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Intrarater Reliability of Rehabilitative Ultrasound Imaging of the Gluteus Maximus, Lumbar Multifidus and Transversus Abdominis Muscles in Healthy Subjects

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Abstract: Objectives: To evaluate intrarater reliability of Rehabilitative Ultrasound Imaging in obtaining thickness measurements of the gluteus maximus , Transversus abdominis and lumbar multifidus muscles at rest and during contractions.
Design: Single-group repeated-measures reliability study.
Setting: University and orthopedic physical therapy clinic.
Participants: healthy subjects (N = 5).
Interventions: Not applicable.
Main Outcome Measures: Thickness measurements of the Gmax, TrA and lumbar MF muscles at rest and during contractions were obtained by using RUSI during 2 sessions within a day. Percent thickness change was calculated as thickness contracted – thickness rest / thickness rest × 100.
Intraclass correlation coefficients (ICC) were used to estimate reliability.
Results: Intraexaminer reliability point estimates (ICC) ranged from 0.57 to 0.96. Reliability estimates were lower for percent thickness change measures than the corresponding single thickness measures for all conditions.
Conclusions: RUSI Thickness and thickness percent change measurement of Gmax, MF and Tra is adequately reliable.
Key words: Gluteus maximus, Transversus abdominis, Multifidus, Rehabilitative Ultrasound Imaging, Reliability.

Introduction

The main purpose of core strengthening is focused on muscular stabilization of the abdominal, paraspinal, and gluteal muscles to induce more stability and control for sporting activity (1). Hip dysfunction (e.g. , weakness and limited range of motion) is one factor that has been related with low back and frequently lower extremity pathologies (2). The trunk extensors and flexors muscles imbalance is rebounded to the vertebral column stabilization insufficienty that is the strong indication of the etiology of low back pain (3). Low back pain is one of the most common problems of the modern society, including to high expenses in the public health area.

Epidemiological study reported that LBP often occurs in physical work in United states with less than 45 years of age (4). Currently, the main aim of exercises in the low back pain rehabilitation and prevention programs was the strengthening of the muscles of trunk extensors and flexors (5). Hip extensors (gluteus maximus) stabilize the pelvis during trunk rotation and movement of the center of gravity. Several studies estimate hip extensor muscle impairment in subjects with LBP (6). The gluteus maximus (Gmax) contains 16% of the total cross-sectional area (7). Function of hip musculature in transferring forces from the lower extremity upward to the spine during upright activities is very remarkable as it's deficit may exacerbate LBP (8).

The transversus abdominis and lumbar multifidus muscles have the significant role in spine stabilization in subjects with LBP (9,10,11). The ADIM has been described as the best task to activate the TrA and is an important exercise in the stabilization exercise program for subjects with LBP (12).

The ADIM ,preferentially is used to activate the TrA muscle more than another superficial lateral abdominal muscles and is an important motor control exercise to contract the TrA muscle (13).

The subject draws the abdominal toward the spine. In ADIM , the main goal is only contraction of TrA (14).

The validity of RUSI for measuring of TrA and MF muscle in comparison with magnetic resonance imaging with fine wire electromyography has been estimated (9,15-17). Whatever the number of examiners that measure thickness of TrA and MF were more,the measurements of the thickness with RUSI is more reliable (18). The studies of researchers showed that TrA thickness measurement of ultrasound imaging in both of healthy subject and low back patients are reliable (19_24). Gnat & et al indicated that in healthy trained volunteers for assessment of intra and interrater reliability of RUSI, it is nessessary two repeations to measure of TrA thickness and three repeations for TrA thickness change ,at least (25). Keisel et al conducted that the results of intra reliability of TrA thickness change measurements in 8 healthy subjects aren't clear (ICC of 0.85). (16). RUSI is a non invasive method that it is used for assessing of morphology of muscles progressively in rehabilitation (26). Also, Nabavi et al demonstrated that RUSI as a noninvasive tool is applied in measurement of muscle thickness reliability (27). In some subjects thickness change of MF is very small or it maybe haven't any thickness change in contraction, that is proposed the diagnosis of this impairment with RUSI (28). Hosseinifar et al used RUSI to measure the MF muscles thickness and CSAs as a reliable instrument in healthy subjects (29). The change of muscle thickness is a most common method in assessment of muscle activations (30).

There is a proximate relation between Muscle thickness change and simultaneous EMG recording from the TrA muscle and lumbar MF muscle in normal subjects (31,16). The reliability of RUSI measurements must be detected for application of it in diagnosis and rehabilitation. However there are many studies about the reliability of RUSI measures of the TrA (32_34) and lumbar multifidus muscles (10 ,16 , 35 _37), there isn't any study about thickness and thickness change measurement of gluteus maximus with RUSI. It's reason maybe difficult measurement and assessment of thickness of gluteus maximus in contraction, because gluteus maximus is the largest muscle of the body. The Researchers has shown that contraction during the early phase of the lift and pelvic stability has important role for a safe and effective movement (38). Weakness of

Gmax muscle can disturb the gait cycle and affect the hip and distal joints during gait (38). The conditions such as knee amputations , low back pain , ankle sprains and another associated defects can alter the function and properties of gluteus maximus (38). Gluteus maximus strengthening often removes Dysfunctions of lumbar spine (38).

The purpose of the present study was to evaluate intrarater reliability of Rehabilitative Ultrasound Imaging in obtaining thickness measurements of the gluteus maximus, TrA and lumbar multifidus muscles at rest and during contractions between 2 sessions (within a day) in healthy subjects.

The secondary purpose was to determine whether differences in percent change in the muscles thickness exist.

List of Abbreviations

Tra	transverses abdominis
MF	multifidus
Gmax	gluteus maximus
LBP	low back pain
RUSI	rehabilitative ultrasound imaging
ADIM	abdominal drawing-in maneuver
CI	confidence interval
ICC	intraclass correlation coefficient

METHODS

Participants

Five healthy subjects aged 20 to 45 were recruited for this study from the students and members of the Rehabilitative college of Medical sciences of University of Zahedan. Inclusion criteria to selecting healthy participants for this study were only those who had not experienced low back pain in the previous six months, had no neurologic disease and had not received any surgical interventions were selected (39).

Participantss signed written informed consent forms. This study approved by the Sport Medicine Science Committee's kish International Campus of Tehran University.

Procedures

This study was single-group repeated-measures design in which all of data were collected in two session of measurement. After providing consent, participants completed self- report measures including demographic/historic information. The demographic characteristics of participants are shown in table 1. We provided subjects with educational information about the abdominal and back extensor musculatures and a standardized overview of the testing procedures.

Images of the TrA , lumbar multifidus and G max muscles were acquired with ultrasound machine in B-mode (ESAOTE S.p.A, My Lab X Vision 50, Italy). we used a 70 mm, 7.5 MHz curvilinear array to measure the thickness of Gmax and MF muscles and 70 mm, 12 MHz linear array for Tra muscle.

Image acquisition for each muscle in two condition of rest and maximal contraction bilaterally (right and left muscles) was performed 3 times by one examiner. All of data were collected within one day, in two session with 30 minutes interval between the sessions. A total of 72 images were taken of each participant (36 during session 1 and 36 during session 2) to be able to calculate average of 3 measurements of muscle thickness in rest condition and 3 measurements in contraction condition were assessed in per session and to calculate all within a day intraexaminer comparisons for all muscle conditions (16, 40,41). The examiner was blinded to her own previous measurements.

Transversus abdominis :

The center of the transducer of ultrasound imaging was placed in a transverse plane just superior to the iliac crest, in line with the mid-axillary line (41). All images of Tra muscle were collected in the end of normal exhalation to control for the influence of respiration (18).

To measure of resting thickness of Tra muscle, the subjects lying supine in a hook lying position, took a relaxed breath in and out (18). Palpation of the muscle is possible just distal to the anterior superior iliac spine (ASIS) and lateral to the rectus abdominis (14).

We used the ADIM in this study to assess changes in muscle thickness associated with a volitional activation of the TrA muscle (18). In contraction position We requested the subject " hollow the abdominal region" or “draw the belly button toward the spine” and hold contraction 10 second. Then the image was recorded in the end of exhalation (42).

We taught the subject using demonstration, verbal cues, and tactile facilitation and Explained that the muscle encircles the trunk; and when activated, the waistline draws inward . Instruct the subject to breathe in, breathe out, then gently draw the belly button in toward the spine to hollow out the abdominal region (14).

Lumbar multifidus :

transducer was placed longitudinally along the spine with the midpoint over the L5 spinous process . It was moved laterally and angled slightly medially to visible the facet joint (16,29).

To measuring of thickness of resting MF muscle, the subjects lying prone position with a pillow under the abdomen and took a relaxed breath in and out (18).

In contraction position the subject kept a weight of 0.5 kg in hand of contralateral of measurement with the elbow in right angle and the arm near the ear. We requested the subject " elevate the contralateral arm "and "hold contraction 10 second" (42).

Then the image was recorded in the end of exhalation (14,43).

Gluteus maximus :

The midpoint of transducer of ultrasound imaging was placed on the ischial tuberosity.

The center of the transducer was in retribution of post superior iliac spine (PSIS) of iliac crest (44,45) (fig 1).

To measuring of thickness of resting Gmax muscle, the subjects lying prone position with the hands in the front of the head, relaxed the muscle completely.

In contraction position the subject was lying prone with the knee of the side of measurement in flexion 90 ^{0} . A belt was secured around the distal of femur during muscle contraction to ensure standardization of resistance. We requested the subject " Extend the hip " or "elavate in contrast of the belt" and "hold contraction 10 second". Then the image was recorded (44,45).

Data Analysis

The dependent measures for the Gmax, TrA and lumbar multifidus muscles were resting thickness, contracted thickness, and thickness percent change. thickness Percent change was calculated for the Gmax , TrA and lumbar multifidus muscles by using the following equation: [thickness contracted–thickness rest / thickness rest × 100] (41).

ICCs with 95% CIs were calculated to assess intraexaminer reliability within one day. All statistical analyses were conducted using SPSS 20.0.

Results were presented as mean values , standard deviation (SD) and the standard error of measurement (SEM). Criterion of significance set as p<0.05. Kolmogrov-Smirnov test used to describe normal distribution. Pearson's correlation coefficient test used to determine intra-rater reliability of variables. The result of kolmogrov-smirnov test showed that all of variables include mean thickness of Gmax, Tra and MF muscles during rest and contraction and thickness Percent change had normal distribution (p> 0.05).

Table 1: Demographic Characteristics of Participants (N=5)

		Range
Gender	[(Male:4) (Female:1)]	
Age (y)	27 ± 9.51	22 - 44
Height (m)	1.71 ± 0.085	1.58 - 1.81
Weight (kg)	65.70 ± 14.59	52-83
BMI (kg/m^2)	22.28 ± 3.90	17.15 – 26.75

NOTE: Values are Mean ± Standard Deviation
BMI = Body . Mass . Index

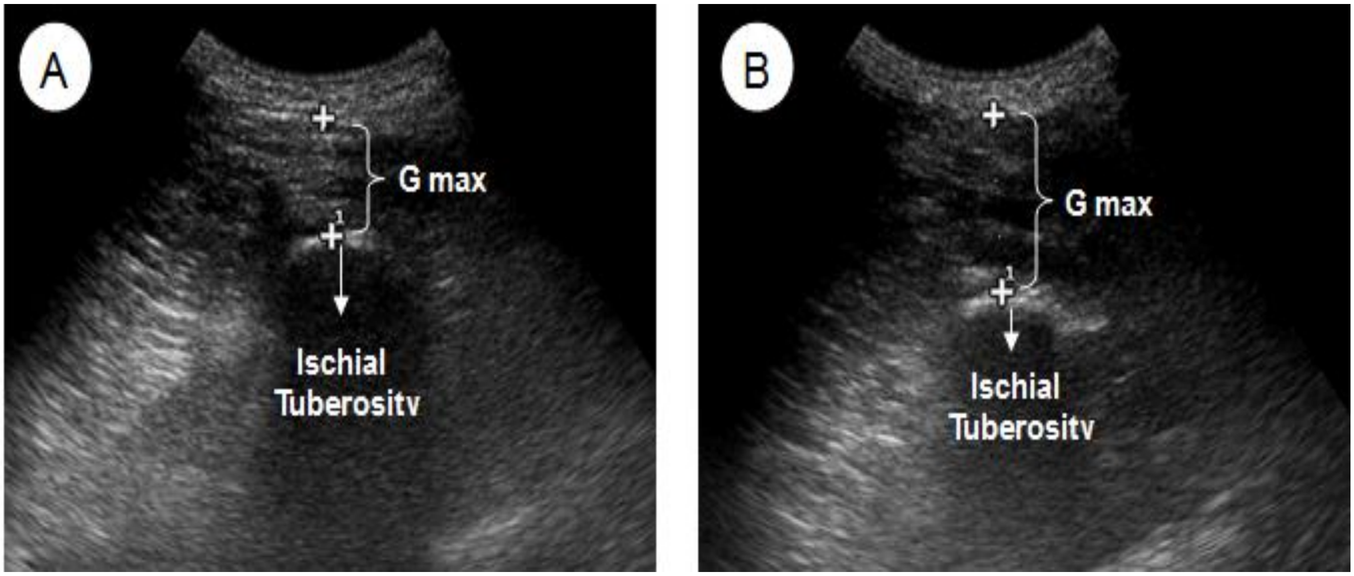

Fig 1. Ultrasound images of Gmax (A) during rest and (B) during contraction.

RESULTS

The Demographic and baseline characteristics of the participants are provided in table 1.

Means and SDs, Reliability coefficients with corresponding 95% CIs (Lower bound and Upper bound) and standard error of measurements are presented in table 2 for resting muscles thickness of intraexaminer estimates and in table 3 for contraction muscles thickness.

Depending on the muscle (Gmax, TrA vs MF), side of body (left vs right) and muscle condition (rest vs contraction), intraexaminer reliability point estimates ($ICC_{3,k}$) of the first thickness measurements ranged from 0.75 to 0.97 and the second thickness measurements ranged from 0.57 to 0.96 in within a day comparisons (see table 2 & 3).

The percent changes in muscle thickness of Gmax, Tra and MF muscles, Reliability coefficients with corresponding 95% CIs (Lower bound and Upper bound) and standard error of measurements are noted in table 4 for the first and second session measurements of intraexaminer estimates .

Measurements of muscle thickness and percent change of thickness was presented good to excellent reliability.

Table 2 : Intrarater Reliability Values of Resting Muscle Thickness

				95% CI			
Muscle	Rest 1	Rest 2	$ICC_{3,k}$	Lower Bound	Upper Bound	SEM1	SEM2
Right Tra	3.25 ± 0.39*	3.14 ± 0.52	0.775	-1.164	0.977	0.17	0.236
Left Tra	3.45 ± 0.90	3.25 ± 0.71	0.941	0.431	0.994	0.40	0.32
Right MF	25.94 ± 3.97	28.63 ± 5.93	0.942	0.439	0.994	1.77	2.65
Left MF	27.21 ± 3.39	28.42 ± 6.02	0.750	-1.404	0.974	1.51	2.69
Right Gmax	27.04 ± 13.79	23.68 ± 7.53	0.892	-0.035	0.989	6.16	3.36
Left Gmax	27.65 ± 12.44	25.39 ± 9.96	0.977	0.779	0.998	5.56	4.45

NOTE: *Values are Mean ± Standard Deviation.
Rest1 = First session measurement of resting muscle thickness
Rest2 = Second session measurement of resting muscle thickness
SEM1 = Standard Error of Mean of First session measurement
SEM2 = Standard Error of Mean of Second session measurement

Table 3 : Intrarater Reliability Values of Contracted Muscle Thickness

Muscle	Cont 1	Cont 2	$ICC_{3,k}$	95% CI Lower Bound	95% CI Upper Bound	SEM1	SEM2
Right Tra	5.05 ± 1.34*	5.25 ± 1.73	0.954	0.556	0.995	0.59	0.77
Left Tra	5.25 ± 1.11	4.87 ± 0.81	0.935	0. 372	0.993	0.49	0.36
Right MF	34.34 ± 4.33	35.50 ± 5.28	0.953	0.551	0.995	1.93	2.36
Left MF	35.68 ± 2.25	35.78 ± 7.38	0. 570	-3.127	0.995	1.00	3.30
Right Gmax	36.39 ± 12.59	32.768 ± 6.55	0.890	-0.061	0.989	5.63	2.93
Left Gmax	37.62 ± 11.78	36.69 ± 11.40	0.967	0.683	0.997	5.26	5.09

NOTE: *Values are Mean ± Standard Deviation.
Rest1 = First session measurement of contracting muscle thickness
Rest2 = Second session measurement of contracting muscle thickness
SEM1 = Standard Error of Mean of First session measurement
SEM2 = Standard Error of Mean of Second session measurement

Table 4 : Intrarater Reliability Values of Muscle Percent Thickness Change

Muscle	PTC 1	PTC 2	$ICC_{3,k}$	95% CI Lower Bound	95% CI Upper Bound	SEM1	SEM2
Right Tra	54.2 ± 31.18*	64.2 ± 28.87	0.843	-0.512	0.984	13.94	12.91
Left Tra	57.80 ± 36.14	52.20 ± 30.61	0.823	-0.705	0.982	16.16	13.69
Right MF	32.40 ± 5.02	24.40 ± 8.84	0.880	-0.148	0.988	2.24	3.95
Left MF	31.60 ± 9.23	25.40 ± 3.04	0.108	-7.567	0.907	4.13	1.36
Right Gmax	41.96 ± 28.08	42.60 ± 24.48	0.880	-0.148	0.988	12.55	10.94
Left Gmax	40.40 ± 22.23	47.80 ± 23.00	0.927	0.296	0.992	9.94	10.28

NOTE: *Values are Mean ± Standard Deviation.
PTC1 = Muscle percent thickness change of first session measurement
PTC2 = Muscle percent thickness change of second session measurement
SEM1 = Standard Error of Mean of First session measurement
SEM2 = Standard Error of Mean of Second session measurement

DISCUSSION

This study evaluated the intraexaminer reliability in obtaining RUSI thickness measurements of the Gmax, TrA and lumbar MF muscles at rest and during maximal contraction in a single session in healthy subjects. Intraexaminer comparisons of thickness measures generally showed excellent reliability with only the ICC point estimate of left MF muscle during contraction reliability below 0.70. These findings are consistent with previous studies that investigated asymptomatic subjects (Kiesel, Ainscough, Hides, Springer, Van). Our results supports our primary hypothesis that RUSI measurements are completely reliable for research and clinical use.

In this study for left MF muscle thickness measures during rest (ICC= 0.75) and contraction (ICC= 0.57) were lowest intraexaminer reliability.

The measurement of left MF muscle contraction thickness was the first task that we requested from the participants to do, this was maybe the reason of lowest reliability. The difference of ICC measure from rest to contraction conditions for left MF is very high (0.75 to 0.57), but this difference of ICC for right MF is very low (0.94 to 0.95). Therefore the effect of learning of contraction about this muscle may associate with lowest intraexaminer reliability. Another reasons for this lowest intraexaminer reliability could be participiant's anxiety or stress, motivation, skill, environmental conditions and instruction from examiner for first task.

The highest SEM measure was presented for right Gmax muscle in rest (SEM=6.16) and contraction (SEM=5.63), it maybe related to lower dominance of the examiner on the right side of the subjects and difficulty of measurement of Gmax muscle thickness of contraction whereas there wasn't literature of any researcher.

However we demonstrated that in healthy subjects Gmax, Tra and MF thickness at rest and contraction , as same as Gmax, Tra and MF percent thickness change were relatively stable and measurable parameters. Our results is in agreement with the studies about percent thickness change as Teyhen 2009, Koppenhaver 2009, Gnat 2012.

Our ICC measures showed intrarater reliability of two sessions measurement was excellent. Though to this time, there wasnot any study of the reliability of RUSI in measurement of Gmax thickness and percent thickness change, this study for first time used RUSI. Wherease there was the difficulties and limitations for measurement of Gmax, reliability of RUSI for contraction thickness and percent thickness change was showed very high (ICC=0.97, ICC=0.92).

Our results, in case of muscle thickness and percent thickness change, with one examiner, in one day, two sessions and in healthy subjects proved to have good and excellent reliability for Gmax,Tra and MF muscles; but we recommend this study with two or three repeated measurements , several examiners and in low back pain subjects for assessment of reliability, because in low back pain subjects the percent change of muscle thickness isn't the same as healthy subjects.

Study Limitations

There are several limitations of this study that should be considered. Our sample size was low which will reduce the power of the results. The examiner was one person that this may allow for some adaptations to take place. Additionally, our sample included healthy subjects without symptoms over the gluteal and low back pain,therefore our results maynot be generalizable to patients. We propose future researchers should assess in subjects with low back pain and gluteal imbalance by two or several examiners.

CONCLUSION

RUSI Thickness and percent thickness change measurements of Gmax, MF and Tra muscles maybe adequately reliable for clinical use of RUSI and patient management designs of lumbar stabilization exercises.

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