JOMH Journal of Men's Health

J. Mens. Health **2022**; 18(2): 041
http://doi.org/10.31083/jomh.2021.122

Original Research

Effect of hip abduction angle on trunk muscle activation during plank exercise

Min-Kyu Kim[1], Seong-Gil Kim[2,*]

[1]Dawoom Rehabilitation Center, 37596 Pohang, Republic of Korea
[2]Department of Physical Therapy, College of Health Science, Sun Moon University, 31460 Asan, Republic of Korea
*Correspondence: niceguygil@gmail.com (Seong-Gil Kim)
Submitted: 9 August 2021 Accepted: 13 September 2021 Available online: 17 September 2021 Published: 10 February 2022

Abstract

Background and objectives: The purpose of this study was to investigate the effect of hip joint abduction an-gle change on trunk muscle activities during plank exercise. **Materials and methods**: This study was conducted with 34 subjects but 4 subjects dropped out during the measurement and 30 subjects completed the study. Muscle activities were measured while performing plank exercise with hip joint abduction angles at 0, 15, 30, or 45 degrees. Electrodes were placed on four muscles: rectus abdominis, external oblique, internal oblique, and erector spinae muscles. Two-way repeated measures ANOVA was used to analyze the interaction between hip joint abduction angle and trunk muscle activities. One-way repeated measures ANOVA was performed to determine trunk muscle activities of each muscle at each hip joint abduction angle. Eta-squared ($\eta 2$) values were used to determine effect sizes. **Results**: A significant interaction was found between hip joint abduction angle and muscle type ($p < 0.05$). Hip joint abduction angle was significantly associated with rectus abdominis and erector spinae activities ($p < 0.05$). **Conclusions**: When the hip joint is abducted during plank exercise in healthy young adults, the muscle activities of rectus abdominis and erector spinae are inversely proportional to hip joint abduction angles.

Keywords: Electromyography; Plank exercise; Trunk muscle; EMG; Hip abduction

1. Introduction

The Muscles play a variety of roles in our bodies. Most obviously, their contractions allow movement, but they also have many other functions [1], which include supporting the body, maintaining correct posture, protecting internal organs, and allowing blood to circulate properly [1,2]. As such, muscle weakening can cause health issues.

Due to science and technology developments, people mainly spend more time sitting, and as a result, body activity is reduced and muscles are weakened or muscle mass even lost, and often results in musculoskeletal disease [1,3]. In particular, trunk muscles that support the body are often weakened [4], and trunk stability decreases. Trunk stability, which is also referred to as body stability, enables the maintenance of correct body posture and greater trunk stability reduces the risk of injury [5,6]. The stability of the trunk is also referred to as core stability, and it plays an important role in the stability of the lumbopelvic-hip complex, which is a complex including the lumbar spine and pelvic and hip joints [7]. The lumbopelvic-hip complex transmits force from the lower extremities to the pelvis and spine during athletic functions and activities, and the instability during movement increases due to this transmitted force, increasing the risk of injury. The stability of the trunk helps to stabilize the pelvis during activity, reducing this instability and risk and preventing injuries [8].

The muscles that affect trunk stability include the rectus abdominis, internal obliques, external obliques, and the erector spinae muscles, and trunk stability requires that these muscles cooperate properly during body movements. When these muscles are activated, they can also maintain abdominal pressure against the weight of the gravitational force applied to the body and maintain the correct posture of the body [6].

Several exercise methods have been devised to strengthen trunk muscles [9–12], and of these exercises, the plank exercise method is widely used by many people [13]. This exercise is performed without any tools in a prone position with both elbows placed on the floor and supported by forearms to keep upper arms perpendicular to the ground [6]. Previous studies on this exercise have reported that it has good effects on trunk muscles and that when the posture is maintained trunk muscle activities increase. Others have shown that regular plank exercise strengthens trunk muscles [10,14]. Interestingly, it has also been reported that if the exercise posture is altered exercise difficulty and trunk muscle activations are changed [15,16]. For this reason, studies on the effect of posture change during plank exercise are being actively conducted.

However, few research studies have addressed the effects of posture changes on trunk muscle activity during plank exercise [15,16]. Therefore, in this study, we investigated the effect of hip joint abduction angle change on trunk muscle activities during plank exercise.

2. Materials and methods

2.1 Subjects

Initially, 40 men in their twenties residing in P city (Korea) were considered for the study, but six refused to provide consent, and thus, 34 subjects were enrolled in the study. The selection criteria were as follows: the absence of any disease that might affect the study, no visual or auditory impairment, no nervous system or vestibular organ condition, and the ability to understand the requirements of the experiment. Four dropped out during the study, and thus, the final study cohort was composed of 30 men. Mean subject age was 22.90 ± 1.56 years, mean height was 171.04 ± 6.52 cm, and mean weight was 69.43 ± 9.55 kg (Table 1). In accordance with the Helsinki Declaration of Ethics, all subjects prior to the experiment were briefed on the purpose and procedure of the study and voluntarily agreed to take part in the experiment. The study was approved by the Institutional Review Board of Daegu Catholic University (CUIRB-2021-0013).

Table 1. General subject characteristics (n = 30).

Variable	Mean ± SD
Age (year)	22.90 ± 1.56
Height (cm)	171.04 ± 6.52
Weight (kg)	69.43 ± 9.55

SD, standard deviation.

2.2 Study protocol

Muscle activities were measured while performing plank exercise with hip joint abduction angles at 0, 15, 30, or 45 degrees. Each posture was maintained for 10 seconds, and muscle activity data collected during the 4th, 5th, 6th, and 7th seconds were subjected to analysis. Subjects took a two-minute rest after each exercise to prevent fatigue. To reduce bias, the order of hip joint abduction movements was randomized for each subject. All measurements were performed 3 times, and results are expressed as means ± standard deviations.

2.3 Plank exercise

Subjects were required to maintain a straight line from feet to head while holding both elbows on the floor in a prone position and supporting them with forearms while keeping upper arms perpendicular to the ground. Hip joint abduction was added according to verbal feedback during the exercise session, and trunk muscle activities were measured in four postures at spreading angles of 0, 15, 30, and 45 degrees.

2.4 EMG

To measure trunk muscle activities, we used the FreeEMG 1000 (BTS, Milano, Italy) wireless system and Ag-Ag/Cl electrodes (diameter 2 cm), which were attached to 4 locations to measure activities of rectus abdominis (RA), external oblique (EO), internal oblique (IO), and erector spinae (ES) muscles. The electrode attachment site of the rectus abdominis muscle was attached to the side about 2 cm from the navel, so that the electrode was parallel to the muscle fiber direction, and the electrodes were attached 3 cm apart from each other. The electrode attachment site of the abdominal internal oblique muscle was attached to the upper part of the anterior superior iliac spine (ASIS) and to the side of the rectus abdominis muscle, and the electrodes were attached so that they were 2 cm apart from each other [17].

The attachment method was made to be parallel to the muscle fiber direction, and was attached after finding the middle part of the muscle belly using a manual test. To minimize skin resistance, after shaving the electrode attachment site, wipe it with alcohol, and after the electrode attachment area was completely dry, two electrodes coated with electrolyte gel were attached to the skin.

The EMG signals were collected at a sampling rate of 1000 Hz and processed by full-wave rectification. Data storage was performed by bandpass filtering at 30~500 Hz using BTS EMG-Analyzer (BTS, Milano, Italy) software and notch filtering at 60 Hz to remove noise.

Each subject had a different skin impedance, so a standardized value was created for each individual in order to generalize the measured values through a standardization process. In order to standardize trunk muscle measured activities, raw data were converted into RMS (Root Mean Square) values [17]. The analysis was performed using the average trunk muscle activities of three measurements. In addition, MVIC (maximal voluntary isotonic contraction) was measured for each muscle and these values were used to standardize muscle activities. MVICs were obtained by performing maximal activity tests using the anti-gravity position of manual muscle testing positions.

2.5 Statistical analysis

SPSS (SPSS, Inc., Chicago, IL, USA) for Windows (version 22.0) was used for the data analysis. Two-way repeated measures ANOVA was used to analyze the interaction between hip joint abduction angle and trunk muscle activities. One-way repeated measures ANOVA was performed to determine trunk muscle activities of each muscle at each hip joint abduction angle. Post hoc analysis was conducted using Fisher's LSD. Eta-squared ($\eta 2$) values were used to determine effect sizes at different hip joint abduction angles. Statistical significance was accepted for p values < 0.05.

3. Results

A significant interaction was found between hip joint abduction angle and muscle type ($p < 0.05$) (Table 2) (Fig. 1), and hip joint abduction angle was significantly as-

Table 2. Interaction of hip joint abduction angle and muscles during plank exercise.

Muscle	0°	15°	30°	45°	F	Interaction (muscle * hip abduction)
RA (%MVIC)	23.64 ± 8.16	21.42 ± 7.07	19.00 ± 5.84	13.86 ± 5.17	6.416	0.000*
EO (%MVIC)	27.05 ± 6.59	27.81 ± 5.24	26.43 ± 4.06	24.91 ± 4.13		
IO (%MVIC)	16.82 ± 5.90	17.55 ± 4.95	16.78 ± 4.72	15.51 ± 6.44		
ES (%MVIC)	4.79 ± 0.48	4.70 ± 0.60	4.44 ± 0.68	4.14 ± 0.68		

*$p < 0.05$; Mean ± SD; MVIC, maximum voluntary isometric contraction; RA, rectus abdominis; EO, external oblique; IO, internal oblique; ES, erector spinae.

Table 3. Comparison of muscle activity on trunk muscles according to hip abduction angle.

Muscle	0°	15°	30°	45°	F	p	effect size (η2)
RA (%MVIC)	23.64 ± 8.16 ^{bcd}	21.42 ± 7.07 ^{acd}	19.00 ± 5.84 ^{abd}	13.86 ± 5.17 ^{abc}	40.571	0.000*	0.648
EO (%MVIC)	27.05 ± 6.59	27.81 ± 5.24	26.43 ± 4.06	24.91 ± 4.13	2.184	0.098	0.090
IO (%MVIC)	16.82 ± 5.90	17.55 ± 4.95 ^{d}	16.78 ± 4.72	15.51 ± 6.44 ^{b}	2.104	0.108	0.087
ES (%MVIC)	4.79 ± 0.48 ^{cd}	4.70 ± 0.60 ^{cd}	4.44 ± 0.68 ^{abd}	4.14 ± 0.68 ^{abc}	19.742	0.000*	0.473

*$p < 0.05$; Mean ± SD; ^{a} Significantly different from 0°; ^{b} Significantly different from 15°; ^{c} Significantly different from 30°; ^{d} Significantly different from 45°.

sociated with rectus abdominis and erector spinae activities ($p < 0.05$, Table 3). For rectus abdominis, hip joint abduction angles of 0°, 15°, 30°, and 45° all showed significantly different muscle activities ($p < 0.05$, Table 3). For erector spinae, trunk muscle activities at 0° and 15° of abduction were not significantly different, but trunk muscle activities at 30° and 45° were ($p < 0.05$, Table 3). Also, muscle activities at 30° of abduction were significantly different from those at 0°, 15°, or 45° ($p < 0.05$, Table 3), and trunk muscle activities at 45° of abduction were also significantly different from those at the other three abduction angles ($p < 0.05$, Table 3).

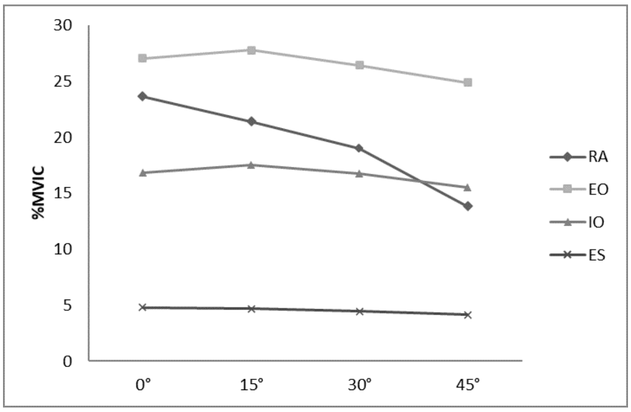

Fig. 1. Muscle activity according to hip abduction. RA, rectus abdominis; EO, external oblique; IO, in-ternal oblique; ES, erector spinae.

4. Discussion

In this study, we investigated rectus abdominis, external oblique, internal oblique, and erector spinae trunk muscle activities at different hip joint abduction angles during plank exercise. In previous studies that examined trunk muscle activities during Plank exercise in young, healthy subjects, as was performed during the present study, reported non-significantly higher or lower levels than we obtained.

Kim *et al.* [14] in a study on 30.44 ± 2.65 year-old adult males reported an overall MVIC level 10% higher than that observed in the present study. However, they also found muscle activity of the EO (external oblique) muscle was slightly higher than that of the RA (rectus abdominis) and lower than that the muscle activity of the IO (internal oblique) muscle was lower than that of the RA, which agrees with our results. Escamilla *et al.* [10] in a study on adults in their twenties, reported an RA muscle activity of 34.00% of MVIC, which was ~10% higher than we observed. Others have reported slightly lower trunk muscle activities than those obtained in the present study. Biscarini *et al.* [18] reported MVICs of RA, EO, IO, and ES (erector spinae) of 15.30%, 19.20%, 16.60%, and 2.72% during plank exercise for subjects in their twenties, which were lower than we found. Calatayud *et al.* [9], measured EO and ES muscle activities in 20-year-old subjects, and reported slightly higher EO and slightly lower ES muscle activities than we observed, and Czaprowski *et al.* [19], reported an RA MVIC of 18.10% during Plank exercise, which was lower than observed in the pre-sent study.

On the other hand, others have reported results similar to those we obtained. Cortell-Tormo *et al.* [13] in a study on adults in their twenties, reported RA, IO, and EO muscle activities were slightly higher than we found, though ES activity (4.74% MVIC) was almost identical. Byrne *et al*. [20] reported an RA activity of 22% MVIC, which was similar to our result, and Lehman *et al*. [12] reported RA and ES MVICs of 26.6% and 4.98%, respectively which agreed with our results. Analysis of the results of these previous studies showed they are comparable with previously reported results for young adults.

When we analyzed trunk muscle activity results at hip joint abduction angles of 0, 15, 30, and 45 degrees, a significant interaction was found between abduction angles and muscle types. Only RA and ES muscles showed significant trunk muscle activity differences at different abduction angles. In particular, muscle activities of RA muscles gradually decreased on increasing hip joint abduction angle. On the other hand, no significant difference was observed between the activities of ES muscles at 0° and 15°, but a significant difference was observed between abduction angles of 30° and 45°.

Previous studies have shown that increased instability of the supporting surface increases trunk muscle activities. Calatayud *et al*. [16] reported muscle activities of RA and ES increased during plank exercise when the support surface was unstable and increased when an unstable posture was adopted, although this study was performed in the supine position. Chanthapetch *et al*. [15] also reported that when the support surface became un-stable trunk muscle activities also increased. Imai *et al*. [21], Lehman *et al*. [12], and Escamilla *et al*. [10] compared trunk muscle activities after performing exercise on stable and unstable surfaces, and also found activities increased when same movements were performed on unstable sides. As mentioned above, our analysis of the results of previous studies suggested that even in the same exercise posture, trunk muscle activities decrease when the stability of the supporting surface body increases. This supports our result that trunk muscle activities decrease when hip joints were abducted in the Plank exercise posture. When the abduction of the hip joint is increased in this posture, the support area of the body gradually increases, which increases postural stability, and it is considered that as postural stability increases, load on trunk muscles decreases, and as a result, trunk muscle activities decrease.

In addition, we found no significant change in EO or IO muscle activities when hip joint abduction angle was increased. We attribute this finding to the fact that the EO and IO muscles are no larger than the RA, and that plank exercise does not involve rotation, which is a function of EO and IO muscles. Furthermore, stability against rotational movement of lumbar bone is controlled by EO, IO, and TA (Transversus Abdominis), which are attached horizontally or diagonally, whereas the RA is attached vertically [22].

Some studies have reported that oblique muscles showed less change than the RA. Escamilla *et al*. [10], compared muscle activity during plank exercise conducted on stable and unstable support surfaces, and found changes in EO and IO activities were less than that of the RA. Fong *et al*. [23] examined changes in muscle activities in various exercise postures, and also found EO changes were smaller than RA changes. These findings show that when the hip joint is abducted during Plank exercise in healthy young adults, the muscle activities of RA (rectus abdominis) and ES (erector spinae) are inversely pro-portional to hip joint abduction angles and that those of the EO (external oblique) and IO (internal oblique) are not significantly affected by hip joint abduction angle changes.

The limitations of this study are that our findings do not represent all adults because all subjects were in their twenties and that we only measured trunk muscle activities. We recommend that future studies be conducted on subjects of different ages and various body parts in different postures.

5. Conclusions

In conclusion, when the hip joint is abducted during Plank exercise in healthy young adults, the muscle activities of RA (rectus abdominis) and ES (erector spinae) are inversely proportional to hip joint abduction angles and that those of the EO (external oblique) and IO (internal oblique) are not significantly affected by hip joint abduction angle changes.

Based on these findings, we suggest hip joint abduction could be added to reduce the level of plank exercise difficulty level for subjects with insufficient muscle strength. In addition, hip joint abduction angle changes could be used to reduce RA activity during plank exercise and to strengthen abdominal oblique muscles (EO and IO).

Abbreviations

EMG, electromyography; ES, erector spinae; EO, external oblique; IO, internal oblique; MVIC, maximal voluntary isotonic contraction; RA , rectus abdominis; RMS, Root Mean Square; TA, Transversus Abdominis.

Author contributions

Conceptualization—SGK; methodology—MKK and SGK; software—MKK; validation—MKK and SGK; formal analysis—SGK; investigation—MKK and SGK; resources—MKK and SGK; data curation—MKK; writing—Original draft preparation—MKK and SGK; writing—Review and editing—SGK; visualization—MKK and SGK; supervision—SGK. All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki, and ap-proved by the Institutional Review Board of Daegu Catholic University (No. CUIRB-2021-0013). Ethical issues regarding plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

Acknowledgment

The authors gratefully thank all subjects for participating in this study.

Funding

This research received no external funding.

Conflict of interest

The authors declare no conflict of interest.

References

[1] Hamilton MT. The role of skeletal muscle contractile duration throughout the whole day: reducing sedentary time and promoting universal physical activity in all people. The Journal of Physiology. 2018; 596: 1331–1340.

[2] Korthuis RJ. Skeletal Muscle Circulation. Colloquium Series on Integrated Systems Physiology: from Molecule to Function. 2011; 3: 1–144.

[3] Genin PM, Dessenne P, Finaud J, Pereira B, Dutheil F, Thivel D, *et al*. Effect of work-related sedentary time on overall health profile in active vs. inactive office workers. Frontiers in Public Health. 2018; 6: 279.

[4] Sions JM, Beisheim EH, Hoggarth MA, Elliott JM, Hicks GE, Pohlig RT, *et al*. Trunk Muscle Characteristics: Differences between Sedentary Adults with and without Unilateral Lower Limb Amputation. Archives of Physical Medicine and Rehabilitation. 2021; 102: 1331–1339.

[5] Kato S, Murakami H, Demura S, Yoshioka K, Shinmura K, Yokogawa N, *et al*. Abdominal trunk muscle weakness and its association with chronic low back pain and risk of falling in older women. BMC Musculoskeletal Disorders. 2019; 20: 273.

[6] Huxel Bliven KC, Anderson BE. Core stability training for injury prevention. Sports Health. 2013; 5: 514–522.

[7] Gilmer GG, Washington JK, Dugas JR, Andrews JR, Oliver GD. The Role of Lumbopelvic-Hip Complex Stability in Softball Throwing Mechanics. Journal of Sport Rehabilitation. 2019; 28: 196–204.

[8] Zambarano EK, Bouillon L, Glaviano NR. Relationship between lumbopelvic-hip complex stability, muscle activity, and 2-dimensional kinematics of the trunk and lower extremity. Physical Therapy in Sport. 2021; 47: 7–14.

[9] Calatayud J, Casaña J, Martín F, Jakobsen MD, Colado JC, Andersen LL. Progression of Core Stability Exercises Based on the Extent of Muscle Activity. American Journal of Physical Medicine & Rehabilitation. 2017; 96: 694–699.

[10] Escamilla RF, Lewis C, Pecson A, Imamura R, Andrews JR. Muscle Activation among Supine, Prone, and Side Position Exercises with and without a Swiss Ball. Sports Health. 2016; 8: 372–379.

[11] Ekstrom RA, Donatelli RA, Carp KC. Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. The Journal of Orthopaedic and Sports Physical Therapy. 2007; 37: 754–762.

[12] Lehman GJ, Hoda W, Oliver S. Trunk muscle activity during bridging exercises on and off a Swiss ball. Chiropractic & Osteopathy. 2005; 13: 14.

[13] Cortell-Tormo JM, García-Jaén M, Chulvi-Medrano I, Hernández-Sánchez S, Lucas-Cuevas ÁG, Tortosa-Martínez J. Influence of Scapular Position on the Core Musculature Activation in the Prone Plank Exercise. Journal of Strength and Conditioning Research. 2017; 31: 2255–2262.

[14] Kim S, Kang M, Kim E, Jung I, Seo E, Oh J. Comparison of EMG activity on abdominal muscles during plank exercise with unilateral and bilateral additional isometric hip adduction. Journal of Electromyography and Kinesiology. 2016; 30: 9–14.

[15] Chanthapetch P, Kanlayanaphotporn R, Gaogasigam C, Chiradejnant A. Abdominal muscle activity during abdominal hollowing in four starting positions. Manual Therapy. 2009; 14: 642–646.

[16] Calatayud J, Casaña J, Martín F, Jakobsen MD, Colado JC, Gargallo P, *et al*. Trunk muscle activity during different variations of the supine plank exercise. Musculoskeletal Science & Practice. 2017; 28: 54–58.

[17] Criswell E. Cram's introduction to surface electromyography. Jones & Bartlett Publishers. 2010.

[18] Biscarini A, Contemori S, Grolla G. Activation of Scapular and Lumbopelvic Muscles during Core Exercises Executed on a whole-Body Wobble Board. Journal of Sport Rehabilitation. 2019; 28: 623–634.

[19] Czaprowski D, Afeltowicz A, Gębicka A, Pawłowska P, Kędra A, Barrios C, *et al*. Abdominal muscle EMG-activity during bridge exercises on stable and unstable surfaces. Physical Therapy in Sport. 2014; 15: 162–168.

[20] Byrne JM, Bishop NS, Caines AM, Crane KA, Feaver AM, Pearcey GEP. Effect of using a suspension training system on muscle activation during the performance of a front plank exercise. Journal of Strength and Conditioning Research. 2014; 28: 3049–3055.

[21] Imai A, Kaneoka K, Okubo Y, Shiina I, Tatsumura M, Izumi S, *et al*. Trunk muscle activity during lumbar stabilization exercises on both a stable and unstable surface. The Journal of Orthopaedic and Sports Physical Therapy. 2010; 40: 369–375.

[22] Sahrmann S, Azevedo DC, Dillen LV. Diagnosis and treatment of movement system impairment syndromes. Brazilian Journal of Physical Therapy. 2017; 21: 391–399.

[23] Fong SSM, Tam YT, Macfarlane DJ, Ng SSM, Bae Y, Chan EWY, *et al*. Core Muscle Activity during TRX Suspension Exercises with and without Kinesiology Taping in Adults with Chronic Low Back Pain: Implications for Rehabilitation. Evidence-Based Complementary and Alternative Medicine. 2015; 2015: 1–6.