Besides, Pearson's correlation was analyzed the correlation between trunk muscle strength which was measured by handheld dynamometer and the frontal hip and knee angles.

Results: Muscle strength of right external oblique abdominis showed a negatively significant correlation with the frontal hip angle ($r = -0.61$, $p = 0.02$). The level of lumbar stabilization exercise had no correlation with the frontal hip and knee angles.

Conclusion: This study demonstrated that trunk stabilizer muscle strength associated with the frontal hip during single-leg squat. Further study should consider the effect of trunk stabilizer muscle on lower extremity biomechanics.

Keywords: Trunk stabilizer trunk muscle strength single-leg squat frontal hip angle frontal knee angle

Introduction

Trunk stability is an importance for preventing lower extremity injury [1] and the instability may play a role as the risk of lower extremity injury in female [2,3]. Impaired core proprioception and deficits neuromuscular control of trunk can predict the knee injury [4,5]. Based on anatomy, trunk muscles connect to the lower extremity muscles [6]. Therefore, either trunk muscle or lower extremity muscle has a problem, then, may effect each other. An improvement of trunk muscle activation may be able to improve the lower extremity movements and stability. Moreover, movement of the pelvis and trunk can influence the moments at the knee [7]. Willson et al evaluated the association between core strength and lower extremity alignment during single-leg squats. The lower extremity alignment present by frontal plane projection angle (FPPA) of knee. The FPPA is an angle between the line from ASIS and mid tibiofemoral joint, and the line from mid tibilofemoral joint and mid ankle joint. They used handheld dynamometer for measure the core muscle strength. The result showed that trunk extensor and trunk lateral flexor muscles strength fair associated with FPPA [8]. In addition, the study about correlation of core muscle strength and frontal plane alignment of lower extremity during single-leg squat found that sidelying plank has fair correlated with the peak FPPA in healthy female. The negative FPPA represented genu valgus while positive FPPA represented genu varus [9]. Previous study reported that the peak ipsilateral trunk lean was correlated with the peak hip adduction and knee abduction angle during single-leg squat in healthy group. Moreover, the study showed that side bridge test was moderate correlated with the peak knee abduction angle during single leg squat in healthy group. There was no correlation in patellofemoral pain group [10].

The single-leg squat is foundation of many functional activation such as walking, running, landing, cutting, and balance. The single-leg squat usually prefers for rehabilitation and assessment of lower extremity, such as dynamic hip control, lower extremity kinematics, and lower extremity alignment. Several study used single-leg squat for assessment knee alignment [8,9]. Excessive knee valgus during single-leg squat could be the result from hip adduction and knee abduction that is the injury risk of anterior cruciate ligament, medial collateral ligament [7].

The information of trunk muscle strength and knee alignment during functional tasks would help to better understanding the risk of knee injury. Diminish study determined the correlation between trunk stabilizer muscle strength by the level of lumbar stabilization exercise and lower extremity angles during single-leg squat. Therefore, the purposes of this study was to investigate the correlation between trunk stabilizer muscle strength and the frontal hip and knee angles during single-leg squat. We hypothesized that trunk stabilizer muscle strength would associate with the frontal hip and knee angles.

Materials and methods

Participants

Fifteen female participated in this study. Their mean age was 23.8 $\pm$ 2.54 years old, BMI was 21.58 $\pm$ 2.09 kg/m^2. All participants were right leg dominant. Exclusion criteria was pain or history of surgery, fracture and serious injury of upper extremity, back, and lower extremity that affect to the testing, musculoskeletal problems that affect to the testing such as scoliosis, flat foot, pronate foot, severe ankle sprain, chronic ankle sprain, abnormal knee alignment : Q angle > 15º , instability of shoulder, knee, and patella, balance problem affect to the testing, obesity (BMI > 24.99 kg/m2), neurological disorder, cardiovascular disorder, pregnancy, taking alcohol, caffeine and medicine effects to muscle performance within 24 hours prior to participant in this study. Protocol of the current study was approved by the Institutional Review Board at Mahidol University. The researcher described the purpose, the advantages, the procedures, and the risk of study to the participants before testing. Each participant signed an informed consent.

Trunk stabilizer muscle strength

Level of lumbar stabilization exercise

The participant was crook lying position with knee flexion approximately 90°. The researcher put the pressure transducer (Stabilizer™ Pressure Bio-feedback, Chattanooga, Australia) under upper border at L1 and lower border at S2. They were asked to relax muscle around lumbar and pelvis. The researcher instructed to participant to move pelvic in anterior pelvic and posterior pelvic tilting to find pelvis in neutral position. Then, the pressure transducer was pumped to 40 mmHg. After that the participants were asked to contract abdominal muscles. Participants placed their hands on lower abdomen (below navel medial to ASIS 2 cm) and pressed abdomen to spine. They needed to feel the contraction abdominal muscles during normal breathing. Participant was practiced for 2 times before test. The test followed the series of lumbar stabilization exercise as Figure 1 [11,12]. The test would be passed to the next level if participant could control pressure 40±4 mmHg without compensation in three breathing cycles.

Muscle strength during MVIC measuring

Maximum force (N) generated from the trunk muscles during MVIC measuring was reported using a handheld dynamometer. A foam 0.5 cm thick was applied between the handheld dynamometer probe and the participant's skin for comfortable. Participant was asked to perform maximum isometric 5 seconds and rest 1 minute between trials in order to prevent fatigue, totally 3 trails. Participant was allowed for rest 3 minutes between muscle groups and side. A researcher's hand was placed on handheld dynamometer to support during contraction. Trunk flexion with rotation was the action of the external oblique abdominis muscles contraction. Trunk extension was the action of the multifidus muscles contraction. Side bridge test the action of test lateral flexor muscles contraction. For trunk flexion with rotation, participant was supine lying on the table with their hands behind the neck. The handheld dynamometer was placed on sternum, beneath belt secure around the upper trunk and the table. A second belt was placed on the distal thigh and secure around the table. The participant was asked to lift trunk by moving shoulder to opposite knee with maximal effort (Figure 2) [10]. For trunk extension, participant was prone lying on the table with their hands behind their neck. The handheld dynamometer was placed between scapular, beneath belt secure around the upper trunk and the table. A second belt was placed on the distal thigh and secure around the table. The participant was asked to lift trunk upward with maximal effort (Figure 3) [10]. For side bridge test, participant was side lying on the table with legs extension. The top foot was placed on the lower foot on the table. The side lying on elbow and the other shoulder across the chest with hand place on opposite shoulder. The handheld dynamometer was placed on the greater trochanter. Participant was asked to lift hip off the table and maintain a straight line over their full body length with maximal effort (Figure 4) [9,10,13].

Level 1: Abdominal hollowing	
Level 2: Unilateral abduction	
Level 3: Unilateral knee extend	
Level 4: Unilateral knee raise	
Level 5: Bilateral knee raise	
Level 6: Bilateral knee raise together	

Figure 1 Level of lumbar stabilization exercise 1 - 6.

Figure 2 Trunk flexion with rotation position.

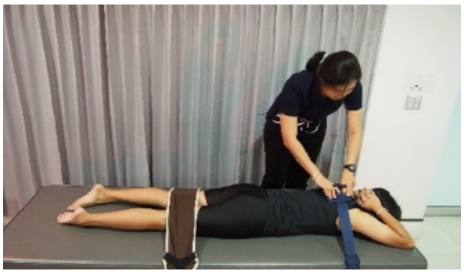

Figure 3 Trunk extension position.

Figure 4 Side bride test position.

Functional tests

The 35 reflective spherical markers were placed on participant's bony prominences of both sides according to the Plug-In Gait Full Body model which consist of 4 markers for head, spinous process of the 7th cervical vertebrae, spinous process of the 10th thoracic vertebrae, jugular notch, xiphoid process, the right scapular, the acromioclavicular joint, the epicondyle of the humerus, the wrist bar thumb side, the wrist bar ulnar side, the head of 2nd metacarpal, the anterior superior iliac spine, the posterior superior iliac spine, lateral 1/3 surface of the thigh, lateral epicondyle of the knee, lower 1/3 of shank, the lateral malleolus, the 2nd metatarsal, and the calcaneous.

The functional tests collected in a Vicon™ Nexus system (Oxford Metrics, Oxford, UK) with ten cameras (100 Hz). Before testing, the static and dynamic calibrations performed. Each participant was asked to perform single-leg squat 3 trials. Participant was allowed for resting 1 minute between trials. Participants was asked to stand on the force platform. The adjustable PVC placed in the behind of subject and the distance was 30 cm from the heel to the adjustable PVC (Figure 5). They were asked to perform the double legs squat to 60° knee flexion. The position of 60° knee flexion during doubled leg squat was marked by using an adjustable the PVC. After adjusting the PVC, participant allowed to practice not over 10 times and rest 5 minutes before the actual testing. Single-leg squat test, participants were asked to stand on force platform. The researcher instructed about the single leg squat. The dominant leg was tested. During single-leg squat, participant was asked to keep straight back and the knee was not allowed to move forward further than the tip of the foot.

Figure 5 Single-leg squat test, (A) adjustable PVC.

Data acquisition and statistical analysis

The 35 marker coordinates were filtered by a fourth-order zero-lag Butterworth digital filter at cut-off frequency of 6 Hz. A three-dimensional model was constructed by the Plug-in-Gait software. The frontal hip and knee angles were analyzed at the timeframe of peak frontal knee angle during single-leg squat. An averaged data from 3 trials was reported.

SPSS for window version 21 was used for data analysis. The statistical significance was set at p-value less than 0.05. Pearson's correlation was used to correlate of trunk stabilizer muscle strength during MVIC measuring and the frontal hip and knee angle. Spearman's rank correlation was used to analyze the correlation of trunk stabilizer muscle strength by the level of lumbar stabilization exercise and the frontal hip and knee angle.

Results

No significant correlation between the level of lumbar stabilization exercise and frontal hip and knee angles was observed (Table 1). However, the level of lumbar stabilization exercise showed a tendency of correlation with frontal knee angles during the single-leg squat (r = -0.45, p = 0.09). Pearson's correlation between trunk muscle strength by MVIC measuring and frontal hip and knee angles presented in Table 2. Right external oblique abdominis muscle strength negatively correlated with frontal hip angles during the single-leg squat(r = - 0.61, p = 0.02).

Table 1 Spearman's rank correlation between the level of lumbar stabilization exercise and the frontal hip and knee angles.

Variable		Frontal hip angles	Frontal knee angles
Lumbar stabilization level	Correlation Coefficient	-0.08	-0.45
	p value	0.79	0.09

Table 2 Pearson's correlation between trunk muscle strength and the frontal hip and knee angles.

Muscle strength		Frontal hip angles	Frontal knee angles
Mulitifidus	Pearson correlation	-0.05	0.33
	p value	0.87	0.23
Right external oblique abdominis	Pearson correlation	-0.61*	0.21
	p value	0.02	0.46
Left external oblique abdominis	Pearson correlation	-0.08	0.26
	p value	0.77	0.34
Right trunk lateral flexor	Pearson correlation	0.02	0.12
	p value	0.95	0.67
Left trunk lateral flexor	Pearson correlation	-0.03	-0.09
	p value	0.93	0.75

*Correlation is significant at the 0.05 level

Discussion

The purpose of this study was to investigate the correlation between trunk stabilizer muscle strength and the frontal hip and knee angles during single-leg squat. This study measured trunk muscle strength by handheld dynamometer and the level of lumbar stabilization exercise. The finding showed no correlation between trunk stabilizer muscle strength by the level of lumbar stabilization exercise and the frontal hip and knee angles. There was no previous study investigated the correlation between the level of lumbar stabilization exercise with the frontal hip and knee angle. However, in this study the level of lumbar stabilization exercise had a tendency of correlation with the frontal knee angle. Some previous studies reported the different result. Stickler L and Nakagawa TH found association between lateral trunk muscle strength and the frontal knee kinematics during single-leg squat [9,10]. They measured trunk muscle strength by handheld dynamometer in more than 30 participants. Nakagawa TH assigned multiple single leg squats but the current study used only one time single leg squat for each trial [10].

This study exhibited that right external oblique abdominis muscle strength had a negative correlation with the frontal hip angle. This result agree with some previous reports. Trunk movement can affect to frontal moment at the knee [7]. Trunk lean was related with hip adduction and knee abduction angles [10]. Stickler et al demonstrated that the sidelying plank test had correlated with the frontal plane projection angle (FPPA) [9]. The FPPA was represented knee valgus. Moreover, Nakagawa *et al.* [10] reported that the side bridge test was negatively associated with the peak knee abduction angle during single-leg squat. The external oblique abdominis muscle was connected with hip muscle [6]. Therefore, the external oblique abdominis muscle strength associated with frontal lower extremity angle. Beside, other factor such as proximal and distal to the knee may impact knee kinematics as well [3,14,15].

Limitation of this study, a sample size was small. The only one time of single-leg squat for each trial used in this study may not challenge for trunk muscle activation. Besides, the variations of trunk strength and squat performance were not enough to show the association of the data. More participant and various condition should be included to see the association.

Conclusions

The level of lumbar stabilization exercise had a tendency of association with the frontal knee angle. Right external oblique abdominis muscle strength was significant associated with the frontal hip angle. These finding supported the concept of the linkage between trunk stabilizer muscle strength and the frontal lower extremity angles during single-leg squat. Further study should investigate trunk kinematics and ankle kinematics which impact to hip and knee angles during single-leg squat.

Ethic Committee No.

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References

[1] DT Leetun, ML Ireland, JD Willson, BT Ballantyne, IM Davis. Core stability measures as risk factors for lower extremity injury in athletes. Med Sci Sports Exerc. 2004; 36(6):926-34.

[2] LY Griffin, J Agel, MJ Albohm, EA Arendt, RW Dick, WE Garrett, et al. Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. J Am Acad Orthop Surg. 2000; 8(3):141-50.

[3] ML Ireland, JD Willson, BT Ballantyne, IM Davis. Hip strength in females with and without patellofemoral pain. J Orthop Sports Phys Ther. 2003; 33(11):671-6.

[4] BT Zazulak, TE Hewett, NP Reeves, B Goldberg, J Cholewicki. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. Am J Sports Med. 2007; 35(7):1123-30.

[5] BT Zazulak, TE Hewett, NP Reeves, B Goldberg, J Cholewicki. The effects of core proprioception on knee injury: a prospective biomechanical-epidemiological study. Am J Sports Med. 2007; 35(3):368-73.

[6] WT Myers. Anatomy Trains. Third edition ed. Edinburgh: Churchill Livingstone Elsevier; 2014, p. 118-143.

[7] CM Powers. The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. J Orthop Sports Phys Ther. 2010; 40(2):42-51.

[8] JD Willson, ML Ireland, I Davis. Core strength and lower extremity alignment during single leg squats. Med Sci Sports Exerc. 2006; 38(5):945-52.

[9] L Stickler, M Finley, H Gulgin. Relationship between hip and core strength and frontal plane alignment during a single leg squat. Phys Ther Sport. 2015; 16(1):66-71.

[10] TH Nakagawa, CD Maciel, FV Serrao. Trunk biomechanics and its association with hip and knee kinematics in patients with and without patellofemoral pain. Man Ther. 2015; 20(1):189-93.

[11] S Thongjunjua, W Jalayondeja, V R achalathiti, C Suwanasri. Effects of lumbar stabilization exercises on exercise level attained in healthy subjects. Thai Journal of Physical Therapy. 2007; 29(1):1-13.

[12] S Thongjunjuea, M Wongprasertgan. Reference values of exercise level attained for lumbar stabilization exercises in young adults. Thai Journal of Physical Therapy. 2012; 34(1):37-44.

[13] SM McGill, A Childs, C Liebenson. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. Arch Phys Med Rehabil. 1999; 80(8):941-4.

[14] TQ Lee, G Morris, RP Csintalan. The influence of tibial and femoral rotation on patellofemoral contact area and pressure. J Orthop Sports Phys Ther. 2003; 33(11):686-93.

[15] CM Powers. The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. J Orthop Sports Phys Ther. 2003; 33(11):639-46.