

The Reliability of Ultrasound Imaging in measuring the Thickness of Lumbar Multifidus Muscle in Gymnastics Athletes with Sway-Back and Normal Posture

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Abstract

Introduction: Sway-Back Posture (SBP) is one of the most common poor postures especially among the female gymnastics athletes. It can result in multifidus muscles insufficiency and inability to support the spinal column. The aim of this study was to evaluate the intra-rater reliability of ultrasound imaging to measure the thickness of lumbar multifidus (LMM) muscle at different lumbar levels during both states of muscle at rest and contraction. **Materials and Methods:** The subjects of this study were 10 females' gymnastics athletes among whom five had sway back posture. To have the posture assessed the plumb line and grid paper were used. The LMM thicknesses of all lumbar segments were measured thrice (with 1hour minutes interval) by the same examiner in both rest and contraction position simultaneous with arm lifts done by a real time Ultrasonography device. **Results:** The results of the relative and the absolute reliability of LMM thickness measurements at the state of rests were $0.97 < ICC < 0.99$, $0.34 < SEM < 0.48$ and $0.94 < MDC < 1.34$ and at the state of contractions they were as: $0.95 < ICC < 0.98$, $0.47 < SEM < 0.71$ and $1.31 < MDC < 1.98$. The results of the Bland-Altman plotting indicated a good level of agreement between two measurements at all lumbar levels in both states of rest and contraction. **Conclusion:** The results of this study indicated that the method of ultrasonography had a high level of reliability and accuracy to measure the thickness of LMM in both states of muscle at rest and contraction. The method is highly recommended in physiotherapy and rehabilitation assessments.

Key words: Gymnastic, Lumbar Multifidus Muscle, Reliability, Sway-Back Posture, Thickness, Ultrasound Imaging

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Introduction

Posture is one of the important factors which have many effects on the quality of athlete's life. Posture that is a relative status of the body is the combination of different positions of the joints at that time. As a matter of fact a well- balanced posture which is the result of the interaction between the musculoskeletal, nervous system and contextual effects (3, 4), imposes less stress on every joint (1, 2).

In other words, any imbalance and limitation in musculoskeletal structures will have a significant effect on the efficiency of movements; resulting in poor or faulty posture (5). Postural dysfunctions are categorized based on the planes of a motion, for example there are poor postures like flat back, sway-back and Kypholordotic posture on the sagittal plane. Also, round back posture can be related to the frontal plane, but the most common deviation or faulty posture is the Sway-back posture (SBP) which is associated with sagittal alignment.

Unfortunately, it is a prevalent abnormality in young Iranian girls (35%) (6) and among female teenagers (31%) (7).

SBP is statistically referred to as the most widespread type of poor posture among the gymnasts. According to the official figures 100% of male gymnasts and 80% of female ones had this posture (8).

Kendall in 2005 reported that SBP results in the anterior pelvis tilt, hypo-lordosis and hyperextension of the hip and knee (2). Magee in 2007 indicated that SBP causes an increase in kyphosis and lumbar lordosis, it also leads into anterior pelvis tilt and extension of hip (1). The main reason contributing to SBP is poor interaction between musculo-skeletal system and nervous system which results in fatigue, weakness, and muscle imbalances. It is clear that individuals with this poor posture show signs of inefficiency of muscles, as well as passive and non-contractible elements. These changes in muscles can be seen as over-activity or hypo-activity (9).

Kendall and Magee indicated that in people with SBP muscles like multifidus, erector spine, iliopsoas, gluteus maximus, transverse abdominous and internal oblique were less activate compared to rectus abdominous, external oblique, tensor fascialata, rectus femoris, hamstring, adductors, priformis, and anterior tibialis (1, 2). Due to the above musculo-skeletal changes, the probability of underlined side effects will increase in individuals with SBP. Some of these side effects are anterior compartment syndrome which results in tibia bone pain, the extension of the knee resulting in patello Femoral Impingement, tears in anterior cruciate ligament, hammer toe deformity due to over-activity in toe extensors and thoracic rotation which increases pain in chest wall.

A significant correlation between SBP and low back pain was reported by O'Sullivan et al. in 2006(10) and in 2002 it was also revealed that the activities of lumbar multifidus decreased when subjects were in sway standing. The multifidus muscle is a segmental and anti-gravity muscle which has the main role in stabilizing the lumbar vertebrae. There are many pieces of evidence showing the decrease in the size and the activity of multifidus muscle; consequently, the low stability of lumbar spine in individuals with low back pain (12, 13).

Ultrasound imaging (USI) is a painless, noninvasive and real-time technique which can be used to examine muscle features like size, thickness and CSA. This technique is practiced as a primary method to assess the function of muscles in either rest or dynamic movements. Hodges et al 2003 noted that muscle thickness changes when the muscle contracts. This thickness change of muscle between rest and contract phase is one factor to measure the muscle efficiency. It has been shown that USI can produce the image of both superficial and deep muscles (15, 16, 17, 18). The

images have high reliability and validity (11, 12, 13, 14) to measure abdominal, lumbar multifidus and pelvic floor muscles thicknesses. In order to have the image of the LMM created the USI method can be used in both prone and side-lying position neither of which has any effect on the results.

The USI method in comparison with MRI as a gold standard method has proven to have high validity (18). Most of the researchers in investigation of the reliability of the lumbar multifidus muscle have confronted some limitations such as examinations in a state of muscle contraction in different lumbar segments and during loading (e.g. arm lift or straight leg raise) in athletes with SBP. As a result, the aim of this study was to examine the relative and the absolute reliability of USI method in measuring the multifidus muscle thickness at all lumbar segments (L1-L5) in both states of muscles at rest as well as contraction in response to arm lift in gymnastic athletes with and without SBP.

Subjects

The subjects were selected from among female gymnastics athletes who came from different cities of Iran to compete in the national artistic gymnastic competition. The studied population consisted of ten female gymnastics athletes (five gymnasts with SBP and five gymnasts with normal posture) who were between the ages of 17 to 30 years.

Age, duration of being active at an elite level, training schedule per week and medical history of surgical procedures/trace of pain in lower back and pelvis were self-reported by all the athletes.

The prior intervention to fix the SBP was not considered as an inclusion criterion for the subjects with SBP. The history of any surgery in spine, lumbar, lower extremity or pelvis, musculoskeletal disease, fracture or dislocation in spine or pelvis was seen as the exclusion criteria.

At first, the study protocol was explained to all participants. After the acceptance, they were given a questionnaire to fill out. Then their height and weight were measured with a meter stick and digital scale respectively. These values were used to obtain their BMI ($BMI = \text{weight} / \text{height}^2$) (Table 1).

Posture analysis

In order to evaluate the posture we implemented a plumb line and grid paper according to Kendall (2), Mulhearn (20) and Dolphens (7). The distance between the grid paper on the wall and plumb line hanged from the roof was forty-five centimeter. Next, we adjusted the plumb line to be coincident with one of the lines on the grid paper and then placed the markers on the seventh cervical spinous process, middle of greater trochanter and middle of lateral malleolus. Next, the gymnasts who had their feet in

Table1. Anthropometric variables of participants (n=10)

	Range	Minimum	Maximum	Mean (SD)
Age(years)	14.00	16.00	30.00	23.30 (4.96)
Weight(Kg)	21.80	36.90	58.70	52.28 (6.72)
Height (Cm)	17.00	151.00	168.00	159.70 (5.59)
BMI (Kg/m ²)	8.24	16.18	24.42	20.49 (2.71)
Lordosis(Degree)	21.76	33.49	55.25	44.81 (5.93)
Pelvic. Tilt	10.50	2.00	12.50	7.87 (3.14)

Table2. Intra-examiner reliability of lumbar multifidus muscle (LMM) thickness measurements at states of rest and contraction by using ultrasonography imaging (USI).

	ICC	95% confidence interval		SEM	MDC	
		Lower bound	Upper bound			
USI (LMM thickness at rest)	L ₁	0.98	0.93	0.99	0.475	1.317
	L ₂	0.99	0.90	0.99	0.458	1.272
	L ₃	0.98	0.93	0.99	0.407	1.128
	L ₄	0.97	0.89	0.99	0.486	1.349
	L ₅	0.99	0.96	0.99	0.341	0.945
USI (LMM thickness at contraction)	L ₁	0.97	0.90	0.99	0.687	1.905
	L ₂	0.97	0.89	0.99	0.559	1.550
	L ₃	0.97	0.90	0.99	0.632	1.752
	L ₄	0.98	0.93	0.99	0.475	1.317
	L ₅	0.95	0.81	0.98	0.717	1.989

Table3. Mean Differences and 95% CI of Differences between first and second measurements of lumbar multifidus muscle (LMM) thicknesses.

Difference between first and second measurement	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
			Lower	Upper
L ₁	.087	-.860	-1.915	.195
L ₂	.576	.180	-.640	1.000
L ₃	.491	.180	-.479	.839
Rest L ₄	.395	-.340	-1.331	.651
L ₅	.022	-.620	-1.096	-.143
L ₁	.034	-1.200	-2.257	-.142
L ₂	1.000	.000	-1.764	1.764
Contraction L ₃	.564	-.340	-1.841	1.161
L ₄	.583	.280	-1.023	1.583
L ₅	.347	-.700	-2.524	1.124

natural toe out position with 15cm distance from each other stood between the grid paper and the plumb line so that the plumb line could passed the middle of the lateral malleolus marker. In the succeeding stage the participants were asked to impose the equal weight on both feet and to stay in this position for three minutes

to have their posture identified, this provided them with enough time to adopt their posture.(7)

To standardize the head position, the gymnasts were asked to look at the marker placed on the wall. We then observed their final posture and checked the plumb line. If C7 and greater

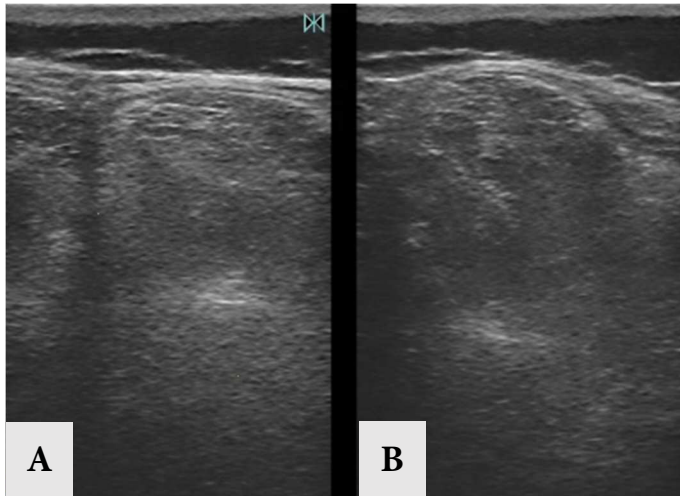


Figure 1. A) Ultrasound image of lumbar multifidus muscle at the fifth level of vertebra with measurement of the muscle thickness at rest; B) Ultrasound image of the lumbar multifidus contraction consequent to arm lift

trochanter appeared to be behind the plumb line, the gymnasts were placed in the experimental group (participants with sway-back posture), otherwise they were considered as the ones with normal posture (21).

Ultrasound imaging protocol:

The technique performed in the study was using B-Mode ultrasonography device (Honda 2100, Honda Co., Japan) with a frequency of 7.5 M Hz and a linear array probe. The athletes were in prone position with a pillow under their abdominal region to keep their lordosis in the flat position. They were asked stay in a relaxed style in order to prevent any muscle contraction. Additionally, we used iliac crest as a landmark to find lumbar vertebrae so that the top of the crest in the spine was identified as L4. As a result of using palpation other vertebrae were delineated on the skin. By putting the probe longitudinally the spinous processes of the vertebrae were seen on the screen. Having observed each one of the vertebra, we put the probe transversally. In this view, we could see the spinous process and both transvers processes of every single vertebra. The echogenic transvers process of the dominant side was taken as a landmark, then the distance between this and the subcutaneous fascia was spotted as multifidus thickness while the subjects were at rest. Then, subjects were asked to elevate their dominant arm up to the level of their ear to contract the multifidus. Once they moved their arm, the muscle thickness was measured at the same side (22) (Figure 1). These subsequent steps and measurements were repeated for all vertebrae from L1-L5. A total of 10 levels for each gymnast were taken through the rest and the contraction of

multifidus muscle in every vertebral segment from L1-L5 (in all 600 measurements).

The thickness of multifidus in both states were measured on the display of the ultrasound device, the thickness variation between rest and contraction states was obtained as a sign of efficiency and ability of tension producing. It should be mentioned that the measurements were repeated three times with an interval of 1 hour within one day. The first measurement was done as mentioned before, and to make the subsequent measurements we removed the markers, then the bony landmarks were identified again as done for the first time. A total of 600 ultrasound images (10 subjects x 5 segments x 3 times x 2 occasions x 2 states) of lumbar multifidus muscle thicknesses were taken and measured during both states of rest and contraction for three times in 10 gymnastic athletes.

Data Analysis:

Statistical analyses were performed by PASW Statistics (SPSS 23). The results (mean) obtained through three-time measurement were used to estimate inter-examiner reliability by applying an intra-class correlation coefficient (ICC) with 95% confidence interval (CI), Based on the proposed ICC cut offs by Fleiss 5, an ICC of greater than 0.75 is excellent and the one between 0.40 to 0.75 is fair to good. We compared the ICC and corresponding 95% CI as the standard and alternative USI measurement techniques. Standard error of measurement (SEM) and minimal detectable changes ($MDC=1.96 \times \sqrt{2} \times SEM$) were subsequently calculated.

Results

Table two demonstrates the values of the within a day reliability for both groups in states of rest and contraction.

The results of the Intra-examiner measurement were excellent for both groups. The ICC of lumbar multifidus thickness measurement was greater than 0.97 for all segments (L1-L5) and it was greater than 0.95 respectively in the rest state and during LMM contraction in response to arm lift.

An agreement between the thickness measurements of LMM for both occasions which can be seen in Figure 2 and 3 were identified by applying Bland-Altman plot. The limits of agreement were defined by the mean difference of both standard deviation measurements (± 1.96). The difference between means should be zero or there should be no significant difference between two means. By casting a glance over the figures, one can compare the thickness of LMM between the first and second measurements in state of rest (L5) and contraction (L1) among gymnastics athletes with and without SBP. The values obtained for the mean difference of L5 at rest and L1 in contraction state

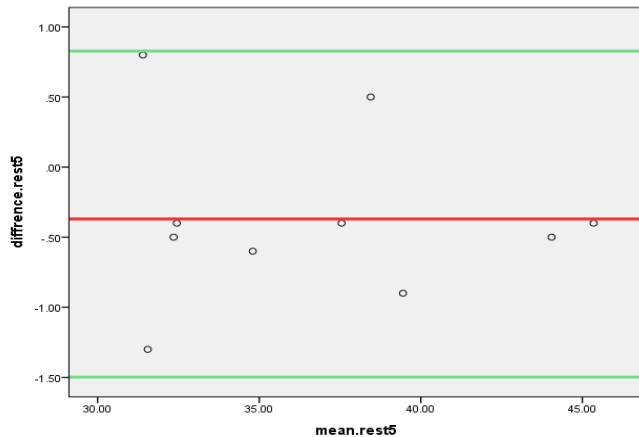


Figure 2. Bland-Altman plot of thickness comparison of lumbar multifidus muscle (LMM) between the first and second measurements in state of rest (L_5)

were -0.37 cm_2 (95% CI of -0.807 to 0.067) and -0.33 cm_2 (95% CI of -1.195 to 0.535) respectively which indicate a good level of agreement between two measurements. The data related to all lumbar segments in state of rest and contraction are presented in table 3.

Discussion

This study evaluated the intra-examiner reliability in obtaining USI thickness measurements of the lumbar multifidus muscles at rest and during submaximal contractions in response to arm lift during a single session in gymnastics athletes with SBP and normal posture.

Despite the theoretical challenges of using USI to measure muscle size, measurements of lumbar multifidus thickness in female gymnasts, in state of rest and contraction, proved to have excellent reliability. Use of the different measurement techniques in assessing the lumbar multifidus muscle thicknesses did not improve reliability compared to the standard technique, so standard technique is recommended to be used (9, 11, 21). Differences in methodology are a consideration when it comes to compare these findings to other USI studies. In different studies, the arm lift or a limb-lift task is typically used to contract the lumbar multifidus muscles (9, 11). It is recommended to calculate ICC, SEM, and MDC not only for a segment of lumbar multifidus thickness at rest, but also for all segments ($L1$ - $L5$) of lumbar multifidus in both states of rest and contraction in response to arm lift. Although the participants in this study were female gymnastics athletes who had SBP or normal posture, and the thickness of multifidus in all lumbar segments at rest and contraction were investigated, the result showed that USI is the method which can be used to assess the muscle thickness in

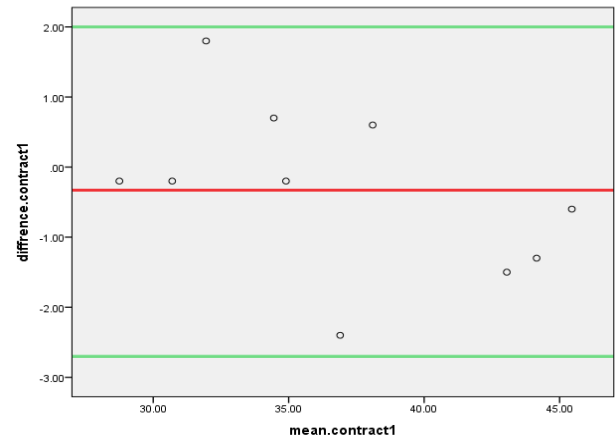


Figure 3. Bland-Altman plot of thickness comparison of lumbar multifidus muscle (LMM) between the first and second measurement in state of contraction in response to arm lift ($L1$)

responds to dynamic and functional tasks. It was also found that this method is applicable in healthy people and individuals with postural dysfunctions. Additionally, the results revealed that thickness of LMM in both states of rest and contract was smaller in gymnasts with SBP than that of subjects with normal posture. The difference of thickness between two groups may be attributed to the possible atrophy of LMM in SBP group.

It is possible to monitor the effect of exercise therapy intervention on muscle dimensions, by using USI as a non-invasive and comfortable tool, which is the second target of the present research.

Conclusion

Using USI in the current study baseline results have been reported for intra-tester reliability in the measurement of the LMM. The current protocol is required to be used in further studies to give a clearer understanding of the role of LMM.

According to the results, the USI is an appropriate and reliable method to measure muscle thickness in both states of rest and contraction in individuals with and without postural dysfunctions. The method is highly recommended in physiotherapy and rehabilitation assessments.

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Conflict of interest:

None

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Authors' contributions:

All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

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