Intra-rater and Inter-rater Reliability of Rehabilitative Ultrasound Imaging of Multifidus Muscle Thickness, Cross Section Area and Bladder Wall Displacement in Multiparous Women

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ABSTRACT

Background. Pregnancy related changes can affect the role of multifidus (MF) and pelvic floor muscles (PFM) in the spinal stability and load transfer mechanism. Rehabilitative ultrasound imaging (RUSI) is a powerful tool that provides unavailable information about the myofascial system.

Objective. This study aimed to determine intra-rater and inter-rater reliability of ultrasound imaging in the measurement of MF thickness, cross section area (CSA) and bladder wall displacement as a reflection of PFM action in multiparous healthy women.

Design. A single-group repeated measures reliability study was conducted.

Methods. Ten healthy multiparous women (mean age=35.36 SD=7.71) participated in this study. Bladder wall displacement in the transverse plan through trans-abdominal (TA) approach, MF muscle thickness at rest and during contralateral arm lift (CAL) and MF muscle CSA were obtained by using RUSI. Intraclass correlation coefficient (ICC) with 95% confidence interval (CI), standard error of measurement (SEM) and minimal detectable change (MDC) were calculated for all variables.

Results: ICC values with 95% CI showed that bladder wall displacement has high intra-rater (ICC: 0.91-0.99) and high inter-rater reliability (ICC: 0.93-0.96), MF muscle thickness has good to high intra-rater (ICC: ranged from 0.85 to 0.98) and good to high inter-rater reliability (ICC ranged from 0.73 to 0.98) and MF muscle CSA has good to high intra-rater (ICC: 0.78-0.86) and fair inter-rater reliability (ICC: 0.54-0.61). SEMs ranged from 0.69 to 3.98 mm and MDCs ranged from 1.92 to 11.03 mm.

Limitation. The number of delivery was not equal between subjects.

Conclusions. RUSI is a reliable method in measurement of bladder wall displacement, MF muscle thickness and CSA in multiparous women.

Key Words. Pelvic Floor Muscle, Multifoods Muscle, Ultrasonography, Reliability.
INTRODUCTION

Pregnancy is a specific experience that leads to several physical changes in women’s body and influence most aspects of their lives. Pregnancy and delivery can cause serious complications such as urinary incontinence, pelvic organ prolapse, faecal incontinence, and low back pain (LBP) that have negative effects on women's sexual, physical, social and psychological health.

Based on Wu et al. systematic review, prevalence of pregnancy related low back pain (PLBP) during pregnancy and postpartum is 45% and 25% respectively. LBP is one of the most current causes of disability and sick leave after delivery. A variety of approaches have been proposed to explain the development of PLBP but the exact mechanism remains unknown. The results of all of these hypothesis advocates of a multifactorial condition during pregnancy and postpartum that frequently associated with biomechanical, hormonal and vascular changes.

The resultant impact of these changes is dynamic instability of lumbopelvic region and altered function of the local stabilizing system. Abnormal load transfer in the lumbopelvic region has been considered as one possible explanation to lumbopelvic pain. The local stabilizing muscles, i.e. the transversely oriented abdominal, diaphragm, the lumbar MF and the PFM Play an important role in load transfer in the lumbopelvic region. Optimal function of these muscles provides anticipatory intersegment stiffness of the joints of the lumbar spine and pelvic.

The MF muscles as a part of the local stabilizing system have been purported to be important in spinal stability and have been shown to have functional deficits in individuals with LBP. It is seen that MF Muscles inhibited and reduced in size in the presence of LBP.

The PFM performs varied functions such as lumbopelvic stabilization, postural adjustment and contribute to the locking mechanism of the urethra and anus. Many women may experience pelvic dysfunction at some stage in their lives and Vaginal delivery due to exerting significant mechanical stress on the muscular, ligamentous and neurological structures of the pelvic floor have been established as one of the most important risk factors for pelvic dysfunction. In addition, Connection between LBP and pelvic floor dysfunction has been suggested.

So, the use of a reliable diagnostic and guiding tool seems necessary to evaluate pregnancy related changes. Rehabilitative ultrasound imaging (RUSI) is a powerful tool as its dynamic, real-time nature. RUSI is the most cost effective, feasible and non-invasive method for tissue measurement and allows clinicians to gather previously unavailable information about the status of myofascial system morphology (length, depth, diameter, CSA, volume), provide unparalleled visual feedback to their patients and monitor the effectiveness of their treatment more objectively.

Several researchers investigated the reliability of RUSI in the measurement of MF muscle thickness, CSA and bladder base displacement as a reflection of PFM action in symptomatic and asymptomatic subjects. To our knowledge, no study determines the reliability of RUSI in the measurement of these variables in women who had at least one pregnancy. So, the aim of this study was to evaluate intra-rater and inter-rater reliability of RUSI for measurement of bladder wall displacement at rest and during PFM contraction, MF muscle thickness at Si level at rest and with contralateral arm lift (CAL) and MF muscle CSA at rest in healthy multiparous women.

MATERIALS AND METHODS

This single-group repeated-measures reliability study was performed at physiotherapy clinic, Zahedan University of medical science, between November and December 2015. Women who have experienced at least one pregnancy were invited through local advertising. They excluded from the study if they had ongoing pregnancy, chronic LBP or pelvic pain, history of spinal or pelvic surgery and neoplasm.
Eligible women enrolled in study at least 3 months postpartum to ensure hormonal effects of pregnancy is gone\textsuperscript{36}. All participants signed the informed consent form. Demographic data, including age, weight, height and body mass index were collected. Ultrasonography measurement was performed twice with an interval of 48 hours by two operators in each session.

Two physical therapist performed independent USI with random determination of the examiner and examination order. Both examiners received USI training before the beginning of the study. To measure the CSA and the thickness of MF muscles and bladder wall displacement, the B-mode ultrasound apparatus (ESAOTE s.p.A, My Lab X vision 50, Italy) with 3.5-7.5 MHz curvilinear probe was used. The MF muscle thickness at level S\textsubscript{1} at rest and during CAL, MF muscle CSA at rest and during PFM contraction were measured through RUSI based on following procedures:

1. **Ultrasound recording of the bladder wall displacement (TA approach)**

   Trans-abdominal (TA) ultrasound imaging was used to assess lifting aspect of a PFM contraction by observation of movement of the bladder wall as a marker for PFM activity during voluntary PFM contraction\textsuperscript{35, 37, 38}. To obtain a clear image of the poster inferior bladder wall, standardized bladder filling protocol accomplished. For this purpose asked the subjects to void 1 hour before testing, then to drink 450-500 ml of water and to not void until after test. In addition correct PFM contraction were taught to the subjects\textsuperscript{39, 40}. Subjects were tested in a crook-lying supine position, hips and knees 60° flexed and head supported with pillow and lumbar spine in neutral position. For transverse plan trans-abdominal imaging 3.5 MHz curvilinear transducer was placed in a transverse orientation, across the midline of the abdomen, immediately superior to the pubic symphysis.

   The marker on the transducer was oriented toward right side of supine subject. Then asked the subjects to perform maximal PFM contraction while breathing normally and point of greatest observed displacement throughout the movement was selected as a reference and bladder diameter at rest and at the end of each contraction was measured in millimeter\textsuperscript{41}.

2. **Ultrasound recording of the MF muscles thickness**

   Measurement of MF muscle thickness was performed in resting position and during contralateral arm lift in both sides through 7.5 MHz curvilinear probe\textsuperscript{34}. Subjects were tested in prone position with a pillow under the abdomen. The transducer was placed longitudinally above the spinous process of L\textsubscript{5}, S\textsubscript{1} vertebrae. Then it was moved to visible the facet joint between the two lumbar vertebrae.

   This point is located directly on MF muscles. For measurement of MF thickness at rest both arms were beside the trunk and during task instructed to subject to elevate her arm with elbow in full extension and glenohumeral joint in 120 abduction. Linear measurements were conducted from the tip of the target facet joint to the inside edge of the superior border of the MF muscles\textsuperscript{31}.

3. **Ultrasound recordings of the MF muscles CSAs**

   MF muscles cross section areas were measured at S\textsubscript{1} vertebral level. Subjects were tested in prone position with a pillow under the abdomen and asked the subjects to relax the para-vertebral musculature. After relaxation, the probe placed transversely over the S\textsubscript{1}spinous process so that lamina and MF muscles can be seen on both sides of the spine.

   Vertebral lamina was used as a landmark to identify deep border of the MF muscles. To assess the CSAs of the MF muscles, we need to border MF muscles superiorly by the thoracolumbar fascia, medially through the spinous process of S1 vertebrae, and laterally by the fascia between MF and longissimus group muscles\textsuperscript{33}. 
**Statistical analysis**

Statistical analysis was performed using SPSS 22 (IBM SPSS Statistic22.Ink). Demographic characteristics were given as mean values with standard deviation (mean (SD)). The Kolmogrov-Smirnov test was used to describe normal distribution. Intraclass correlation coefficient (ICC) with 95% confidence interval (CI) was used to estimate intra-rater and inter-rater reliability. For the purpose of interpretation ICC ≥ 0.75 was considered excellent, 0.40-0.75 was fair to good and 0.0-0.40 was poor. Standard error of measurement (SEM) and minimal detectable change (MDC) was calculated. $[SEM= SD.\sqrt{1-ICC}]$, $[MDD= SEM.\sqrt{2.1.96}]$

**RESULT**

A total of 10 multiparous women, according to inclusion and exclusion criteria were enrolled in this study. Demographic data summarized in table 1. All variables include bladder diameter at rest and during PFM contraction, MF muscle thickness at rest and with CAL and MF muscle CSA at rest on both sides had a normal distribution ($P>0.05$). These finding showed that RUSI in measurement of bladder wall displacement had high intra-rater reliability (ICC: 0.99 and 0.91 for rest and PFM contraction respectively) and high inter-rater reliability (ICC: 0.96 and 0.93 for rest and PFM contraction respectively). ICC values with 95% CI for MF muscles thickness showed high intra-rater reliability (ICC: 0.98 and 0.88 for right and left side respectively) and high inter-rater reliability (ICC: 0.83 and 0.90 for right and left respectively) at rest. So, these values for contracted thickness measurement showed high intra-rater (ICC: 0.85 and 0.91 for right and left side respectively) and high inter-rater reliability (ICC: 0.73 and 0.98 for right and left respectively).

Intra-rater reliability for MF muscle CSA was good to high (ICC: 0.78 and 0.86 for right and left respectively) and inter-rater reliability was fair (ICC: 0.54 and 0.61 for right and left respectively). SEM values were in normal range for all variables) and ranged from 0.69 to 3.98 mm. Also, MDC values were calculated to determine when a "true change" has occurred pre-to post-treatment and ranged from 1.92 to 11.03 mm (Table 2 and 3).

**DISCUSSION**

The results of this study showed that RUSI is a reliable method for measurement of the MF muscle thickness, CSA and bladder wall displacement as a reflection of the PFM action in healthy multiparous women. The ICC values indicated that the TA approach has high reliability, both between day and within a day, in measurement of bladder wall displacement as a marker for PFM activity during voluntary PFM contraction. These findings are consistent with previous studies that investigated healthy subject and healthy no pregnant women. The ICC values of the present study (ICC: 0.91-0.99) were higher than Sherburn et al. (2005) (ICC: 0.81-0.89) and were similar to Hosseinifar et al. (2015) (ICC: 0.96-0.95). Sherburn et al. (2005) investigated both within-day inter-rater (ICC: 0.86-0.88) and between-day intra-rater (ICC: 0.81-0.89) reliability of bladder contraction in sagittal and transverse planes. SEM values of this study were lower than of present study due to different method of measurement.

Hosseinifar et al. examined intra-rater reliability of bladder diameter both at rest and PFM contraction (ICC: 0.96 and 0.95 respectively) in the transverse plane with a similar measurement method. However SEM values of the present study were lower. In addition, this study showed that RUSI is a reliable method, both inter-rater and intra-rater, in measurement of MF muscle thickness and CSA at S1 level in asymptomatic multiparous women. In this study rest thickness of MF muscles at the L5-S1 level had high intra-rater reliability (ICC: 0.88-0.98 for Lt and Rt side respectively) and high inter-rater reliability (ICC: 0.83-0.90 for Rt and Lt respectively). Also, ICCs values for contraction thickness of MF muscle indicated high intra-rater reliability (ICC: 0.85-0.91 for Rt and Lt).
respectively) and good to high inter-rater reliability (ICC: 0.73-0.98 for Rt and Lt respectively). These findings confirmed the results of previous studies that evaluated MF muscle thickness at level L2-L3\textsuperscript{31}, L4-L5\textsuperscript{31, 32} in healthy subjects and at level L4-L5 in patients with nonspecific LBP\textsuperscript{23, 30}.

These studies demonstrated both within day inter-rater and between day intra-rater reliability of RUSI for MF muscle thickness. Wall work et al. (2007) evaluated intra and inter-rater reliability of rest thickness measurements of the MF muscles at two levels (L2-L3, L4-L5) in healthy subjects. They found intra-rater ICCs ranged from 0.89-0.94 at L2-L3 level and 0.88-0.95 at L4-L5 level. Also, they showed that when used of average of 3 measures ICCs values improved and SEM values decreased\textsuperscript{31}.

Our results were consistent with their finding when they used of single measure. However In the present study, we investigated MF muscle thickness at rest and contraction on both sides at L5-S1 level. Despite high inter and intra-rater reliability of RUSI in the measurement of MF muscle thickness and bladder diameter in the present study, ICC values for MF muscle CSA at level S\textsubscript{1} was good to high for between day intra-rater reliability (ICC: 0.78 – 0.86) and fair to good for within a day inter-rater reliability (ICC: 0.54-0.61). While, similar studies have shown excellent reliability of RUSI in the evaluation of MF muscle CSA at level L4-L5 in healthy subjects (intra-rater ICC: 0.75 and 0.91 for right and left side respectively)\textsuperscript{34} and in patients with chronic low back pain (ICC ≥ 0.93 on pain side and pain free side at rest and during two PNF patterns)\textsuperscript{33}. This disagreement may be was due to more BMI of our subjects in comparison with other studies (BMI: 24.97±2.55 Vs 21.1±2.8). Also seems that this difference is due to level of measurement in present study. Other studies were measured MF muscle CSA at level L4-L5 that bony landmarks is clear and MF muscle mass is well measurable while present study has been done in L5-S1 level.

Dr. Hosseinfar and Zahra Teymuri provided concept/idea/research design. Dr. Hosseinfar and Zahra Teymuri provided writing. Dr. Hosseinfar and Zahra Teymuri provided data collection. Dr. Hosseinfar, Dr. Ansari moghaddam and Zahra Teymuri provided data analysis. Dr. Hosseinfar, Dr. Ghiasi and Zahra Teymuri provided project management. Dr. Hosseinfar, Dr. Akbari and Zahra Teymuri provide study participants. Dr. Hosseinfar, Ansari moghaddam, Dr. Ghiasi and Dr. Asgari provided consultation (including review of manuscript before submission)

**Table 1. Demographic Characteristics**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Mean(SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>35.36 (7.71)</td>
<td>23-48</td>
</tr>
<tr>
<td>Weight</td>
<td>62.18 (4.02)</td>
<td>56-69</td>
</tr>
<tr>
<td>Height</td>
<td>158.0 (6.18)</td>
<td>149-156</td>
</tr>
<tr>
<td>BMI</td>
<td>24.97 (2.55)</td>
<td>22.43-31.07</td>
</tr>
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</table>

SD: standard deviation
BMI: Body Mass Index

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Session 1</th>
<th>ICC (95% CI)</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean(SD)</td>
<td>SEM</td>
<td>MDC</td>
</tr>
<tr>
<td>Bladder diameter (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest</td>
<td>66.01(14.81)</td>
<td>1.48</td>
<td>4.10</td>
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<tr>
<td>Contraction</td>
<td>56.42(12.78)</td>
<td>3.83</td>
<td>10.61</td>
</tr>
<tr>
<td>MF Thickness (mm)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Rest Rt</td>
<td>21.44(6.30)</td>
<td>0.89</td>
<td>2.46</td>
</tr>
<tr>
<td>Rest Lt</td>
<td>23.54(6.14)</td>
<td>2.12</td>
<td>5.89</td>
</tr>
</tbody>
</table>

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**Table 2. Intra-rater reliability of Examiner 1**

Values are Mean (Standard Deviation)

<table>
<thead>
<tr>
<th>Session</th>
<th>Mean(SD)</th>
<th>SEM</th>
<th>MDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rt</td>
<td>25.52(6.79)</td>
<td>2.62</td>
<td>7.28</td>
</tr>
<tr>
<td>Lt</td>
<td>25.67(6.32)</td>
<td>1.89</td>
<td>5.25</td>
</tr>
<tr>
<td>contraction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rt</td>
<td>6.56(1.47)</td>
<td>0.58</td>
<td>1.63</td>
</tr>
<tr>
<td>Lt</td>
<td>5.83(1.32)</td>
<td>0.78</td>
<td>2.16</td>
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</table>

**Table 3. Interpreter reliability of Examiner 2**

<table>
<thead>
<tr>
<th>Session</th>
<th>Examiner1</th>
<th>Examiner2</th>
<th>ICC (95% CI)</th>
<th>SEM</th>
<th>MDC</th>
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<tbody>
<tr>
<td></td>
<td>Mean(SD)</td>
<td>Mean(SD)</td>
<td>(95%CI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bladder diameter (mm)</td>
<td>66.81(15.78)</td>
<td>66.29(15.89)</td>
<td>0.99 (0.99-0.99)</td>
<td>1.60</td>
<td>4.43</td>
</tr>
<tr>
<td>contraction</td>
<td>61.06(16.17)</td>
<td>61.20(15.89)</td>
<td>0.99 (0.99-0.99)</td>
<td>1.58</td>
<td>4.37</td>
</tr>
<tr>
<td>Rt</td>
<td>18.18(3.68)</td>
<td>22.14(5.73)</td>
<td>0.68 (-0.28-0.96)</td>
<td>3.24</td>
<td>8.98</td>
</tr>
<tr>
<td>Lt</td>
<td>20.54(4.79)</td>
<td>21.98(5.60)</td>
<td>0.72 (-0.21-0.96)</td>
<td>2.96</td>
<td>8.20</td>
</tr>
<tr>
<td>Rest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF Thickness (mm)</td>
<td>21.52(4.26)</td>
<td>24.32(6.34)</td>
<td>0.81 (0.01-0.97)</td>
<td>2.76</td>
<td>7.65</td>
</tr>
<tr>
<td>contracti on</td>
<td>23.20(5.77)</td>
<td>24.32(7.19)</td>
<td>0.71 (-0.24-0.96)</td>
<td>3.87</td>
<td>10.72</td>
</tr>
<tr>
<td>Rt</td>
<td>6.56(2.06)</td>
<td>6.47(1.85)</td>
<td>0.78 (-0.07-0.97)</td>
<td>0.86</td>
<td>2.40</td>
</tr>
<tr>
<td>Lt</td>
<td>6.72(1.95)</td>
<td>6.09(1.77)</td>
<td>0.86 (0.17-0.98)</td>
<td>0.66</td>
<td>1.83</td>
</tr>
</tbody>
</table>
Intra-ratter and Inter-ratter Reliability of Rehabilitative Ultrasound Imaging of Multifoods Muscle Thickness, Cross Section Area and Bladder Wall Displacement in Multiparous Women

| MF CSA (mm) | Rest Lt | 5.09 (1.15) | 6.09 (1.77) | 0.61 (0.39-0.95) | 1.19 | 3.32 |

Table 4. Within-day Interpreter reliability for RUSI

REFERENCES


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