RESEARCH ARTICLE

Sonoelastography of Multifidus, Piriformis, Quadratus Lumborum, and Gluteus Medius Muscles in Patients with Unilateral Discogenic Lumbar Pain and Healthy Subjects: A Reliability Study

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Abstract

Background: This study aimed to estimate the within-day and between-day reliabilities of sonoelastography to measure the strain ratios of lumbopelvic muscles, including multifidus (MF), piriformis (P), quadratus lumborum (QL), and gluteus medius (GM), in a resting position by the sonoelastography device in both patients with unilateral discogenic lumbar pain and healthy individuals. Failthe treatment of deep infection of peri-articular fracture fixation.

Methods: First of all, the participants (n=25) were enrolled in this study, including patients (n=15) and healthy subjects (n=10). In the first session, an examiner estimated the strain ratio of lumbopelvic muscle three times by sonoelastography. The last session was held at a one-week interval. The collected data were analyzed using an intraclass correlation coefficient (ICC) and a standard error of measurement.

Results: The ICC calculated for MF, P, QL, and GM measurements indicated good to excellent reliabilities in both healthy and patient groups for within- and between-intra-examiner reliabilities, which were obtained at 0.94-0.91 and 0.86-0.86, 0.87-0.89 and 0.82-0.82, 0.88-0.86 and 0.86-0.86, 0.88-0.84 and 0.84-0.84, respectively. Furthermore, the standard errors of intra-examiner reliability for MF, P, QL, and GM strain ratio measurements in both healthy and subject groups were estimated at the ranges of 0.52-0.51 and 0.64-0.65, 0.60-0.62 and 0.77-0.78, 0.23-0.25 and 0.25-0.25, 0.25-026 and 0.30-0.35, respectively.

Conclusion: The results revealed that sonoelastography seemed to be a reliable instrument to measure MF, P, QL, and GM muscle strain ratios in healthy subjects and patients with unilateral lumbar radicular pain. However, further studies are recommended to support the findings of the present study in other patients.

Level of evidence: III

Keywords: Lumbar radicular pain, Sonoelastography, Strain ratio, Trigger points

Introduction

One of the main reasons for the pain and functional disability in muscles is myofascial pain syndrome (1). Many people suffer from this muscle syndrome, and this pain imposes a lot of costs on societies (2). Myofascial pain syndrome is a routine muscle dysfunction and a kind of musculoskeletal disorder that is disposed to the trigger points (TrPs) (3). The pathophysiology of myofascial pain syndrome is still unclear. Myofascial

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TrPs have been defined as anatomic and physiologic effects in the pathophysiology of myofascial pain syndrome. They are purposed as sensitive hard palpable nodules positioned within taut bands of the contracted muscles (4). Consequently, diagnostic methods, such as electromyography, magnetic resonance elastography, and ultrasonography, have been introduced to identify and determine the location of the myofascial TrPs and their characteristics (5). Sonoelastographic technique, if employed in real-time mode, can display and image superficially and deeply TrPs located as active or latent in the lumbopelvic muscles. It acts based on the created tissue compression strain (displacement). Strain shows stiffness and relative deformation. Stiff tissues show less strain, compared to the softer tissues, when participants are exposed to an identical force. The lower strain ratios and hypoechoic regions of the nodules may be the reason for the contraction of nodules resulting from a high muscle fiber contraction or a local injury, and/or localized regions of ischemia. Muscle ultrasonography has been reported to be a valuable technique for muscle size evaluation (6). An ultrasonography device is an accurate, reliable, and non-invasive instrument to evaluate muscle size and shape and examine the effects of the different pathologies and interventions. The muscle layers seem darker with a less grey shadow, while the covered fascia seems quite white. Elastography, also known as elasticity imaging, is an in vivo non-invasive assessment of the mechanical strain changes in tissues. Sonoelastography is a safe, available, portable, and cost-effective imaging instrument for the declaration of myofascial TrPs and estimation of the effectiveness of the therapeutic interventions. So far, sonoelastography has been a method based on ultrasound that shows the stiffness of the soft tissues both qualitatively and quantitatively (strain ratio) (7). The strain ratio is actually the movement of the target tissues concerning other tissues (such as fat) following the surface pressure, that is employed for estimating the elasticity of the living tissues (8). This study aimed to investigate whether sonoelastography could reliably measure the strain ratios of the lumbopelvic muscles (multifidus [MF], quadratus lumborum [QL], gluteus maximus [GM], and piriformis [P]) in their resting positions in both intact subjects and patients with unilateral discogenic lumbar pain.

Materials and Methods

Subjects

This methodological study was conducted on patients with unilateral lumbar radicular pain (n=15) and healthy subjects (n=10), out of which 16 and 9 individuals were male and female, respectively. The patients had a mean age of 38.53±8.13 years, mean weight of 83.87±13.01 kg, and mean height of 174.9±0.11 cm. The mean scores of healthy individuals' age, weight, and height were obtained at 35.8±8.81 years, 74.80±13.01 kg, and 172.4±0.09 cm, respectively. The inclusion criteria were being 25-60 years old and having radiating pain in one leg during the last 6-12 months. On the other hand, patients with fibromyalgia, previous lumbar injury, severe lumbar osteoarthritis, and lumbar myelopathy were excluded from the study. Low back pain was defined as muscle pain, stiffness, or inflammation perched below the rib cage and above the buttock, with or without leg pain (sciatica). Healthy subjects were free of unilateral lumbar radicular pain; however, patients had unilateral lumbar radicular pain during the last 6-12 months. Informed consent was obtained from all subjects.

Procedure

All participants were visited in the clinic on two different days. The first and second measurements were conducted in a day with a two-hour interval (within-day reliability), and the third one was performed following an interval of 1 week (between-day reliability). All subjects completed the validated Iranian version of the Functional Rating Index, and their pain levels (5.93±1.28) were recorded on a Visual Analogue Scale.

Measurement of lumbopelvic muscles strain ratio by sonoelastography

An ultrasound device (Ultrasonic, Supersonic, France) with a linear wave frequency of 5-14 MHz was employed. Sonoelastography could produce two types of images, including elastogram on the left side of the monitor and two-dimensional sonography on the right side. The images of the elastogram were identified by different colors as tough (red), average (green), and soft (blue) (9). The examiner employed the ultrasound probe vertically on the target tissues and rotated parallel to the muscle fibers to obtain the best image of the middle part of the marked region of the muscle. We could use system feedback in real-time to obtain the best possible image, which revealed the proper value of the pressure in the assessed area (10). The participants stayed in the prone position with their elbows on the examination bed and their heads midway on the bed. Muscle stiffness was significantly reduced in the prone position. The main clinical features for diagnosing myofascial taut band were (1) palpable taut bands, (2) local tenderness in the taut bands (TrPs), and (3) pain recognition. As a result, the examiners registered the number of TrPs and highlighted the active TrPs in the central region of the muscle for measurements. It is a remarkable point that the position of the examiner and participants may affect the precision of imaging. The previous article reported that the stiffness of the upper trapezius muscle was significantly greater in the sitting position, compared to the prone position. In the present study, the prone position was chosen during measurements, and due to the muscle relaxation, the images were recorded at the end of their expiration. The strain ratio was calculated numerically and based on the formula $Kx=F0$ (10). It should be noted that only the movement is calculated in this formula. Moreover, to recognize the best image, it is needed to use stable mild pressure on the skin by controlling the pressure indicator feedback. The pressure indicator feedback was shown on a scale of 1 to 6 levels, which could recognize the mean changes in the strain within the target zone per frame. The best surface constant pressure to the employed standard images could stay on level 4, which was the optimal strain and the best frame

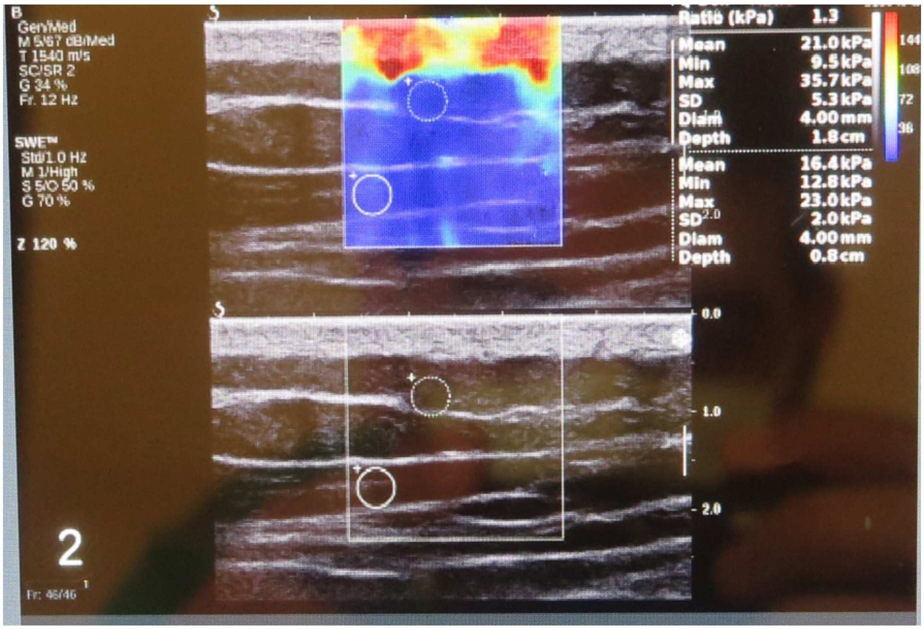

Figure 1. Sonoelastography Image of gluteus medius muscle.

for measurements. The elastography software computed the relationship of movements in two tissues of a muscle and fat automatically and numerically and showed them on the monitor as strain ratios (11) [Figure 1].

Data Management and Analysis

The statistical analysis was completed using a paired t-test to display the cases of systematic bias between the scores of the tests and re-tests. The examiner computed the average of three trials to determine both within- and between-session intra-rater reliabilities for each participant (11). Data distribution was normal, which was determined by Shapiro-Wilk test results. According to these points, paired t-tests and interclass correlation coefficient (ICC) were assumed to be suitable for the study variables (12). The standard error of the measurement (SEM) was computed to estimate the measurement error. The reliability coefficients were introduced according to a general rule: ICCs of ≥ 0.75 are suggested as good and ICCs of ≥ 0.90 are suggested as excellent (13). To evaluate the clinical notable changes between the two times of measurements, the minimal detectable change was introduced as a 95% confidence interval of SEM (1.96 SEM) (14). Furthermore, to define the similarities and differences in the absolute reliability between measurements, the coefficient of variation ([standard deviation/mean]×100) was computed. Significance levels were set at $P < 0.05$ for all measurements (13).

Results

The demographic characteristics of the participants are presented in Table 1 and the descriptive data (mean±SD) of lumbopelvic muscles are summarized in Table 2. The findings of within-day and between-day reliabilities of lumbopelvic muscle strain ratios at the resting position are tabulated in tables 1 and 2. The ICCs for MF, QL, GM, and P measurements indicated good to excellent reliabilities for both healthy and patient groups as their within- and between-intra-examiner reliabilities were obtained at 0.94-0.91 and 0.86-0.86, 0.87-0.89 and 0.82-0.82, 0.88-0.86 and 0.86-0.86, 0.88-0.84 and 0.84-0.84, respectively. Furthermore, the standard errors of the intra-examiner reliability for MF, QL, GM, and P strain ratio measurements in both healthy and patient groups

Table 1. Demographic characteristics of participants

Age (year)		Weight (kg)	Height (cm)	VAS (mm)	BMI (kg)	FRI %
Healthy subjects	27.5±6.4 (25-55)	65.7±18.4 (63-98)	170.2±5.8 (160-200)	24.7±3.2 (21.5-34.7)		
Patients with low back pain	35.4-5.5 (29-54)	61±9.6 (61.5-92.5)	167.2±4.7 (167-187)	41.1±20.5 (7.1-69.6)	24.2±3.9 (20.1-31.7)	30.4±11.2 (5-16)

BMI: Body mass index; VAS: Visual analogue scale; FRI: Functional rating index;

Table 2. Results of within-day and between-day reliabilities for the MF, PF, QL, and GM strain ratios in participants of both groups

Groups	Sessions	ICC for MF (SEM)	ICC for PF (SEM)	ICC for QL (SEM)	ICC For GM (SEM)
Healthy subjects	Within-day	0.96	0.97	0.95	0.94
	Between-day	0.75	0.78	0.77	0.73
Patients group	Within-day	0.94	0.93	0.95	0.91
	Between-day	0.98	0.95	0.96	0.95

MF: Multifidus; PF: Piriformis; QL: Quadratus lumborum; GM: Gluteus medius; ICC: Intraclass correlation coefficient; SEM: Standard error of measurement

were estimated at the ranges of 0.52-0.51 and 0.64-0.65, 0.60-0.62 and 0.77-0.78, 0.23-0.25 and 0.25-0.25, 0.25-0.26 and 0.30-0.35, respectively.

The span of 0.82 to 0.94 of ICC vouched high for both within-day and between-day reliabilities. In addition, the standard error and minimal detectable changes proposed stability and excellent reliability of the computing expanse for the lumbopelvic muscles in the participants with/without lumbopelvic pain (LBP).

Discussion

The present research aimed to evaluate the reliability of measuring the lumbopelvic muscle strain ratio by sonoelastography in individuals with/without LBP. The results of this study reported high intra-rater reliability for the assessment of the lumbopelvic muscle strain ratio. The findings of a study by Muraki et al. showed that the strain ratio of the supraspinatus muscle decreased after isometric contraction and that the muscle contraction could increase muscle stiffness (14). Moreover, accordingly, the reliability of the supraspinatus muscle and tendon strain ratio was high (ICC=0.93-0.98) in intact participants. Furthermore, a fat layer usually has stable stiffness, and in numerous studies on sonoelastography, the fat layer has been considered a reference zone for the calculation of the strain ratio. Leong et al. indicated high intra-rater (0.87-0.97) and inter-rater (0.78-0.83) reliabilities for the upper trapezius stiffness, which were evaluated by the sonoelastography imaging (14). They offered that for a highly reproducible method for computing the lumbopelvic muscle strain ratio, the body landmark should be correlated with the part of the scanned target muscle, the picture setting, and the position and dimension of the target area. Inter-rater reliability extent for sonoelastography varies from poor to excellent; therefore, some studies have reported a limitation of SE, while, many studies have defined acceptance in real-time elastography (15). Sonoelastography could evaluate the muscle elasticity in subjects with LBP, and it was a more appropriate device to evaluate muscle elasticity, compared to magnetic resonance elastography (MRE). Sildar et al. employed MRE in their study and concluded that subjects with LBP had more stiffness in the target area than other parts of the muscle tissues, compared to the healthy participant's intact tissues (16).

It was revealed from the evidence that the reliability of sonoelastography depends on several elements. Firstly, it is dependent on the position of the target muscle. Regarding this, higher reliability results would be achieved in more superficial muscles (e.g., the trapezius), whereas deeper muscles (e.g., the gastrocnemius) would yield lower reliability; this is because the pressure may not reach the deeper muscles. Secondly, the reliability is influenced by the position of the target muscle and the affected point (fat layer). Finally, the pressure applied to the target muscle, visible on the SE monitor, affects the reliability. In this regard, the green color represents the optimal amount of the employed pressure.

The findings of this study indicated that the sonoelastography protocol employed in this research could reliably measure the strain ratio in the resting position, in both healthy and patient participants. According to the results of the latest available studies, sonoelastography imaging establishes reliable measurements of lumbopelvic muscle strain ratio in patients with unilateral discogenic lumbar pain and intact individuals.

A sonoelastography device was employed in the present study as a clinical instrument that estimated the elastic properties of the soft tissues. Although all physiotherapists can assess the muscular stiffness by palpation, sonoelastography can make a quantitative and qualitative plan of the muscular stiffness (17). To the best of our knowledge, so far, no study has evaluated the reliability of the lumbopelvic muscle strain ratio in different positions, such as resting position or contraction state.

One of the limitations of the present study was related to the issue that the target zone was on the middle part of the muscle bulk (initial location of the TrPs of the lumbopelvic muscles), which might cause the exact zone of the TrPs relative to the fat layers undetermined. Another limitation was associated with the not assessment of the other part of the lumbopelvic muscle strain ratio. Moreover, the correlation among biomechanical properties (e.g., stiffness and heterogeneity index) of lumbopelvic muscles was unknown in patients with musculoskeletal dysfunction. The other limitation was regarded to the population, meaning that the information obtained in this study can only be generalized to patients with unilateral discogenic lumbar pain.

To improve the generalizability of the findings, it is recommended to perform further relevant studies using a longer interval and larger sample size. In addition, it is recommended to assess the sonoelastography reliability to be able to calculate other muscles among participants with and without LBP. The strain ratios of the lumbopelvic muscles (MF, QL, GM, and P) were estimated by sonoelastography in participants with unilateral discogenic lumbar pain that was very repeatable with the fair intra-examiner reliability. Therefore, the computation of the lumbopelvic muscles strain ratio, in case that the protocol (e.g., reference zone and ultrasound applicator) set out in this study is employed, would lead to improvement in assessing the level of the overdone lumbopelvic muscles concerning TrPs. Future studies can evaluate other low back muscles, such as iliocostalis lumborum, and the strain ratio can be computed by sonoelastography with a larger sample size that can be generalized to all participants with LBP.

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