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The changes of rectus abdominis muscle thickness according to the angle during active straight leg raise

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Objective: The purpose of this study was to investigate changes of abdominal muscles thickness according to the angle during the active straight leg raise (ASLR) in young healthy subjects.
Design: Cross sectional study.
Methods: Twenty-three healthy university students (13 men and 10 women) voluntary participated to the study in S University. The ASLR was performed with the subject lying supine with lower extremities straight on a standard plinth, hands resting on the chest, and elbows on the plinth. When one subject performed ASLR from each angles (30^o, 45^o, 60^o, 90^o), compared changes in the thickness of rectus abdominis muscle. Changes in muscle thickness during ASLR test were assessed with ultrasonography. All subjects were to provide enough time of rest after performed ASLR. Rectus abdominis thickness were measured using rehabilitative ultrasound image.
Results: Good quality rectus abdominal muscle activation data were recorded during ASLR. The length changes of linea alba showed significantly shorter in between 0^o and 30^o ($p < 0.05$). The thickness of rectus abdominis muscle were significantly different between 0^o and 30^o, 0^o and 45^o, 0^o and 60^o, 0^o and 90^o. According to increase of pelvic angle, the thickness of rectus abdominis muscle were more thickening ($p < 0.05$).
Conclusions: This result is changes of abdominal muscles thickness according to the angle during the ASLR.

Key Words: Abdominal muscles, Rectus abdominis, Ultrasonography

Introduction

The anterior abdominal wall consists of four major muscles, the rectus abdominis, external oblique, internal oblique, and transverses abdominis. Rectus abdominis is considered the main responsible of trunk flexion [1]. The rectus abdominis muscle is paired straplike muscles, separated at the midline by the linea alba [2]. Also, the fibers of each lateral wall muscle cross midline and attach to the fibers from the contra-lateral lateral abdominal wall muscle to from the linea alba. The linea alba helps transmit loads between the sides of the abdominal wall [3]. The rectus abdominis muscle will flex the trunk by approximating the pelvis and ribcage. The supraumbilical portion is emphasized by trunk flexion, while activity in the infraumbilical portion may be greater in posterior pelvic tilting [4]. Biomechanical research has demonstrated the role of trunk muscle activation during functional activates and exercise [5]. In particular, endurance and coordination of trunk muscle activity are key characteristics to maintain the stability of the spine, and therefore decrease the effects of low back pain [6]. According to Kendall *et al*. [4], the abdominal muscles can also prevent anterior tilting of the lower extremities. Although qualitative electromyographic (EMG) evidence of partic-

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ipation by the abdominal musculature in lower extremity activities such as unilateral and bilateral straight leg raising has been reported [7,8].

The active straight leg raise (ASLR) test used to assess the functional ability to transfer loads through the pelvis, and has been used to healthy subjects. The test-retest reliability measured with Pearson's correlation coefficient between the two ASLR scores 1 week apart was 0.87. The intra-class correlation coefficient (ICC) was 0.83. Pearson's correlation coefficient between the scores of the patient and the scores of a blinded assessor was 0.78; the ICC was 0.77 [9]. The ASLR test is performed with the patient lying supine. The test is judged to be positive when the patient flexes the hip by lifting the lower extremity with the knee fully extended off the table 5 cm and experiences unilateral pain, discomfort, or a feeling of heaviness relative to when the opposite leg is lifted [10]. The ASLR involves hip flexion, but also challenges the stability of the lumbar spine due to the large moment of gravity and the muscles. Investigation of the ASLR is also clinically relevant, as ASLR is often limited in pregnancy related pelvic girdle pain [11]. However, despite the purported usefulness of the ASLR, The ASLR exercise research is lack of about abdominal muscles are most active in any hip flexion angle.

Skeletal muscle architecture, the macroscopic arrangement of muscle fibres within a muscle relative to the axis of force generation, is the primary determinant of muscle function. Muscle force is proportional to the physiological cross-sectional area while fibre length is proportional to the absolute maximum contraction velocity of the muscle [12]. Rehabilitative ultrasound imaging (RUSI) provides a safe, non-invasive and relatively inexpensive method for the quantification of muscle architecture [13]. Recent advancements in the field of rehabilitative RUSI have allowed assessments of the abdominal muscles' behavior during specific tasks. RUSI has proven a reliable and valid measurement of muscle activity and thickness based on comparisons with electromyography and magnetic resonance imaging [14]. RUSI measures of abdominal muscle thickness correlate well with those made using magnetic resonance imaging [15], and thickness changes in the muscle during activation correlate well with the EMG activity of the muscle, suggesting that such measures can be used as a surrogate index of muscle activation [16]. Several studies have reported good reliability for measurement of individual abdominal muscle thickness at rest or in contracted state [17-19].

The purposed of this study were to determined most active of the abdominal muscle in the any hip flexion angle during ASLR in healthy subjects without low back pain.

Methods

Subjects

Twenty-three healthy university students (13 men and 10 women) voluntary participated to the study in S University. Subjects had inclusion criteria including: (1) having no history of low back pain during the last 6 months, (2) having no systemic disease that might affect the musculoskeletal function, (3) having no musculoskeletal deformity or abnormality which could influence the thickness of muscle layer. The age of participants were 21.23 (1.74) years (mean, SD) in men and 20.50 (0.53) years in women. The height of participants was 174.15 (4.47) cm in men and 165.30 (4.24) cm in women. The weight were of participants were 64.46 (6.27) kg in men and 53.56 (6.73) kg in women (Table 1). Participants gave written informed consent.

Study design

This study used a cross-sectional study design. When one subject performed ASLR from each angles (30^o, 45^o, 60^o, 90^o), compared changes in the thickness of rectus abdominis muscle. All subjects were to provide enough time of rest after performed ASLR.

Procedure

The ASLR was performed with the subject lying supine with lower extremities straight on a standard plinth, hands resting on the chest, and elbows on the plinth. To the accuracy angle, the plate setting marked angle. Before the evaluation, we were makes as much as possible relax during 30 seconds. Changes in muscle thickness during ASLR test were assessed with ultrasonography. To coordinate the timing of the ASLR test and ultrasonography assessment. Participants were told which lower extremity to lift. Then

Table 1. General characteristics of the subjects (N=23)

Parameter	Male (n=13)	Female (n=10)
Age (yr)	21.23 (1.74)	20.50 (0.53)
Height (cm)	174.15 (4.47)	165.30 (4.24)
Weight (kg)	64.46 (6.27)	53.56 (6.73)

Values are presented as mean (SD).

given the preparatory command "prepare to lift", and the command of execution, "lift". After holding the lower extremity in the raised position for 10 seconds, participants were given the commands "prepare to lower", and "lower", to return the lower extremity to the resting position. All subjects performed the ASLR test with both lower extremities. An average of 3 repetitions of the ASLR test per lower extremity was used to assess changes in muscle thickness of the rectus abdominis muscle during the ASLR test according each angles (30°, 45°, 60°, 90°). To minimize the influence of fatigue, a 30 seconds rest period was provided each ASLR angles. Real-time B-mode (brightness) ultrasonography (MYSONO U5, Samsung Medicine, Seoul, Korea) with a 7.5 MHz linear transducer were used to measure rectus abdominal muscle. Thickness of rectus abdominis muscle measured vertically at the mid-point of the width of the belly between the inside edges of the superior and inferior fascial border. Resting thickness values were obtained at the end of a normal expiration as determined based on visual observation of the ultrasonography. Also, each angle of ASLR was defined as random. We reported that thickness changes of rectus abdominis msucle from per angles was calculated as a percentage.

Percentage (%)=(contraction thickness/relaxation thickness/relaxation thickness)×100

Data analysis

Statistical analyses were performed using PASW Statistics 18.0 (IBM Co., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to assess the normality of the data. To the degree of contraction according to the angles of ASLR, we used repeated ANOVA. Furthermore, post-hoc analysis used Bonferroni's correction. Results were considered significant at $p<0.05$.

Table 2. Differences of linea alba length according to angle

Angle 1 (a)	Angle 2 (b)	Mean difference (a-b)	Standard error	p
1	2	0.25	0.05	0.001
	3	0.17	0.06	0.07
	4	0.16	0.06	0.14
	5	0.12	0.07	0.87
2	3	−0.08	0.05	1.00
	4	−0.09	0.04	0.47
	5	−0.13	0.05	0.11
3	4	−0.01	0.06	1.00
	5	−0.05	0.04	1.00
4	5	−0.04	0.06	1.00

1=0°, 2=30°, 3=45°, 4=60°, 5=90°.

Results

General characteristics at inclusion were no significant differences. The results of the length changes of linea alba showed significantly shorter in between 0° and 30° ($p<0.01$) (Table 2). The results of the thickness changes of linea alba demonstrated significantly more thickening according to increase of the angle (when compared between 0° and 30°, 0° and 45°, 0° and 60°, 0° and 90°) ($p<0.01$) (Table 3).

The thickness of rectus abdominis muscle were significantly different between 0° and 30°, 0° and 45°, 0° and 60°, 0° and 90°. According to increase of pelvic angle, the thickness of rectus abdominis muscle were more thickening ($p<0.01$) (Table 4).

Table 3. Differences of linea alba thickness according to angle

Angle 1 (a)	Angle 2 (b)	Mean difference (a-b)	Standard error	p
1	2	−0.08	0.02	0.001
	3	−0.17	0.03	0.006
	4	−0.10	0.02	0.006
	5	−0.08	0.02	0.009
2	3	−0.03	0.02	1.00
	4	−0.02	0.02	1.00
	5	−0.01	0.02	1.00
3	4	0.01	0.02	1.00
	5	0.02	0.03	1.00
4	5	0.01	0.02	1.00

1=0°, 2=30°, 3=45°, 4=60°, 5=90°.

Table 4. Differences of rectus abdominis thickness according to angle

Angle 1 (a)	Angle 2 (b)	Mean difference (a-b)	Standard error	p
1	2	−0.29	0.03	0.001
	3	−0.26	0.04	0.001
	4	−0.32	0.05	0.001
	5	−0.30	0.04	0.001
2	3	0.02	0.03	1.00
	4	−0.04	0.04	1.00
	5	−0.02	0.04	1.00
3	4	−0.06	0.03	0.74
	5	−0.04	0.05	1.00
4	5	0.02	0.04	1.00

1=0°, 2=30°, 3=45°, 4=60°, 5=90°.

Discussion

Rectus abdominis muscle is a large muscle with primary function of approximating the rib cage with the pelvis by producing a flexion moment in the sagittal plane [20]. The muscle is few important roles of the thickness of the rectus abdominis muscle. First, in rectus abdominis muscle flap for chest wall or breast reconstruction, a proper thickness of the rectus abdominis muscle helps ensure the flap elevation is safe [21]. When the muscle is too thin, there is a possibility of injury of the pedicle, if the pedicle is exposed to tension such as from retracting hand power during dissection. When the muscle has sufficiently thick, it prevents injury of the pedicle or the segment of the perforator because it bears more tension. Second, a proper muscle thickness can indicate the condition of the pedicle. If the rectus abdominis muscle is thick and healthy, the muscle has sufficient blood supply and the pedicle is in good condition. Therefore, the thickness of the rectus abdominis muscle is clinically very important [22]. Measurement of the rectus abdominis muscle with USI is unique amongst the abdominis muscles, as it is the only abdominal muscle for which cross-sectional area (CSA) may be measured. The rectus abdominis muscle has the greatest thickness of all the abdominal muscles, and men have a larger thickness than females in both absolute size and when normalized for body mass [20]. Also, the study of postpartum characteristic of rectus abdominis muscle demonstrated rectus abdominis muscle was significantly thinner than controls. Reid and Costigan [23] showed no significant differences in the CSA of the rectus abdominis muscle associated with age. Previous study reported in their study 86 women using ultrasonography that the thickness of the right rectus abdominis muscle was 10.2 (1.6) mm. Based on the work by Rankin *et al*. [20], this study measured rectus abdominis muscle thickness by measurement of the greatest perpendicular thickness between the superficial to deep facial layers. As a result, we showed that similar results with previous studies.

In healthy subjects the physical load of an ASLR elicited a motor response in the abdominal wall that was primarily tonic, presumably contributing to lumbopelvic stability and effective load transference through the pelvis [24]. In previous study, the angle of straight leg raise (SLR) with the ankle fixed in dorsiflexion was less than the angle of SLR with the ankle relaxed in plantarflexion for both active and passive SLR. Accordingly, our study measured not fix in dorsiflexion of ankle. Previous study demonstrated the ASLR test could be a suitable instrument to quantify and qualify disability in diseases related to mobility of the pelvic joints [10]. Another study demonstrates that the ASLR has utility as a screen of lumbar spine stability and abdominal bracing ability. The ASLR maneuver can assess control of lumbar rotational movements in the transverse plane [25]. Lehman and Mcgill [26] demonstrated the activity during the abdominal muscle isometric leg raise was greater when compared with the external oblique muscle activity during the curl-up and the isometric curl-up.

This study showed that the thickness of rectus abdominis muscle was significantly different in all range. According to increase of pelvic angle, the thickness of rectus abdominis muscle were more thickening.

There were several limitations regarding the generalizability of this study. First, present study recruited small samples (only twenty-three young healthy subjects), therefore, these results cannot be generalized to all population. Seconds, this study may have been confused variable by the difference of body flexibility between subjects. Finally, different degree of strength between the experimenter.

Present study demonstrated that changes of abdominal muscles thickness according to the angle during the ASLR. However, the result was not correlated according to the change in the angle. Finally, further studies will needs to determine reliability of various ages classified according to the degree of the ASLR.

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