Variations in lateral abdominal muscle thickness during abdominal drawing-in maneuver in three positions in a young healthy population

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Objective: To investigate the appropriate position for abdominal drawing-in maneuver (ADIM) exercise by rehabilitative ultrasound image.

Design: Cross-sectional study.

Methods: Twenty-eight young adults with no history of low back pain participated in the study. Three positions compared were crook lying position with hip 60° flexion, standing position with the feet hip width apart and knees straight, and saddle standing position unsupported with the knees 20° flexed. Once in the appropriate position, the subjects were verbally cued to draw in their abdominal wall, with the intention of pulling their navel inward toward their lower back. The thickness of each transversus abdominis (TrA), internal oblique (IO), and external oblique (EO) muscles were measured via ultrasound and recorded at the end of inspiration.

Results: When compared to the TrA thickness of rest, the TrA thickness was significantly increased in all three positions (crook lying, standing, and saddle standing) during the ADIM ($p < 0.05$). IO thickness was significantly greater in standing and saddle standing than in crook lying ($p < 0.05$). EO thickness was constant in all the three positions.

Conclusions: The present study suggests that standing and saddle standing positions could be recommended for the ADIM to maximize recruitment of the TrA and IO activation. Specifically, the saddle standing position with knees flexed to 20° was observed to increase the TrA activation more than the standing position. These findings should be considered when core stability exercises such as the ADIM are conducted.

Key Words: Abdominal muscles, Position, Ultrasound

Introduction

Spinal stabilization exercises have been utilized as conservative treatment intervention for low back pain (LBP) and have been shown to decrease LBP symptoms [1,2]. These exercises attempt to restore function of local spine stabilization muscles including the transversus abdominis (TrA), multifidus, pelvic floor, and diaphragm [3,4]. The TrA is one of the dynamic stabilizer muscles pre-activated

during functional movement. Much research has been published with regard to motor control and the sequencing of muscle contractions during the stabilization of the spine [5,6]. Previous studies suggest the TrA is consistently the first abdominal muscle to contract in an anticipatory feed-forward manner [7-9].

Since the TrA muscles are deep to other abdominal muscles, they are difficult to evaluate and palpate. Rehabilitative ultrasonographic imaging (RUSI) is a relatively simple and

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accurate method for measuring the deep spinal musculature [10,11]. RUSI is a non-invasive, accessible, safe, and low-cost tool for muscle size measurement [12], with results comparable to those obtained with magnetic resonance imaging [13-16].

The abdominal drawing-in maneuver (ADIM) is commonly used clinically as a spinal stabilization exercise that isolates the TrA [3,4,17,18]. The ADIM is designed to activate the TrA while minimally contracting the internal oblique (IO) and external oblique (EO) muscles [19]. Previous studies involving ADIM have been performed with subjects in various positions such as supine, crook lying, sitting, four points kneeling, and wall support standing [20-22]. O'Sullivan [23] recommends weight-bearing positions such as standing as a first ADIM exercise. Mew [22] and Akuthota and Nadler [24] also stated that standing positions were most effective for performing TrA contraction. In addition, Hwang *et al.* [21] studied variations in TrA contraction ratios with variation of knee flexion during ADIM in wall support, reporting that performing ADIM in the wall supported standing with knee flexion of 20° appears to be the most appropriate position for the preferential contraction ratio of the TrA.

The ADIM may be conducted in various positions, and physical therapists need to ensure the best position for the ADIM to achieve optimal outcome. However, there has been little research on which position is most effective for the ADIM exercise.

This study is aimed to investigate the appropriate position for the ADIM exercise by using a RUSI.

Methods

Subjects

Twenty-eight young adults (14 men, 14 women, aged 19-29 years) with no history of LBP were recruited from the student population of the Sahmyook University in Seoul. The exclusion criteria were as follows: history of pelvic or abdominal surgery, current LBP, or pregnancy. All subjects completed a questionnaire recording their sex, age, height, weight, and a history of any previous LBP. No subjects had any previous experience of ADIM exercise. The purpose of the study was explained to the participants and informed consents were obtained. The study protocol was approved by the institutional review board of the Sahmyook University in Seoul.

Measurements

A RUSI system (Myosone U5; Samsung Medison, Korea) with a 7.5-MHz linear transducer was used to obtain images of the EO, IO, and TrA muscles. RUSI measurements were carried out by one examiner with 5 years of RUSI experience. The transducer was transversely placed on the middle abdominal region between the border of the 11th costal cartilage and the iliac crest [25]. To standardize the position of the transducer, the anterior fascial insertion of the

Figure 1. Three examination positions. (A) Crook lying position with hip 60° flexion, (B) standing position with the feet hip width apart and knees straight, (C) saddle standing position with the knees 20° flexed.

TrA was positioned approximately 2 cm from the medial edge of the ultrasound image [26].

The three positions compared were crook lying, standing, and saddle standing (Figure 1). Two sequential US images were taken at rest and during the ADIM in each of the three positions. Subjects in the crook lying position had their hips flexed to 60°. Subjects in the standing position stood with their feet hip width apart, and subjects in the saddle standing position stood with their feet hip width apart and with knees flexed to 20°. The subjects were verbally cued to draw in their abdominal wall with the intention of pulling their navel towards their low back [27]. The thickness of the TrA, IO, and EO muscles were collected at end of inspiration when the TrA was at its thinnest [28].

The RUSI image showed skin, fat, and three muscles. On the RUSI image, the top skin was mildly echogenic, and the fat under the skin was hypoechoic. The three muscles were the EO, IO, and TrA from superficial to deep, respectively (Figure 2). Each muscle layer was differentiated from the next by the hyperechoic epimysium. The examiners measured the vertical length 2 cm away from the anterior fascial insertion of the TrA on the RUSI between the inferior echogenic fascial line and the superior line of each muscle.

Data analysis

Statistical analysis was performed using the IBM SPSS Statistics 19.0 (IBM Co., Armonk, NY, USA). The general characteristics of the participants were analyzed by descriptive statistics and presented as mean (standard deviation)

Figure 2. Rehabilitative ultrasound image of the lateral abdominal muscle was measured. The most superficial layer is the external oblique (EO) muscle, the middle layer is the internal oblique (IO) muscle, and deepest layer is the transversus abdominis (TrA) muscle.

(SD). The changes in muscle thickness of the TrA, IO, and EO at rest and during the ADIM in the crook lying, standing, and saddle standing positions were compared using repeated measure ANOVA. Statistical significance was set at 0.05.

Results

Participants had a mean age of 22.3 (2.3) years (mean [SD]), a mean height of 168.7 (7.8) cm, a mean weight of 62.6 (10.2) kg, a mean bust circumference of 87.0 (7.4) cm, a mean waist circumference of 76.2 (7.0) cm, and a mean body mass index of 21.9 (2.7) (Table 1).

The thicknesses of the TrA, IO, and EO during rest and during ADIM in crook lying, standing, and saddle standing are summarized in Table 2. During ADIM, the TrA thickness was significantly increased in the crook lying, standing, and saddle standing positions greater than during resting. IO thickness was significantly greater in standing and saddle standing than in crook lying ($p < 0.05$). EO thickness was not significantly changed in all the three positions. In the standing and saddle standing position, the TrA and IO thickness were significantly higher than in the crook lying position. However, there was no significant change of the IO or TrA thickness between the standing and saddle standing positions (Table 2). Figure 3 shows the changes in TrA, IO, and EO thickness according to the three positions.

Discussion

In this cross-sectional study, the TrA thickness was significantly increased in the standing and saddle standing positions. Standing and saddle standing produced statistically significant increases in the IO thickness. One possible

Table 1. General characteristics of subjects (N=28)

Parameters	Value
Sex	
Male/female	14/14 (50.0/50.0)
Dominant side	
Right/left	27/1 (96.41/3.6)
Age (y)	22.3 (2.3)
Height (cm)	168.7 (7.8)
Weight (kg)	62.6 (10.2)
Body mass index	21.9 (2.7)
Bust circumference (cm)	87.0 (7.4)
Waist circumference (cm)	76.2 (7.0)

Values are presented as n (%) or mean (SD).

Table 2. Changes in muscle thickness of TrA, IO, and EO with resting, crook lying, standing, and saddle standing positions during ADIM (N=28)

Parameter	Positions			
	Resting	ADIM crook lying	ADIM standing	ADIM saddle standing
TrA (cm)	0.21 (0.07)	0.33 (0.11) ^a	0.42 (0.16) ^{a,b}	0.46 (0.20) ^{a,b}
IO (cm)	0.66 (0.19)	0.74 (0.25)	0.88 (0.29) ^{a,b}	0.88 (0.27) ^{a,b}
EO (cm)	0.43 (0.13)	0.40 (0.14)	0.40 (0.12)	0.41 (0.14)

Values are presented as mean (SD).

TrA: transversus abdominis, IO: internal oblique muscle, EO: external oblique muscle, ADIM:abdominal draw-in maneuver.

^aSignificant difference compared to resting ($p<0.05$). ^bSignificant difference compared to ADIM in crook lying ($p<0.05$). ^cSignificant difference compared to ADIM in standing ($p<0.05$).

Figure 3. Changes in transversus abdominis (TrA), internal oblique (IO), and external oblique (EO) thickness according to the positions (crook lying, standing, and saddle standing) during resting and abdominal draw-in maneuver.

explanation for these results might be the need for increased activation of the TrA and IO muscles to maintain standing posture with a smaller base of support than in the crook lying posture [29]. Beith *et al.* [29] demonstrated that differences in thickness were found within the TrA and IO muscles in standing compared with lying. They suggest standing is less stable than lying and requires more support for the vertebral column, and therefore requires more activation of the TrA. The finding of a constant EO thickness suggests the EO plays no part in stabilizing the spine. The change in thickness of the IO muscle was intriguing, but there is some suggestion that there might be different activation patterns in different parts of the IO muscle.

We investigated abdominal muscle thickness in the saddle standing position, which reduces the support from the knee hyperextension when standing. Many studies have used the saddle standing position with knees flexed between 20°-30° to reduce support by the knee skeletal system [21,30]. No significant differences were found in the TrA and IO thick-

ness between standing and saddle standing positions. However, in the saddle standing position, TrA thickness we observed that the increase more than in the standing position (Figure 3). Previous studies suggest that the standing position should require smaller tonic recruitments of the TrA muscle compared to saddle standing because the body weight loaded onto the spine would be decreased by support from the knee skeletal system [21]. Hwang *et al.* [21] suggest that saddle standing with the knees flexed to 20° during an ADIM is the most effective position. In their research, as knee flexion increased, support by the knee skeletal system decreased. In other words, the recruitment of the TrA increases in more difficult positions [31]. Additionally, Richardson *et al.* demonstrated that as knee flexion increases, the TrA activity also increases to stabilize the sacroiliac joint as well as the lumbar and pelvic regions [32].

Previous studies have indicated that the supine position is more effective at recruitment of the TrA activation than the standing position [30,33]. However, in line with this study, many researchers recommend the standing position for an ADIM [21-23].

LBP is often a result of suboptimal lumbar segmental control and may be partially due to dysfunction in local segmental muscles such as the TrA [34]. The ADIM has been shown to be effective in the treatment of LBP and significantly reduces LBP symptoms and disability [3,23]. Therefore, we suggest a further study targeting LBP patients for the appropriate position of the ADIM.

The present study suggests that standing and saddle standing positions could be recommended for the ADIM to maximize recruitment of the TrA and IO activation. Specifically, the saddle standing position with knees flexed to 20° was observed to increase the TrA activation more than the standing position. These findings should be considered when core

stability exercises such as the ADIM are conducted.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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