Relations Between Lateral Abdominal Muscles Thickness, Body Mass Index, Waist Circumference and Skin Fold Thickness

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Abstract- In light of provided progresses in ultrasound measurements of lateral abdominal muscles, an important role for these muscles, particularly transverse abdominis (TrA) muscle in stability of the spine has been suggested. Some authors have found significant correlations between body mass index (BMI) and thickness of these muscles. The aim of this study was to examine possible association between different methods of measurements of fatness and lateral abdominal muscles thicknesses, employing ultrasound imaging in healthy subjects. Ninety healthy male volunteers aged 18 to 38 (mean= 31.37, standard deviation=5.09) who met our inclusion criteria participated in this study. BMI, skin fold thickness, weight and waist circumference were assumed as the major outcomes for measurement of fatness of the subjects. Employing ultrasound measurements, the thickness of TrA, internal oblique (Int Obl) and external oblique (Ext Obl) muscles were also measured. We found positive significant relation between Ext Obl muscle thickness and all methods of measurements of fatness. Reversely, the results show that Int Obl muscle thickness significantly decreases with the rise of all methods of fatness measurement except weight which had no significant correlation with Int Obl thickness. No significant relation between the TrA muscle thickness and different measurements of the fatness of the subjects were found. In the studies investigate the thickness of lateral abdominal muscles; the authors try to match the participants of different groups of their study regarding the BMI. We found that both waist circumference and skin fold thickness measurements might be assumed as surrogate of BMI, in aim of matching the participants on Ext Obl muscle thickness.

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Introduction

Respecting the published studies regarding the role of transverse abdominis (TrA) in spinal stability, some authors have recommended special exercises for TrA muscle conditioning to treat low back pain (LBP) (1-5). In this regards, two findings have been reported as a contributing factor for LBP: 1) early contraction of TrA muscle during limb movement in normal subjects in comparison to patients complaining from LBP (6-9), 2) decrease in ability of TrA muscle thickening in patients with LBP in comparison to normal subjects (10,11). Richardson *et al.* found that TrA muscle contraction in comparison to simultaneous contraction of all three layers of lateral abdominal muscles might lead to more efficient outcomes in treatment of patients with low back pain (12).

In most of focused studies on the function and demographic features of lateral abdominal muscles, Ultrasound imaging has been utilized as a reliable and noninvasive tool to measure muscle thickness (13-16). Easiness in usage and fewer complications for the subjects might be other advantages of ultrasound imaging that has promoted its application in practice. Reliability of ultrasound measurements of lateral abdominal muscles were also reported in previous studies (13,17-19).

Springer *et al.* reported positive correlation between BMI and TrA muscle and total lateral abdominal muscles thickness (11), as it was previously suggested

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for muscle strength and body mass index (BMI) by Lue *et al.* (20). This finding could suggest that in studies on which TrA muscle thickness needs to be measured, BMI of participants should be considered as a source of error. However, this is a controversial issue as Rankin *et al.* reported a significant correlation only between the external oblique (Ext Obl) muscle thickness and BMI and not between other lateral abdominal muscles thicknesses and BMI (21).

Two other measurements that could indicate the magnitude of fatness of people and might be related to the TrA muscle thickness are skin fold thickness and waist circumference (22,23). These measurements could indirectly show the magnitude of abdominal fatness. Both skin fold thickness and waist circumference measurements have been used widely in both clinical and research settings (24-27). To our knowledge, no study has clarified the relation between skin fold thickness or waist circumference and lateral abdominal muscles thickness. In this study, we tried to examine these probable relations employing ultrasound imaging in healthy subjects.

Materials and Methods

Subjects were ninety healthy male volunteers aged 18 to 38 (mean=31.37, SD=5.099) with no history of low back pain in recent 6 months [according to the definition used in previous studies (11,28)] and no history of performing core stability exercises in the past 3 months. None of participants reported any experiences in rotational sports (sports that involve rotation and repetitive movements e.g. Tennis, golf and hockey) none of them had any systemic diseases that could affect the musculoskeletal system. A written informed consent for participation in this study was signed by all the volunteers. This study was approved by the University's ethical committee for research.

Body weight measurement

Using a calibrated digital scale all participants were weighted to the nearest 0.02 kg. For these measurements subjects wore previously provided T-shirt and light cotton short. While the digital number of the scale was fixed for 5 seconds and the subjects were stably stood up on the scale without any deviations to any sides, the weight of participants was recorded.

Height measurement

Subjects were required to remove their shoes and while their heels were joined together and were stood straight up, after taking a deep inspiration, the height was measured. In this procedure, the head of participants was asked to be straight and they were looking forward. The data were recorded in centimeters (29).

Waist measurement

With the subjects standing upright and relaxed, a horizontal measure was taken at the greatest anterior extension of the abdomen at the level of the umbilicus. The measured values were recorded at the end of a normal exhalation without pulling the tape tightly.

Skin folds thickness measurement

Standard Harpenden skin fold caliper (British Indicators Ltd, UK) was employed in this study (5,24,30). For measurement of skin fold, tester grasped a fold of skin firmly between the thumb and index finger of his left hand and lifted it away from the body. He rolled the fold to ensure that subcutaneous tissue (not muscles) were being measured, then jaws of the caliper positioned over the skin fold just 1 cm under his fingers. After releasing the grip, he waited 1 to 2 seconds then read the value was being showed on the caliper. The measurements were performed according to a triplicate protocol. In this regard, in sites of measurements, the tester carried out the measurements for three times and in case of more than 3 mm variations in three mentioned values, the measurement for the fourth time was being performed. We measured all sites on the right body side. Subjects were relaxed and standing upright in the course of measurements.

The skin fold thickness of following sites were being measured (29); 1) Abdominal site: in a raised vertical fold; 2 cm toward the right lateral side of the omphalion (midpoint of the navel); 2) Triceps site: in a raised vertical fold; on the posterior surface of the right arm in mid, acromion-olecranon line; 3) Sub-scapular site: in a raised oblique fold (45-degree angle), 1 to 2 cm under the lower angle of the scapula. Sum of three mentioned values were used in statistical analysis of the data.

Ultrasound measurements

Subjects were required to place in supine hook-lying position (supine position with hips flexes to almost 30°) where small pillows were laid under their knees and head (5,24,31).

A SonoSite ultrasound imaging machine and a linear transducer (6-13MHz) were utilized to find the muscle thickness of lateral abdominal muscles. The angle of the probe was adjusted (<10°) until a clear image of all 3 lateral abdominal muscles (External Oblique, Internal

Oblique and Transverse Abdominis) (32). In addition, respective of fat layer thickness of individuals, depth of view was adjusted to find final clear view of subjects' muscles, however finally the thickness of three muscles layers was tried to fill 40-50% of monitor field. The point of probe position was set at 25 mm anteromedial to the midpoint between the inferior rib and the iliac crest on the mid-axillary line, as it was previously used in other studies (31). As it was also recommended in other studies (33,34), adequate ultrasound gel was used between the head of transducer and skin of subjects to find clearer views and diminish any need for inward pressure of abdomen by the assessor.

At the end of normal expiration (35), the distance between the upper and lower fascial layers (excluding facial thickness) were considered as muscle thickness (16,34) and in center of the image the assessor using caliper of the machine, performed the measurement of muscle thickness (21). In aim of prevention from probable thickening of muscles, as the biofeedback role of ultrasound imaging has been suggested in previous studies, the subjects were forbidden to see the monitor of ultrasound machine. As it was mentioned, measurements were performed in both sides; the final values entered into the statistical analysis of the study, were defined as the mean of muscle thicknesses of both sides.

Using bivariate Pearson correlation, as one of modules of SPSS 16 (SPSS Inc, Illinois, USA) software the correlation between skin folds and waist circumference measurements and muscles layer thicknesses were looked for. The statistical level of significance was set at P-value<0.05.

Results

Basic characteristics of subjects participated in this study is provided in table 1. Descriptive analyses regarding muscle and skin fold thickness of all subjects have been shown in tables 2 and 3.

Table 1. Demographic data of participants in the study.

Variables (unit)	Mean	SD	Range
Age (Years)	31.51	4.95	(18 to 38)
Weight (kg)	81.33	13.53	(52 to 109)
Height (cm)	173.03	5.79	(163 to 189)
BMI (kg/m^2)	27.20	4.54	(16.07 to 36.62)
Waist Circumference (cm)	94.84	12.84	(68 to 123)

Table 2. Abdominal muscles thicknesses of participants in both sides (0.1 mm).

	Right		Left		Mean (SD) *
	Range	Mean (SD)	Range	Mean (SD)	
Ext Obl	19-88	45.46 (14.80)	22-78	47.54 (13.56)	46.50 (12.76)
Int Obl	39-118	64.39 (16.69)	34-116	63.71 (16.00)	64.05 (14.41)
TrA	19-66	37.14 (9.47)	21-64	37.90 (8.49)	37.52 (8.02)

Abbreviations: Ext Obl, External oblique muscle; Int Obl, Internal oblique muscle; TrA, Transverse abdominis muscle;

*mean of both sides in all patients were considered

Table 3. Values (mm) of Skin fold thicknesses in three different sites of measurements.

Variables	Mean	Standard Deviation	Range
Abdominal site†	26.92	10.23	(8 to 45.5)
Triceps site‡	21.29	11.17	(4.6 to 49)
Scapular siteꓡ	18.96	7.62	(5 to 38)

† 2 cm toward the right lateral side of the omphalion

‡ On the posterior surface of the right arm in mid, acromion-olecranon line

ꓡ 1 to 2 cm under the lower angle of the scapula

Table 4. Correlation between different fat related measurements (BMI, sum of skin fold thickness, weight and waist circumference) and the mean of both sides of three lateral abdominal muscles thicknesses.

	BMI		**Sum of Skin Fold Thickness†**		**Weight**		**Waist circumference**	
	Correlation	***P*-value**	**Correlation**	***P*-value**	**Correlation**	***P*-value**	**Correlation**	***P*-value**
Ext Obl	0.360	<0.001*	0.392	<0.001*	0.340	0.001*	0.344	0.001*
Int Obl	-0.220	0.037*	-0.289	0.006*	-0.175	0.099	-0.254	0.016*
TrA	0.113	0.291	0.079	0.459	0.157	0.140	0.071	0.507

Abbreviations: Ext Obl, External oblique muscle; Int Obl, Internal oblique muscle; TrA, Transverse abdominis muscle;

* The correlation is statistically significant

† The sum of values from three sites of skin fold thickness measurement

As it is shown in table 4, a positive and negative significant correlation were found between BMI and muscle thickness of Ext Obl and Internal Oblique (Int Obl) muscles respectively (obtained from mean of both sides) but, these correlations were weak (for Ext Obl, r =0.360, *P*<0.001 for Int Obl, r=-0.220, *P*=0.037). However there was no significant relation between TrA muscle thickness (mean of both sides) and BMI of subjects.

Similar to the data on BMI and muscle thickness, there was a significant relation between Int Obl and Ext Obl muscle thicknesses (obtained from mean of both sides) and sum of skin fold thicknesses but, similarly, correlation were weak (for Ext Obl, r=0.392, *P*<0.001. for Int Obl, r=-0.282, *P*=0.006). However, no significant correlation was found between sum of skin fold thickness and TrA muscle layer thickness (mean of both sides).

The correlations between muscle thickness and waist circumference and also with weight of subjects were also investigated and approximately similar patterns of relations to skin fold thickness and BMI were found. In this regard, waist circumference measurements had positive significant correlation with mean of both sides of Ext Obl muscle. Reversely the significant negative relation was found between the waist circumference measurement and Int Obl muscle thicknesses. In addition, there was no correlation between mean of both sides of TrA muscle thickness and waist circumference of subjects. Meanwhile, weight of subjects only presented positive significant relation with muscle thickness of Ext Obl.

Discussion

According to the outcomes of this study, thickness of two superficial layers of lateral abdominal muscles (Int Obl and Ext Obl) have statistically significant relation with both the body mass index (*P*=0.037 and *P*<0.001 respectively) and the skin fold thickness (*P*=0.006 and *P*<0.001 respectively) of normal subjects participated in this study. These correlations were positive between Ext Obl and both BMI and skinfold thickness and negative for Int Obl. However we found no relation between the thickness of TrA muscle and both BMI and skin fold thickness of participants. This finding is in contrast with previous reports provided by Springer *et al.* (11) and Mannion *et al.* (33) who found positive correlation between TrA muscle thickness and BMI. In our study there was a significant positive correlation between Ext Obl and BMI; These results are in consistence with the study of Rankin *et al.* (21) who reported a significant mil to moderate correlation (r=0.42-0.57) between the Ext Obl muscle thickness and BMI and not between other lateral abdominal muscles and BMI. In explanation of these discrepancies following probable reasons can be noted; only male subjects were recruited in our study but other studies were performed using both genders. This variation in subject recruitment might be assumed as a reason for discrepancies found in obtained results between the studies, since the effect of sexuality on thickness of lateral abdominal muscles have been reported previously. Springer *et al.* (11) reported that relative muscle thickness of TrA (as a ratio with total thickness of lateral abdominal muscles) in females is significantly more than the same value in males. In addition, not only in different studies variable points of transducer positions were used to measure the muscle thickness but also some authors (33) recorded the muscle thickness in contracted condition while the others (21) measured the thickness of relaxed muscles. In this study we measured the thickness of relaxed muscles although it seems that thickness of contracted muscles might be assumed as a more important variable in comparison to resting muscles thickness in assessment of patients with LBP (15,33). Another possible reason for these variations might be due to the age of our subjects; in our study subjects were 90 males, ages 18-38 years (31.37±5.09) but in the study of Rankin *et al*. (21) subjects were older (40±14.1). In younger ages, men tend to be more of a muscle build. Also in these ages people are in a wide range of physical activity (36) which was considered neither in our subject recruitment nor in data analysis.

Interestingly we found that waist circumference of participants have also positive and negative correlation with the thickness of Ext Obl (P=0.001) and Int Obl (P=0.016) respectively. Springer *et al.* (11) have recommended in their study that the investigators might need to control the participants for BMI similarity in aim of well matching of subjects when measuring TrA muscle thickness. Respecting the obtained data in this study, it can be suggested that waist circumference measurement and skin fold thickness measurement might be used as surrogate of BMI measurement in matching of participants when measuring lateral abdominal muscles (Int Obl and Ext Obl) thickness. While further investigations seem to be required in aim of application of mentioned indices in practical setting, particularly waist circumference measurement seems to be inexpensive and easy for use in both clinical practices and research studies.

We measured the skin fold thicknesses in only 3 sites. Although significant findings were obtained between the thickness of Int Obl and Ext Obl muscles and skin fold thickness, measurement of skin fold thickness in more sites of measurements might lead to variable correlations with the muscle thickness of lateral abdominal muscles. Besides, weight of participants was significantly correlated with the Ext Obl muscle thickness. The difference between the findings regarding the correlation of waist circumference, skin fold thickness and BMI on one hand and weight of the subjects on the other hand with the muscle thickness of lateral abdominal muscles might be due to the effect of different body fat distribution on the thickness of muscles. It seems more controlled and prospective studies should be run in aim of better clarifying this important assumption. As it was mentioned before, only male and healthy subjects participated in this study, which can be assumed as limitation of the study. As another limitation, we evaluated the thickness of muscles irrespective of hand dominancy; but mean of muscle thickness was entered into statistical analysis and in this way, we tried to decrease the mentioned error.

In conclusion, we found that among lateral abdominal muscles, only Ext Obl has a positive relation with BMI. Both waist circumference and skin fold thickness measurements might be used instead of BMI in aim of control for performing research on Ext Obl muscle thickness. In addition, the effect of pattern of fat distribution on muscle thickness of lateral abdominal muscles and thereby spinal stability should be investigated in future studies. Generalization of achieved outcomes to patients with low back pain could also be investigated in future studies.

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