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ORIGINAL ARTICLE

The effect of food consumption on the thickness of abdominal muscles, employing ultrasound measurements

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Abstract Recently, the roles of transabdominal muscles particularly TrA (transverse abdominis) muscle in spinal stability leading to treatment of low back pain have been suggested. Both in clinical setting and follow up studies, abdominal muscle thickness measurements need to be repeated at a later point in time to demonstrate efficacy of a therapeutic intervention. Different issues have been suggested as source of error in the repeated measurements of abdominal muscle thickness in different days such as patient position and stability of probe location. The level of stomach fullness has not been investigated as a source of error in ultrasonic measurements of transabdominal muscles thickness. This study was performed to evaluate the effect of food consumption on thickness of lateral abdominal muscles. Lateral abdominal muscles thicknesses of 63 healthy volunteer men were measured before and after food consumption. All the measurements were performed in two transducer positions and both sides. Waist circumference and body weight of participants were also measured before and post-food consumption. The thickness measures of all three muscles layers of lateral abdominal muscles (external oblique, internal oblique and transversus abdominis) in both sides and measured positions were significantly reduced after food consumption. We found no correlation between the increase of waist circumference and reduction of muscle layer thicknesses after food consumption. In case of comparison between the values of transabdominal muscle thicknesses over the time, the effect of food consumption on muscle thickness might be assumed as a potential source of error.

Keywords Ultrasonography · Low back pain · Abdominal muscle thickness · Spinal stability

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Introduction

Recently spinal stabilization exercises in which patients are taught to perform isolated contractions of the transverse abdominis (TrA) have become increasingly popular in prevention and treatment for low back pain [1, 9, 28]. Also unilateral or bilateral weakness of TrA is suggested as an etiology of LBP [12, 13, 15]. Therefore, many interests have been attracted to transabdominal muscle particularly TrA muscle thickness measurement employing ultrasonography [3, 8, 17, 30, 31].

Ultrasonic waves have been utilized in measurements of abdominal muscle thickness [27]. Several studies have reported good reliability for measurement of individual abdominal muscle thicknesses at rest or in contracted state [10, 11, 18, 30]. Also ultrasonic biofeedback is used to teach TrA contraction in patients with LBP [2, 3, 23]. Some attempts have been made to find a standard measurement method for measuring lateral abdominal muscle thickness, however, more researches are needed in this area.

Both in clinical setting and follow up studies, abdominal muscle thickness measurements needs to be repeated at a later point in time to demonstrate efficacy of a therapeutic intervention. Different issues have been suggested as source of error in the repeated measurements of abdominal muscle thickness in different days such as patient position and stability of probe location, and also probe orientation and magnitude of inward pressure [32]. In this study we investigated whether the level of stomach fullness might be a source of error in this situation.

Fullness and emptiness of stomach because of its elastic structure can lead to expansion and shrinkage of stomach, respectively. Besides, stomach has been placed just posterior to the anterior abdominal wall and its enlargement can directly bring about tension of TrA and thereby other external muscle layers and lead to variable thicknesses reduction of these muscles. Therefore, after food consumption the thickness of abdominal muscle might be reduced.

Respecting the importance of TrA muscle thickness in spinal stability [14, 15, 24], and also in aim of standardizing general condition of ultrasonic measurements of TrA muscle thickness, the authors of this manuscript decided to run the present study to evaluate and to quantify the effect of food consumption on thickness of lateral abdominal muscles. It was hypothesized that degree of stomach fullness could affect the thickness of lateral abdominal muscles and therefore could be a source of error in the repeated measurements of abdominal muscle thickness in different days. This could imply to both clinical and research-based abdominal muscle thickness measurements.

Methods

The subjects were 63 healthy volunteer men who met our inclusion criteria including; (1) having no history of low back pain during the last 6 months. (2) Having no systemic diseases that might affect the musculoskeletal functions. (3) Having no musculoskeletal deformity or abnormality which could influence the thickness of muscle layers. All subjects were offered to eat food at lunch time. Before and after food consumption, the following measurements were made on all subjects by the same examiner.

General evaluations

Before food consumption, weight, height, waist circumference and transabdominal muscle thickness of all recruited individuals were measured using standard protocols. All subjects ate no food but water during 2 h before the first measurement. Post-food consumption evaluations were also performed in the same condition in 30 min after food consumption.

Food consumption

The same kind and quantity of meal was offered to all individuals; however, they ate it in variable amounts. The meal was selected as a traditional Iranian food and all subjects had experienced the taste of food previously.

Height measurement

Subject removed their shoes and stood straight up with heels together, took a deep breath and held it. Subject stood with head level, looking straight ahead. The height of subject was then recorded in centimeters [4].

Body weight measurement

Total body weight of the subjects was measured using a calibrated digital scale to the nearest 0.02 kg. Subjects were weighted wearing light cloths (a t-shirt and short). Any defecation and urination was also measured in this period.

Waist measurement

To evaluate the magnitude of abdominal extension because of food consumption, waist circumferences of all subjects were measured both before and after eating the food. These were measured, in two different positions. 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 (first position). The second position was defined as the distance around the body while the fabric meter passes from the midway between the navel and costal angle (lower border of xiphoid). The measured values were recorded at the end of a normal exhalation without pulling the tape tightly.

Ultrasound measurements

Abdominal muscles thicknesses were measured at rest and were taken with subjects in a crook-lying position with pillows under the head and the knees [16].

A SonoSite ultrasound machine and a linear transducer (6–13 MHz) were employed to record the abdominal muscle thicknesses in M mode format. Transducer was positioned in transverse plane and measurement of muscle thickness was made at the center point of the image using caliper of the machine [27]. To prevent feedback effects, subjects could not view the scanner screen. In all subjects freezing of the view for the measurement was timed to coincide with the end of normal expiration when the muscles were likely to be at their thickest position in resting condition [3]. The distance between the top of inferior fascial layer and bottom of superior fascial layer were considered as muscle thickness and fascial layers were excluded from measurement [19, 22].

Two transducer positions used in previous studies to measure abdominal muscle thickness were employed in this study. (1) A point 25 mm anteromedial at the midpoint between the inferior rib and the iliac crest to the mid-axillary line [16]. (2) A point immediately under the rib-cage in direct vertical alignment with the anterior superior iliac spine (ASIS) [27]. We marked the transducer positions at the pre food consumption measurements and used the same position at the after food consumption measurements. Both pre and post-food consumption measurements were carried out in both sides.

The angle of probe was adjusted until a clear image of the abdominal muscles, (TrA, internal oblique and external oblique) was recognized. In addition, the depth of the image was manipulated in such a way in which the muscle layers filled approximately 40–50% of the ultrasound display. Adequate ultrasound gel was used between the transducer head and the skin to increase the area of contact and minimizes the need for inadequate inward probe pressure [19, 20].

Reliability of measurements in the mentioned positions was achieved in a pilot study by the assessor. All three muscle layers could be clearly distinguished visually in the monitor of used ultrasound device.

The study was approved by the ethical board committee of Tehran University of Medical Sciences. In addition, all the participants in the study were informed regarding the aim and process of study. A written informed consent was signed by all subjects.

Quantitative collected data were analyzed using paired sample *t* test as one of statistical facilities of SPSS.16 (SPSS Inc, IL, USA) software and level of significance was set at 0.05.

Results

The subjects (63 people) had a mean age of 27.8 (range 18–56, SD 7.76) and mean pre food consumption weight of 70.9 kg (range 49.6–109.7, SD 14.20) and pre food consumption BMI (body mass index) of 24.30 (range 16.96–34.81, SD 4.05). After food consumption, it was found that mean weight of participants have increased 0.9 kg (SD 0.3).

Muscle thickness

The thickness values of all three muscles (external oblique, internal oblique and transversus abdominis) in both sides and both measured positions were significantly reduced after food consumption (Tables 1, 2).

Waist circumference

After food consumption waist circumference of the subjects was significantly increased in both measured positions (Table 3).

Table 1 Pre-food consumption (pre) and post-food consumption (post) values of the abdominal muscle thicknesses measured at the right side

Variable		Mean (mm)	Standard deviation	Mean difference	95% CI pre and post differences	*P* value
Position1[a]						
Ext Obl	Pre	7.0	1.9	1.3	1.03–1.58	<0.001
	Post	5.7	1.8			
Int Obl	Pre	8.5	2.3	1.6	1.35–1.92	<0.001
	Post	6.9	2.2			
TrA	Pre	3.0	0.9	0.8	0.60–0.89	<0.001
	Post	2.2	0.6			
Position2[b]						
Ext Obl	Pre	3.7	1.0	0.7	0.54–0.84	<0.001
	Post	3.0	0.7			
Int Obl	Pre	7.3	2.0	2.0	1.64–2.29	<0.001
	Post	5.3	1.7			
TrA	Pre	3.5	1.0	0.8	0.63–0.97	<0.001
	Post	2.7	0.6			

Ext Obl external oblique muscle, *Int Obl* internal oblique muscle, *TrA* transverse abdominis muscle

[a] A point 25 mm anteromedial at the midpoint between the inferior rib and the iliac crest to the mid-axillary line

[b] A point immediately under the ribcage in direct vertical alignment with the anterior superior iliac spine

Table 2 Pre-food consumption (pre) and post-food consumption (post) values of the abdominal muscle thicknesses measured at the left side

Variable		Mean (mm)	Standard deviation	Mean difference	95% CI pre and post differences	*P* value
Position1[a]						
Ext Obl	Pre	6.9	1.8	1.4	1.04–1.75	<0.001
	Post	5.5	1.3			
Int Obl	Pre	8.5	2.2	1.4	1.16–1.75	<0.001
	Post	7.1	1.9			
TrA	Pre	2.8	0.7	0.8	0.61–0.88	<0.001
	Post	2.0	0.4			
Position2[b]						
Ext Obl	Pre	4.1	1.2	0.8	0.51–0.92	<0.001
	Post	3.3	0.8			
Int Obl	Pre	7.0	1.8	1.6	1.26–1.80	<0.001
	Post	5.4	1.5			
TrA	Pre	3.4	0.7	0.8	0.71–0.99	<0.001
	Post	2.6	0.5			

Ext Obl external oblique muscle, *Int Obl* internal oblique muscle, *TrA* transverse abdominis muscle

[a] A point 25 mm anteromedial at the midpoint between the inferior rib and the iliac crest to the mid-axillary line

[b] A point immediately under the ribcage in direct vertical alignment with the anterior superior iliac spine

Correlations between the changes in the waist and weight values due to food consumption and abdominal muscle thickness values

No Significant correlation was found when the rates of reduction of the muscle layer thicknesses due to food consumption were compared with the obtained increases in the waist circumferences of the subjects. In addition, pre and post-food consumption differences in the weight and BMI values of the subjects showed no significant correlation with the decrease in values of each layer muscle thicknesses.

Discussion

The major outcome of this study is that after food consumption the thicknesses of all three layers of transabdominal muscles in both sides are decreased significantly.

Recently, special exercises for spinal stabilization and treatment of low back pain have been recommended widely [7, 25]. Repeated measurements of abdominal muscle thickness in different times in the course of rehabilitation might be employed to evaluate the effects of these exercises on lateral abdominal muscle thicknesses [32]. We found that after food consumption, regardless of transducer position and side of measurements, the thickness of TrA decreases in a range of 23–27%. The thickness of Int Obl (internal oblique) and Ext Obl (external oblique) muscles were also reduced in a range of 17–27% and 18–20%, respectively. Therefore, fullness level of stomach should be considered as a source of error in repeated measurement of lateral abdominal muscle thicknesses.

Mannion et al. [19] investigated the between day measurement error in evaluating transabdominal muscle thickness and reported that standard error of measurement (SEM) for both sides of TrA was 0.40 mm; and SEM for Ext Obl in left and right side were 1.03 and 0.84 mm, respectively. The obtained data regarding SEM for Int Obl were also 0.72 and 0.58 mm for left and right sides, respectively. The reported errors of measurements might be partly because the level of stomach fullness was not matched in repeated measurements in this study. The results of our study suggests that if all the initial measurements are made when all the subjects are fasted and all the repeated measurements are made in a short period after food consumption, this might lead to a maximum error of about 0.6–1 mm in repeated measurements of TrA. This error could be even higher in repeated measurements of Ext Obl at 1–1.7 mm and for Int Obl at 1.2–2.3 mm.

In the study performed by Teyhen et al. [30] they found that in group of patients with low back pain performing traditional exercises using ultrasound biofeedback, the thickness of TrA after an average of 4 days increased from 0.21 (±0.10) to 0.44 (±0.20); the same measurement for patients recruited particularly for traditional exercises without receiving any biofeedback were increased from 0.21 (±0.10) to 0.45 (±0.22). The level of stomach fullness was not considered as a possible source of measurement error in this study that might affect the results.

Table 3 Pre-food consumption (pre) and post-food consumption (post) waist circumferences values of the subjects

Variable		Mean (cm)	Standard deviation	Mean difference	95% CI pre and post differences	*P* value
UL[a]	Pre	86.1	12.0	2.3	1.91–2.56	<0.001
	Post	88.4	12.2			
MidL[b]	Pre	83.1	11.6	3.2	2.52–3.80	<0.001
	Post	86.3	11.2			

UL umbilical level, *MidL* midway level

[a] Waist circumference at the umbilicus level

[b] Waist circumference at the level of midway between the umbilicus and the lower border of xiphoid

In studies performed in the aim of finding the relation among muscle thickness and some demographic characteristics of healthy subjects, divergent results have been reported [20, 27, 29]; respecting obtained results from current study, it can be assumed that absence of subjects matching regarding food consumption might be a potential reason for mentioned discrepancies. Besides, post manipulative [26] post Pilate exercise [5] and post upper limb exercise [21] evaluation of TrA muscle thickness did show improvement in thickness and strength of muscles. It seems in none of these studies the subjects have been matched regarding emptiness or fullness of stomach.

The achieved results regarding differences in waist and BMI of each participant were assumed as other potential outcomes in this study. In this regard, it was found that waist circumference of all subjects increased significantly after food consumption and this finding was observed in both positions of waist measurement. This finding could be due to the same mechanism that affected the thickness of muscles (i.e. enlargement of stomach might lead to increase in waist of participants). Using independent *t* test we found that there is no significant correlation between increase in waist circumference (in both positions) and decrease in muscle thickness (in both positions and sides). It means that rate of increase of waist circumference in some subjects have been corresponded well with the rate of decrease in muscle thickness, however, in some other subjects, this relative coincidence cannot be found. This finding might be due to variations in muscular fitness levels of the subjects. In this regard, the muscle thickness of subjects with more thickened and thereby strengthened muscles might be affected less by food consumption; this could be because of resistance the muscles would present against any tension which can lead to more resistance of strengthened muscles against stomach enlargement and thereby less decrease in muscle thickness. Besides, variations in the participants abdominal fat thickness levels could also be considered as another reason for this finding; as more thickened abdominal fat layer any individual have, less relative increase in waist might be shown after food consumption. This might be because of probable less elastic features of fat in comparison to other soft tissues. Meanwhile, due to type of distribution of collected data for subjects, minute values were found as the variance of measurements for both differences of muscle thickness and waist circumferences. This issue can lead to underestimation of correlation we investigated for using bivariate Pearson correlation test.

As a limitation no female subject attended in this study. Also all measurements were performed in relaxed position while as it is advocated in previous studies, investigating the characteristics of contracted muscles (particularly in TrA) are also clinically important.

In different studies thickness of transabdominal muscles has been measured in different body positions such as spine and four point kneeling position [3, 6]. In our study, the measurements were all performed in supine crook-lying position and at the end of normal exhalation. It might be speculated that in other body positions, the levels of stomach fullness could affect the abdominal muscle thickness as well, thereby the quantity of this effect needs to be evaluated in future studies.

For further studies, it can be suggested to carry out well controlled studies in aim of comparison of muscle thickness changes as a result of food consumption in elite athletes (with strength transabdominal muscles) and in non athletes. Finding the rates of decrease in muscle thickness of patients with low back pain due to food consumption particularly in comparison to healthy subjects can also be recommended as further studies. The period in which the thicknesses of the lateral abdominal muscles return to the level of before food consumption also is needed to be investigated.

In conclusion, after food consumption the thickness of lateral abdominal muscles in both sides will decrease significantly. Therefore, in case of comparison between the values or ratios of transabdominal muscle thicknesses over the time, the effect of food consumption on muscle thickness might be assumed as a potential source of error. To minimize this error, it can be suggested that the time between food consumption and ultrasound measurements in different days should be consistent for each person.

Conflict of interest None.

References

1. Akuthota V, Nadler SF (2004) Core strengthening. Arch Phys Med Rehabil 85(3 Suppl 1):S86–S92
2. Bunce SM, Moore AP, Hough AD (2002) M-mode ultrasound: a reliable measure of transversus abdominis thickness? Clin Biomech (Bristol, Avon) 17(4):315–317
3. Critchley D (2002) Instructing pelvic floor contraction facilitates transversus abdominis thickness increase during low-abdominal hollowing. Physiother Res Int 7(2):65–75
4. Ehrman JK (2010) ACSM resource manual for exercise testing and prescription. Lippincott Williams & Wilkins, Philadelphia
5. Endleman I, Critchley DJ (2008) Transversus abdominis and obliquus internus activity during pilates exercises: measurement with ultrasound scanning. Arch Phys Med Rehabil 89(11): 2205–2212
6. Ferreira PH, Ferreira ML, Hodges PW (2004) Changes in recruitment of the abdominal muscles in people with low back pain: ultrasound measurement of muscle activity. Spine 29(22):2560–2566
7. Ferreira PH, Ferreira ML, Maher CG, Herbert RD, Refshauge K (2006) Specific stabilisation exercise for spinal and pelvic pain: a systematic review. Aust J Physiother 52(2):79–88
8. Henry SM, Westervelt KC (2005) The use of real-time ultrasound feedback in teaching abdominal hollowing exercises to healthy subjects. J Orthop Sports Phys Ther 35(6):338–345
9. Hicks GE, Fritz JM, Delitto A, McGill SM (2005) Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program. Arch Phys Med Rehabil 86(9):1753–1762
10. Hides J, Wilson S, Stanton W, McMahon S, Keto H, McMahon K et al (2006) An MRI investigation into the function of the transversus abdominis muscle during “drawing-in” of the abdominal wall. Spine 31(6):E175–E178
11. Hides JA, Miokovic T, Belavy DL, Stanton WR, Richardson CA (2007) Ultrasound imaging assessment of abdominal muscle function during drawing-in of the abdominal wall: an intrarater reliability study. J Orthop Sports Phys Ther 37(8):480–486
12. Hodges PW (1999) Is there a role for transversus abdominis in lumbo-pelvic stability? Man Ther 4(2):74–86
13. Hodges PW, Richardson CA (1997) Contraction of the abdominal muscles associated with movement of the lower limb. Phys Ther 77(2):132–144
14. 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
15. Hodges PW, Richardson CA (1996) Inefficient muscular stabilization of the lumbar spine associated with low back pain: a motor control evaluation of transversus abdominis. Spine 21(22):2640–2650
16. John EK, Beith ID (2007) Can activity within the external abdominal oblique be measured using real-time ultrasound imaging? Clin Biomech (Bristol, Avon) 22(9):972–979
17. Kermode F (2004) Benefits of utilising real-time ultrasound imaging in the rehabilitation of the lumbar spine stabilising muscles following low back injury in the elite athlete—a single case study. Phys Ther Sport 5(1):13–16
18. Kidd AW, Magee S, Richardson CA (2002) Reliability of real-time ultrasound for the assessment of transversus abdominis function. J Gravit Physiol 9(1):P131–P132
19. Mannion AF, Pulkovski N, Gubler D, Gorelick M, O’Riordan D, Loupas T et al (2008) Muscle thickness changes during abdominal hollowing: an assessment of between-day measurement error in controls and patients with chronic low back pain. Eur Spine J 17(4):494–501
20. Mannion AF, Pulkovski N, Toma V, Sprott H (2008) Abdominal muscle size and symmetry at rest and during abdominal hollowing exercises in healthy control subjects. J Anat 213(2): 173–182
21. McEvoy MP, Cowling AJ, Fulton IJ, Williams MT (2008) Transversus abdominis: changes in thickness during an incremental upper limb exercise test. Physiother Theory Pract 24(4): 265–273
22. McMeeken JM, Beith ID, Newham DJ, Milligan P, Critchley DJ (2004) The relationship between EMG and change in thickness of transversus abdominis. Clin Biomech (Bristol, Avon) 19(4): 337–342
23. Misuri G, Colagrande S, Gorini M, Iandelli I, Mancini M, Duranti R et al (1997) In vivo ultrasound assessment of respiratory function of abdominal muscles in normal subjects. Eur Respir J 10(12):2861–2867
24. O’Sullivan PB, Twomey LT, Allison GT (1997) Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis of spondylolisthesis. Spine 22(24):2959–2967
25. Rackwitz B, de Bie R, Limm H, von Garnier K, Ewert T, Stucki G (2006) Segmental stabilizing exercises and low back pain. What is the evidence? A systematic review of randomized controlled trials. Clin Rehabil 20(7):553–567
26. Raney NH, Teyhen DS, Childs JD (2007) Observed changes in lateral abdominal muscle thickness after spinal manipulation: a case series using rehabilitative ultrasound imaging. J Orthop Sports Phys Ther 37(8):472–479
27. Rankin G, Stokes M, Newham DJ (2006) Abdominal muscle size and symmetry in normal subjects. Muscle Nerve 34(3):320–326
28. Saal JA (1990) Dynamic muscular stabilization in the nonoperative treatment of lumbar pain syndromes. Orthop Rev 19(8): 691–700
29. Springer BA, Mielcarek BJ, Nesfield TK, Teyhen DS (2006) Relationships among lateral abdominal muscles, gender, body mass index, and hand dominance. J Orthop Sports Phys Ther 36(5):289–297
30. Teyhen DS, Miltenberger CE, Deiters HM, Del Toro YM, Pulliam JN, Childs JD et al (2005) The use of ultrasound imaging of the abdominal drawing-in maneuver in subjects with low back pain. J Orthop Sports Phys Ther 35(6):346–355
31. Whittaker J (2004) Abdominal ultrasound imaging of pelvic floor muscle function in individuals with low back pain. J Man Manip Ther 12(1):44–49
32. Whittaker Jl (2007) Ultrasound imaging for rehabilitation of the lumbopelvic region, a clinical approach. Elsevier, Philadelphia