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Comparison of Muscle Thickness of Abdominal Muscles According to Various Types of Abdominal Crunch Exercise

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Abstract

Purpose : The purpose of this study was to compare the effect of additional isometric contraction of trunk, shoulder, and hip muscles during abdominal crunch exercise on abdominal muscle thickness and to identify the most effective intervention for core muscle activation.

Methods : This study was conducted on 22 healthy male adults. Subjects performed three types of crunch exercises (abdominal crunches accompanied by internal and external isometric rotation of the hip, horizontal shoulder adduction and abduction, and rotation of the trunk). The thickness of the transverse abdominis (TrA), internal oblique (IO), and external oblique (EO) were evaluated using ultrasonography. The collected data used one-way repeated ANOVA statistics. Wilcoxon signed-rank test of nonparametric statistics was used for post-test analysis.

Results : The IO thickness was significantly lower than general abdominal crunch when shoulder adduction was added ($p<.05$). The crunch with shoulder abduction, hip external rotation, and ipsilateral trunk rotation was significantly higher than the abdominal crunch ($p<.05$). The EO thickness was significantly greater in the crunch with hip external rotation than in the abdominal crunch ($p<.05$).

Conclusion : The level of contraction in abdominal muscles appears to vary when isometric contractions of the trunk, shoulder, and hip muscles are added to the abdominal crunch exercise. Therefore, the use of isometric contractions of other joints to selectively induce contraction of the abdominal muscles may be considered.

Key Words : abdominal muscle, crunch exercise, muscle thickness, ultrasonography

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Ⅰ. Introduction

Recently, core exercise has been used in several studies and exercise programs in place of functional rehabilitation or functional training (Kato et al., 2019). Core exercise is to stabilize the trunk when the patient's posture is unstable and to adjust the spinal neutral position that can be adapted under load on the spine in conscious or unconscious situations (Lee et al., 2014a). The trunk muscle is the muscle surrounding the spine that functions to pressure the waist with deep muscles close to the spine, providing the role and structural support to maintain body stability (Desai & Marshall, 2010).

The trunk muscles used to stabilize the trunk are transverse abdominis (TrA), internal oblique (IO), external oblique (EO), and multifidus. These muscles play an important role in stabilizing the trunk and are used in various daily activities including walking (Park & Yu, 2013). Trunk stabilization exercises strengthen these body muscles, improving spine mobility and stability (Imai et al., 2010; Stokes et al., 2011). The rectus abdominis (RA), which travels in the vertical direction of the abdomen, protects organs in the abdomen from external injury or damage, raises abdominal pressure during contraction, and provides stability in maintaining posture during abdominal movement (Moon et al., 2013; Park et al., 2015). Furthermore, EO, which travels from the lateral to medial side of the trunk, plays a role in generating a powerful force during the rotation of the trunk, helping with extra-body stability (Kim & Kim, 2013; Shim et al., 2014). EO and RA help maintain body posture, improving body stability and providing the necessary muscle strength for abdominal exercises such as flexion or rotation of the body (Park & Lee, 2010). TrA is the abdominal muscle that is activated first before movement of the upper extremities and lower extremities, creating and controlling pressure in the abdomen along with IO, diaphragm, and pelvic floor to increase the strength of the lumbar spine, improving body stability (Hodges & Richardson, 1997). Located deep in the abdominal muscles, TrA and IO are directly connected to the spine, providing fine regulation of spinal movement and stability between vertebral segments (McGill et al., 2003).

Co-activation of these abdominal muscles contributes to the stability of the trunk by creating abdominal pressure and improves the ability of the upper and lower extremities to move in static and dynamic states (Key, 2013). They emphasized the importance of abdominal muscle strengthening exercises because this weakening of muscle strength and abnormal muscle activation of abdominal muscles reduces the body instability, upper extremity, and lower extremity movement ability (Key, 2013).

Crunch exercise programs are commonly used for trunk muscle stabilization exercises, which can be easily performed to improve abdominal muscle strength in any location without any special equipment (Stevens et al., 2007). Crunch is an isotonic exercise that is more effective in activating the TrA, IO, and EO compared to other abdominal exercises (Kim & Kim, 2015; Lee et al., 2014b). Nakai et al(2019) reported that body stabilization exercises using isometric hip rotation induce greater contraction of TrA, IO, EO, and the multifidus compared to regular crunch actions. In addition, studies by Lee et al(2013) have reported increased abdominal muscle contraction in isometric shoulder horizontal abduction performed with latex resistance bands. These various isometric exercises induced abdominal muscle activation, and when performing voluntary upper and lower extremities movement, the trunk muscles were activated involuntarily (Misirlioglu et al., 2018).

Such prior studies have shown increased abdominal muscle thickness and activation in cases of additional upper and lower extremities movements, such as hip rotation or abduction of the shoulder joint (Lee et al., 2013; Nakai et al., 2019). However, no studies have been conducted on the thickness increase of abdominal muscles when additional upper extremities and lower extremities movements are applied in crunch exercise. Therefore, the purpose of this study was to compare the effect of additional isometric contraction of trunk, shoulder, and hip muscles during abdominal crunch exercise on abdominal muscle thickness and to identify the most effective intervention for core muscle activation.

Ⅱ. Methods

1. Subjects

This study has been conducted on 22 healthy male adults. Prior to participating in the study, all subjects were given a sufficient explanation of the purpose and the method of the study. The subjects who agreed to join the study were pre-tested, and those who did not have records of extreme trauma, injury in the shoulder, and the hip joint participated in the study. The exclusion criteria were those who had no history of surgery or orthopedic history within three months and had no abnormal health conditions. The general characteristics of the subjects are shown in Table 1. The subjects conducted the experiment without knowing what arbitration they were applying by setting the conditions to Single-blind. After obtaining consent from the subjects to participate in the experiment, the consent forms were signed by the subjects and the experiment proceeded. Prior to the study, the research was conducted after obtaining approval from the Institutional Review Board (IRB) of Sunmoon University.

Table 1. General characteristics of subjects

Characteristics	Male (n=22)
Age (years)	24.66±2.10
Height (cm)	176.45±5.39
Weight (kg)	75.63±7.33
Body mass index (kg/m^2)	24.53±2.25

Mean±standard deviation

2. Experimental procedures

Abdominal crunch exercises were performed based on the procedures of previous studies (Lee et al., 2013; Nakai et al., 2019). The abdominal crunch was practiced in the given conditions: the knees were bent 90 degrees in a supine position. The head and the shoulders were lifted as well as both hands to prevent then from pushing the ground. This posture was maintained for 8 seconds in total. Abdominal crunches with horizontal isometric shoulder adduction and abduction were performed while maintaining abdominal crunches. The examiner used a portable handheld dynamometer (model 01163; Lafayette Instrument Company, Lafayette, IN) to maintain resistance in the inner and outer side of the elbow, preventing the widening and gathering of the arms and the posture was maintained for 8 seconds (Fig 1A). Abdominal crunches with internal and external isometric rotation of the hip were performed by using a dynamometer, which applied resistance to the inner and outer knees to maintain the resistance to the inner and the outer hip rotation for 8 seconds (Fig 1B). Abdominal crunches with rotation of the trunk were performed while maintaining crunch posture, where the stretched hands crossed the ipsilateral and contralateral knees (Fig 1C).

Following prior work, the portable dynamometer was set to a load of 80 N and matched the output power of 80 N for 8 seconds (Nakai et al., 2019). The subjects were instructed not to hold their breath while exercising. Each movement was maintained for 8 seconds under isometric contraction and repeated 3 times. Each subject had a 30-second break between each test and was given two-minute break between test conditions to prevent muscle fatigue.

Fig 1. Abdominal crunch exercise
A; abdominal crunch with isometric shoulder adduction and abduction, B; abdominal crunch with isometric hip rotation, C; abdominal crunch with isometric trunk rotation

3. Muscle thickness; ultrasonography

For quantitative morphological observations of the muscles, ultrasonography B-mode (Ezono 3000, Germany, 2011) was used to investigate the muscle thickness during various abdominal crunch exercises (Fig 2 and 3). To measure the thickness of TrA, IO, EO, and RA, the subject was placed in a supine position, and a single investigator used the B mode of ultrasonography at 7~10 ㎒.

RA was measured by positioning the ultrasonography probe head 2~3 ㎝ above the navel, and it was moved to the anterior lateral side along the mid-clavicle line so that the cross-sectional area of the muscle was located in the center of the screen. When measuring TrA, IO, and EO, a virtual line parallel to the navel was drawn and the probe head was positioned 2.5 ㎝ outward (right). Then the measuring was done by moving the head gently while keeping the muscles parallel to the projected screen. Resting muscle thickness was captured and recorded at the end of a normal exhalation of breath in the supine position. The measured muscle thickness during exercises was expressed as a percentage of the muscle thickness at rest

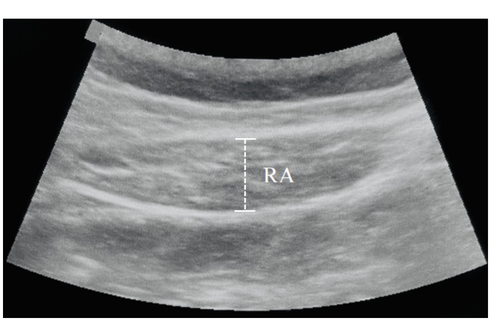

Fig 2. Ultrasonography images of rectus abdominis

Fig 3. Ultrasonography images of transverse abdominis, internal oblique, and external oblique

(thickness during exercise/thickness at rest×100)(Miura et al., 2014).

4. Statistical Analysis

SPSS 22.0 (SPSS INC. Chicago, IL) was used for all statistical analyses. Descriptive statistics are used to assess general characteristics. The collected data used one-way repeated ANOVA statistics. The normal distribution was confirmed through the Shapiro-Wilk test. The normal distribution analysis was insufficient to support the hypothesis and a nonparametric statistical analysis Freidman test was used on 7 different exercises to analyze the muscle thickness difference. Wilcoxon signed-rank test of nonparametric statistics was used for post-test analysis. For confirmation of the hypothesis, all statistical significance α was set to .05.

Ⅲ. Results

Table 2 and Fig 4 show the abdominal muscle thickness during various abdominal crunch exercises. In the case of IO thickness, it was significantly lower than general abdominal crunch when shoulder adduction isometric contraction was added ($p<.05$). In addition, the crunch with shoulder abduction, hip external rotation, and ipsilateral (right) trunk rotation isometric contraction was significantly higher than the general abdominal crunch ($p<.05$). The EO thickness was significantly greater in the crunch accompanied by hip external rotation than in the general abdominal crunch ($p<.05$). However, There was no significant difference in TrA thickness between abdominal crunch and crunch with additional contractions of the trunk, shoulder, and hip muscles ($p>.05$). There was no significant difference in RA thickness between the various crunch exercises ($p>.05$).

Table 2. Abdominal muscle thickness during abdominal crunch and crunch with additional contractions (percentage (%) of thickness at rest).

	Rectus abdominis	Transverse abdominis	Internal oblique	External oblique
Abdominal crunch	142.14±19.49	152.59±46.84	141.89±29.92	111.10±29.19
Sho_h_add	141.01±19.39	139.02±42.51	121.76±27.90	105.62±26.48
Sho_h_abd	144.95±21.24	164.70±46.14	166.62±36.30	120.61±34.53
Hip_IR	146.77±28.65	142.18±26.33	142.06±31.72	97.87±25.60
Hip_ER	145.88±25.50	164.64±36.82	158.38±39.44	123.84±24.79
Rot_to_L	145.85±26.26	160.81±67.56	152.55±42.32	119.62±29.14
Rot_to_R	152.83±26.08	165.66±40.00	171.51±57.66	115.77±27.86
p	.088	.005	<.001	<.001

Mean±standard deviation, Sho_h_add: shoulder horizontal adduction, Sho_h_abd: shoulder horizontal abduction, Hip_IR: hip internal rotaion, Hip_ER: hip external rotation, Rot_to_L: Rotation to left, Rot_to_R: rotation to right.

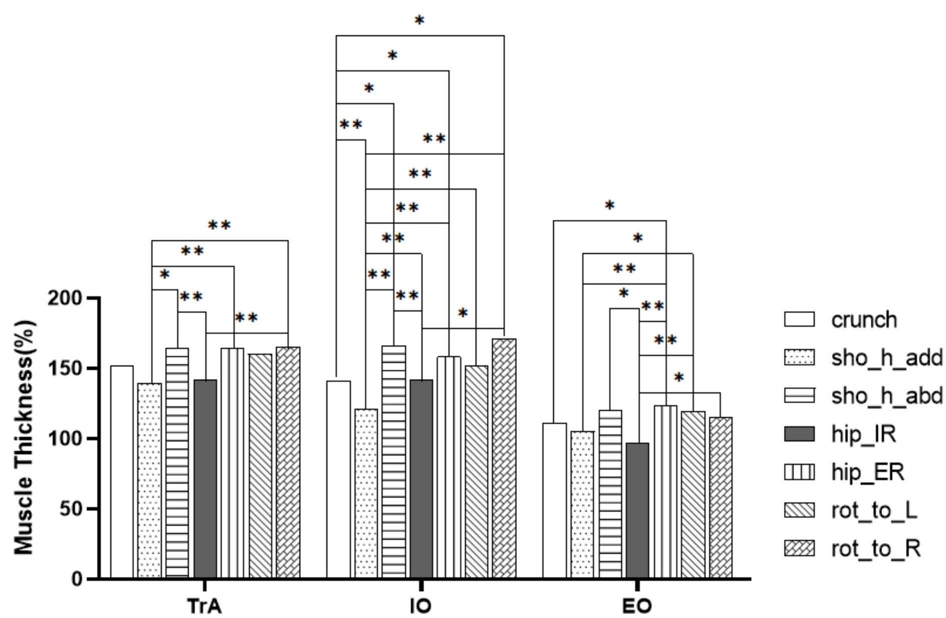

Fig 4. Comparison of muscle activity and muscle thickness. Muscle thickness as a percentage relative to rest. TrA; transverse abdominis, IO; internal oblique, EO; external oblique, Sho_h_add; shoulder horizontal adduction, Sho_h_abd; shoulder horizontal abduction, Hip_IR; hip internal rotaion, Hip_ER; hip external rotation, Rot_to_L; rotation to left, Rot_to_R; rotation to right. **p<.01, *p<.05

Ⅳ. Discussion

This study has been conducted to examine how additional movements during abdominal crunch affect the body muscle thickness of healthy adult males. We compared abdominal muscle thickness according to crunch exercise type. Consistent with some of our hypotheses, TrA and IO increased muscle thickness when trunk rotations to the ipsilateral (right) were applied during crunch exercises, but EO increased when hip external rotations were applied.

It has been reported that TrA and IO muscles are not activated separately but contracts simultaneously (Masse-Alarie et al., 2015; Kim et al., 2017). According to the results of this study, there was no significant difference in TrA thickness between general abdominal crunch and crunch exercise with an additional isometric contraction. This suggests that TrA was maintained at a relatively constant level during various crunch exercises, stabilizing the trunk. IO is extensively attached to the vertebra body, which plays an important role in providing stability in the lumbar region during rotation (Goncalves et al., 2011). In addition, Sugaya et al(2014) found that the thickness of TrA and IO increased significantly during ipsilateral rotation of the trunk. Similarly in this study, when trunk rotation was performed ipsilaterally during the crunch exercise, the muscle thickness of TrA and IO was the highest when compared with other crunch exercises. Considering the muscle direction of the IO, it is presumed that it had a greater effect on the ipsilateral trunk rotation. Both TrA and IO are located deep in the trunk and both muscles act on the rotational movement of the spine. As a result, both TrA and IO are located deep in the trunk, and both muscles can act to stabilize the trunk against rotational movements of the spine.

EO rotates the trunk in a contralateral direction. This is the opposite action of TrA and IO to rotate the trunk ipsilateral with respect to the kinematic function of the abdominal muscles during trunk rotation (Richardson & Jull, 1995). The muscle fibers of the EO extend down the iliac crest from the ribs and move diagonally downward and inward (Han & Kim, 2014). According to Nakai et al(2019), EO thickness increased to the greatest extent by performing hip external rotation during trunk stabilization exercises. This study supports the results of previous studies by confirming that it coincides with the increase in EO muscle thickness when hip external rotation is performed during crunch exercise.

RA is located on the surface of the body and moves in a vertical direction and contracts in the direction of movement (Reeves et al., 2008). On the other hand, muscle fibers in IO and EO act in a diagonal rather than vertical direction. In this experiment, the thickness of the abdominal muscle had shown a significant difference since the external resistance was applied in a horizontal direction of the shoulder, hip, and trunk rather than the vertical direction. RA maintained a certain level of muscle thickness without significant changes as the direction of the resistance was not parallel to the orientation of the muscle fibers.

Core muscles respond predictively in everyday life before upper and lower extremity movements begin (Kim et al., 2016). A previous study has shown an increase in isometric hip rotation and trunk muscle contraction in shoulder horizontal abduction using latex resistance bands in the sitting positions (Lee et al., 2013; Nakai et al., 2019). This study also confirmed that additional external resistance increases the contraction of the trunk muscles. These results show that additional resistance to the upper and lower extremities during crunch exercise leads to further contraction of the trunk muscles. The results of this study are also considered in line with these previous studies, suggesting the possibility that the use of additional isometric contractions of other joints when performing crunches for trunk stabilizing muscles could be a more effective intervention in clinical practice.

First, since this study was conducted on healthy adult males, caution is needed in generalizing to various populations. Second, in this study, only the abdominal muscles of the extremities on which isometric contractions were performed were investigated. Third, the long-term effects of the crunch exercise were not investigated. Finally, considering that TrA, which is a relatively deep muscle, may have decreased activation during simultaneous contraction of EO and RA, only TrA isolated from EO and RA could not selectively contract during crunch exercise in this study.

Ⅴ. Conclusion

In healthy young men, the level of contraction of each abdominal muscles appears to vary when isometric contractions of the trunk, shoulder, and hip muscles are added to th abdominal crunch exercise commonly used to activate the core muscles. According to the observation of changes in muscle thickness using ultrasonography, the muscle thickness of TrA and IO was greatest in abdominal crunch exercise combined with ipsilateral trunk rotation, and the thickness of EO was greatest in abdominal crunch exercise combined with hip external rotation. Therefore, the use of additional isometric contractions of other joints to selectively induce strong contraction of the abdominal muscles may be considered.

Reference

Desai I, Marshall PW(2010). Acute effect of labile surfaces during core stability exercises in people with and without low back pain. J Electromyogr Kinesiol, 20(6), 1155-1162. https://doi.org/10.1016/j.jelekin.2010.08.003.

Goncalves M, Marques NR, Hallal CZ, et al(2011). Electromyographic activity of trunk muscles during exercises with flexible and non-flexible poles. J Back Musculoskelet Rehabil, 24(4), 209–214. https://doi.org/

10.3233/BMR-2011-0297.

Han JM, Kim KS(2014). Muscle thickness changes with angle changes of shoulder joint and hip joint in tetrapod posture. J Korea Acad-Industr Cooper Soc, 15(2), 934–939. https://doi.org/10.5762/KAIS.2014.15.2.934.

Hodges PW, Richardson CA(1997). Feedforward contraction of transversus abdominis is not influenced by the direction of arm movement. Exp Brain Res, 114(2), 362-370. https://doi.org/10.1007/pl00005644.

Imai A, Kaneoka K, Okubo Y, et al(2010). Trunk muscle activity during lumbar stabilization exercises on both a stable and unstable surface. J Orthop Sports Phys Ther, 40(6), 369-375. https://doi.org/10.2519/jospt.2010.3211.

Kato S, Murakami H, Demura S, et al(2019). Abdominal trunk muscle weakness and its association with chronic low back pain and risk of falling in older women. BMC Musculoskelet Disord, 20(1), Printed Online. https://doi.org/10.1186/s12891-019-2655-4.

Key J(2013). 'The core': understanding it, and retraining its dysfunction. J Bodyw Mov Ther, 17(4), 541-559. https://doi.org/10.1016/j.jbmt.2013.03.012.

Kim CY, Kim HD(2015). The effect of supplementary shouting technique on muscle activity to rectus abdominis and external oblique during crunch exercise in healthy subjects. J Korean Phys Ther, 27(1), 1-6. https://doi.org/10.18857/jkpt.2015.27.1.1.

Kim JS, Seok CH, Jeon HS(2017). Abdominal draw-in maneuver combined with simulated weight bearing increases transversus abdominis and internal oblique thickness. Physiother Theory Pract, 33(12), 954-958. https://doi.org/10.1080/09593985.2017.1359866.

Kim SY, Kang MH, Kim ER, et al(2016). Comparison of EMG activity on abdominal muscles during plank exercise with unilateral and bilateral additional isometric hip adduction. J Electromyogr Kinesiol, 30, 9-14. https://doi.org/10.1016/j.jelekin.2016.05.003.

Kim SY, Kim NS(2013). Effects of Mulligan's mobilization with sustained natural apophyseal glides on the paraspinal muscle activity of subjects with chronic low back pain. J Korean Phys Ther, 25(1), 10–15. https://doi.org/10.12674/ptk.2013.20.1.010.

Lee DK, Kang MH, Kim JW, et al(2013). Effects of non-paretic arm exercises using a tubing band on abdominal muscle activity in stroke patients. NeuroRehabilitation, 33(4), 605-610. https://doi.org/10.3233/NRE-131003.

Lee GC, Bae WS, Kim CH(2014a). The effects of bridge exercise with contraction of hip adductor muscles on thickness of abdominal muscles. J Korean Soc Phys Med, 9(2), 233–242. https://doi.org/10.13066/kspm.2014.9.2.233.

Lee GW, Yoon TL, Kim KS, et al(2014b). EMG activity of abdominal muscles during lumbopelvic stabilization exercises. Phys Ther Korea, 21(2), 1-7. https://doi.org/10.12674/ptk.2014.21.2.001.

Massé-Alarie H, Beaulieu LD, Preuss R, et al(2015). Task-specificity of bilateral anticipatory activation of the deep abdominal muscles in healthy and chronic low back pain populations. Gait & posture, 41(2), 440-447. https://doi.org/10.1016/j.gaitpost.2014.11.006.

McGill SM, Grenier S, Kavcic N, et al(2003). Coordination of muscle activity to assure stability of the lumbar spine. J Electromyogr Kinesiol, 13(4), 353-359. https://doi.org/10.1016/s1050-6411(03)00043-9.

Mısırlıoğlu TÖ, Eren İ, Canbulat N, et al(2018). Does a core stabilization exercise program have a role on shoulder rehabilitation?. A comparative study in young females. Turk J Phys Med Rehabil, 64(4), 328-336. https://doi.org/10.5606/tftrd.2018.1418.

Miura T, Yamanaka M, Ukishiro K, et al(2014). Individuals with chronic low back pain do not modulate the level of transversus abdominis muscle contraction across different postures. Man Ther, 19(6), 534-540. https://doi.org/10.1016/j.math.2014.05.010.

Moon HJ, Choi KH, Kim DH, et al(2013). Effect of lumbar stabilization and dynamic lumbar strengthening exercises in patients with chronic low back pain. Ann Rehabil Med, 37(1), 110-117. https://doi.org/10.5535/arm.

2013.37.1.110.

Park BS, Noh JW, Kim MY, et al(2015). The effects of aquatic trunk exercise on gait and muscle activity in stroke patients: a randomized controlled pilot study. J Phys Ther Sci, 27(11), 3549-3553. https://doi.org/10.1589/jpts.27.3549.

Park DJ, Lee HO(2010). Activation of abdominal muscles during abdominal hollowing in four different positions. J Phys Ther Sci, 22(2), 203-207. https://doi.org/10.1589/jpts.22.203.

Park SD, Yu SH(2013). The effects of abdominal draw-in maneuver and core exercise on abdominal muscle thickness and Oswestry disability index in subjects with chronic low back pain. J Exerc Rehabil, 9(2), 286-291. https://doi.org/10.12965/jer.130012.

Park SY, Oh S, Baek KH, et al(2022). Comparison of Abdominal Muscle Thickness between the Abdominal Draw-in Maneuver and Maximum Abdominal Contraction Maneuver. Healthcare, 10(2), 251. https://doi.org/10.3390/healthcare10020251.

Reeves NP, Cholewicki J, Milner T, et al(2008). Trunk antagonist co-activation is associated with impaired neuromuscular performance. Exp Brain Res, 188(3), 457-463. https://doi.org/10.1007/s00221-008-1378-9.

Richardson CA, Jull GA(1995). Muscle control-pain control. What exercises would you prescribe?. Man Ther, 1(1), 2-10.

Shim HB, Cho HY, Choi WH(2014). Effects of the trunk stabilization exercise on muscle activity in lumbar region and balance in the patients with hemiplegia. J Korean Phys Ther, 26(1), 33-40.

Stevens V, Witvrouw E, Vanderstraeten G, et al(2007). The relevance of increasing resistance on trunk muscle activity during seated axial rotation. Phys Ther Sports, 8(1), 7-13. https://doi.org/10.1016/j.ptsp.2006.09.021.

Stokes IA, Gardner-Morse MG, Henry SM(2011). Abdominal muscle activation increases lumbar spinal stability: analysis of contributions of different muscle groups. Clin Biomech (Bristol, Avon), 26(8), 797-803. https://doi.org/10.1016/j.clinbiomech.2011.04.006.

Sugaya T, Abe Y, Sakamoto M(2014). Ultrasound evaluation of muscle thickness changes in the external oblique, internal oblique, and transversus abdominis muscles considering the influence of posture and muscle contraction. J Phys Ther Sci, 26(9), 1399-1402. https://doi.org/10.1589/jpts.26.1399.

Nakai Y, Kawada M, Miyazaki T, et al(2019). Trunk muscle activity during trunk stabilizing exercise with isometric hip rotation using electromyography and ultrasound. J Electromyogr Kinesiol, 49, 102357. https://doi.org/10.1016/j.jelekin.2019.102357.