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RESEARCH

Reliability of ultrasound shear-wave elastography in assessing tensor fascia latae, gluteus medius, and iliotibial band elasticity in health individuals

Sağlıklı bireylerde tensör fasya lata, gluteus medius ve iliotibial bant elastikiyetinin değerlendirilmesinde shear-wave elastografinin güvenilirliği

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Abstract

Purpose: Gluteus medius (GMed), tensor fascia latae (TFL), and iliotibial band (ITB) play important roles in stabilizing the hip joint and are often prone to overuse syndromes such as greater trochanteric pain syndrome and runner's knee. Shear-wave elastography (SWE) presents a new avenue for rapidly assessing these structures in an out-patient setting. This study aims to assess the intra- and interobserver reliability of sWE in evaluating the GMed, TFL, and ITB.

Materials and Methods: Twelve healthy volunteers (6 men and 6 women) were examined by two physiatrists using SWE. To assess inter-observer reliability, both physiatrists measured the thickness, velocity, and stiffness of GMed, TFL, and proximal and distal ITB. One physiatrist repeated the same measurements under identical conditions one week later to assess intra-observer reliability. Intra-class correlation coefficients (ICC) were calculated to evaluate reliability.

Results: Inter-observer measurements showed poor reliability (ICC < 0.4) for all parameters, except for GMed thickness (ICC=0.412), which was moderately reliable. Intra-observer measurements showed varying degrees of reliability, with TFL thickness (ICC=0.733), ITBP thickness (ICC=0.592), ITBD velocity (ICC=0.634), and ITBD stiffness (ICC=0.701) demonstrating moderate reliability. However, no excellent ICC scores were observed across both intra- and inter-observer assessments.

Conclusion: While SWE demonstrates promise in assessing hip stabilizers, its inconsistent reliability across different parameters highlights the need for further research. Comparative studies involving healthy and pathological groups are needed for better understanding of SWE's applicability in clinical settings.

Öz

Amaç: Gluteus medius (GMed), tensör fasya lata (TFL) ve iliotibial bant (İTB) kalça ekleminin stabilizasyonunda önemli rol oynayan kaslardandır ve büyük trokanterik ağrı sendromu ve koşucu dizi gibi aşırı kullanım sendromlarında sıklıkla tutulabilir. Shear-wave elastografisi (SWE), bu yapıların kliniklerde hızlı bir şekilde değerlendirilmesi için yeni bir yol sunar. Bu çalışma, GMed, TFL ve İTB'nin değerlendirilmesinde SWE'nin gözlemci içi ve gözlemciler arası güvenilirliğini değerlendirmeyi amaçlamaktadır.

Gereç ve Yöntem: On iki sağlıklı gönüllü (6 erkek ve 6 kadın) iki fiziyatrist tarafından SWE kullanılarak muayene edildi. Gözlemciler arası güvenilirliği değerlendirmek için her iki fiziyatrist de GMed, TFL ve proksimal ve distal İTB'nin kalınlığını, hızını ve sertliğini ölçtü. Bir fiziyatrist, gözlemci içi güvenilirliği değerlendirmek için aynı ölçümleri bir hafta sonra aynı koşullar altında tekrarladı. Güvenilirliği değerlendirmek için sınıf içi korelasyon katsayıları (ICC) hesaplandı.

Bulgular: Gözlemciler arası ölçümler, orta derecede güvenilir olan GMed kalınlığı (ICC=0.412) dışında tüm parametreler için zayıf güvenilirlik (ICC< 0.4) gösterdi. Gözlemci içi ölçümler, orta derecede güvenilirlik gösteren TFL kalınlığı (ICC=0.733), proksimal İTB kalınlığı (ICC=0.592), distal İTB hızı (ICC=0.634) ve distal İTB (ICC=0.701) sertliği ile değişen derecelerde güvenilirlik gösterdi. Ancak hem gözlemciler arası hem de gözlemciler arası değerlendirmelerde mükemmel ICC puanları gözlenmedi.

Sonuç: SWE, kalça stabilizatörlerinin değerlendirilmesinde umut verici olsa da, farklı parametrelerdeki tutarsız güvenilirliği daha fazla araştırmaya duyulan ihtiyacı vurgulamaktadır. SWE'nin klinik ortamlarda uygulanabilirliğinin daha iyi anlaşılması

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için sağlıklı ve patolojik grupları içeren karşılaştırmalı çalışmalara ihtiyaç vardır.

Anahtar kelimeler: Elastografi, doku elastisitesi, ultrasonografi, musculoskeletal, kalça kasları, güvenilirlik

INTRODUCTION

The hip's stabilizing structures, notably the gluteus medius (GMed), tensor fascia latae (TFL), and iliotibial band (ITB), are prone to overuse syndromes. Gluteus medius tendinopathy is a key factor in greater trochanteric pain syndrome[1], which accounts for 10-20% of hip pain cases in primary care[2]. The distal attachment of GMed is closely related to ITB and TFL. Previous studies have also shown significantly increased volumes using magnetic resonance imaging of TFL and gluteus medius in chronic hip joint pain syndromes[3]. The proximal end of ITB can be affected by both abrasion against the underlying hypertrophied muscles as well as its origin from the junction of GMed and TFL. Furthermore, the distal end of ITB is often subject to abrasion against the lateral femoral epicondyle and Gerdy's tubercle in runners' knee, which can also cause reflected pain on the gluteal region[4].

Various pathologies such as metabolic diseases of the muscle, overuse syndromes, denervation, and derangements of the hip joint can affect the function of myofascial structures[4]. While diagnostic tools like Magnetic Resonance Imaging and Electrophysiologic studies provide valuable insights, the primary rapid diagnostic method for out-patient settings relies solely on physical examination.

Increased utilization of musculoskeletal ultrasonography presents a new avenue for rapidly assessing muscle condition in out-patient settings[5]. While shear-wave imaging encompasses a range of techniques for analyzing shear waves in tissues, shear-wave elastography (SWE) specifically focuses on quantifying tissue stiffness by measuring the speed of these waves. Previous studies assessing musculoskeletal structures using SWE, specifically for TFL[6], gluteus maximus[6], and ITB[7] have shown variable results. However, no previous studies conducted SWE investigation of GMed. Furthermore, no studies examining these important hip stabilizers together is present at the time of writing this paper.

The primary aim of this study was to assess intra- and inter-user reliability of SWE measurements of GMed, TFL, and ITB in terms of thickness, velocity, and stiffness. To our knowledge, no other study has previously investigated the reliability of GMed using SWE and assessed these four important hip stabilizer structures together. This study aims to assess the baseline reliability of sonoelastography for hip stabilizers and provide a deeper understanding of its feasibility for out-patient clinical practice.

MATERIALS AND METHODS

Sample

The sample size for this cross-sectional study was determined as twelve using the sample size table based on the intraclass correlation coefficient (ICC) from Temel G. and Erdogan S.'s article[8]. Ethical approval for the study was obtained from the Medical Ethics Committee at Koç University on 15.10.2019 under the approval number 2019.347. IRB1.062.

Inclusion criteria encompassed healthy individuals with moderate daily activity between the ages of 18 and 30 years, without any musculoskeletal pathologies involving pelvic, hip, and/or knee regions. Participants older than 30 years were excluded to minimize age-related variability, as previous studies comparing the variability of muscle elastography measurements showed differences across young, middle, and elderly age groups[9].

Exclusion criteria were recent complaints of pelvic, hip, and/or knee pain, previous history of trauma or surgery, including the lumbar, pelvic, hip, or knee region, congenital or acquired pathologies of pelvis or lower extremity, presence of infection or open wounds at the measurement sites. A total of 12 healthy subjects, comprising 6 women and 6 men, were recruited among clinical staff and all volunteers signed an informed consent form. No additional subjects were approached as both number and gender distribution were satisfied.

Measurement and procedure

Demographic variables such as age, gender, height, weight, and body mass indices (BMI) were recorded. All measurements were conducted at Koç University

Hospital Department of Physical Medicine and Rehabilitation by physical medicine and rehabilitation physicians with 10 and 8 years of musculoskeletal ultrasonography experience. Measurements were recorded and stored digitally. Thickness and SWE values of TFL, GMed, as well as proximal and distal parts of ITB (ITBP and ITBD, respectively) on the left side of participants were measured using a GE LOGIQ E9 XDclear (GE Healthcare, WI, USA) ultrasound device with a linear array transducer (9L-D, B-mode, frequency 9-5 MHz). SWI was performed in a 2x1.5-centimetre window. Due to anisotropic features of the muscles, the current study evaluated shear wave velocity (SWV) (expressed in m/s) instead of Young's Modulus (expressed in kPa)[5]. Three 5 mm diameter region of interest (ROI) was located most homogeneous part of the color map.

All participants were asked to unveil their left hip region in a side lying position with the left leg up and were placed in neutral position across the hip, knee, and ankle joints using a towel under the ankle. To measure the thickness and elasticity of TFL, the transducer was placed longitudinally over the anterior-superior iliac spine (ASIS) and then shifted to show the proximal attachment of TFL[10]. Once the proximal attachment of TFL was visualized, the transducer was further shifted caudally, just below ASIS, and the thickness was measured 20mm from the left border of the image[10].

In order to assess the GMed muscle, the transducer was placed longitudinally on the lateral side of the hip just above the greater trochanter and on the anterior 1/4 of between the ASIS and PSIS[11]. The evaluation of the proximal part of ITB was done by placing the transducer over the greater trochanter on the transverse plane. Location was verified by the insertion of the GMed tendon on the greater trochanter, which is located just beneath the ITB. The thickness was measured on the level of lateral facet of trochanter[12]. The distal segment of ITB was visualized by placing the transducer longitudinally on the lateral femoral epicondyle nearly 2 cm above the lateral joint line of the knee[13].

For sufficient image quality and shear wave signals a large amount of gel was used and minimum pressure was applied on the probe. The positions of transducers were selected based on previous studies[11,14] and testing on different subjects. In order to assess inter-observer reliability, three images were taken at each location (TFL, GMed, prox. ITB, dist. ITB) and the mean measurement was recorded by the two physiatrists. For SWE, three identically sized regions of interest were designated for each measurement and the mean was used for analysis. To assess the intra-observer reliability, one physiatrist reassessed each participant after 7 days under identical room conditions at the same time of day.

Statistical analysis

Data was analyzed using Python 3 (Python Software Foundation, Wilmington, Delaware USA 2009) and Pingouin Statistics Library (Journal of Open Source Software)[15]. Descriptive statistics was used to evaluate demographic variables, median measurements, and interquartile range. The normality of the measurements was assessed using Shapiro-Wilk test. Intraclass Correlation Coefficient (ICC) was employed to assess the reliability of measurements between two different conditions, for the present study design, ICC3 was deemed suitable. The ICC was calculated using Pearson's product-moment correlation coefficient. The ICC reliability scores are graded as poor (< 0.4), fair (0.4-0.59), good (0.6-0.74), and excellent (>0.75).

To quantify the uncertainty in the ICC estimates, 95% confidence intervals were calculated for each pair of measurements. This involved transforming the Pearson correlation coefficient to a Fisher Z-value, then computing the standard error and applying the Z-score for a 95% confidence level. The resulting values were transformed back to correlation coefficients to give the lower and upper bounds of the 95% confidence intervals.

RESULTS

A total of 12 participants, 6 men and 6 women, volunteered for the study. Age, height, weight, and body mass index findings of the population are shown in Table 1. The median age of participants was 25.5. The median male participant was found to be three years older than the median female participant (26.5 years and 23.5 years). The median height of participants was 1.84m for males, 1.65m for females, and 1.77cm for total. Median weights recorded were 80.5 kg for males, 56.0 kg for females, and 71.0 kg for the total group. The median BMI was found to be 24.75 for males, 21.21 for females, and 22.77 for the total group.

Table 1. Summary of age, height, weight, and body mass index (BMI) of study population based on gender.

	Women (n=6)		Men (n=6)		Total (n=12)	
Parameter	Median	IQR	Median	IQR	Median	IQR
Age	23.5 years	3.0 years	26.5 years	2.5 years	25.5 years	4.25 years
Height (m)	1.65 meters	0.06 meters	1.84 meters	0.04 meters	1.77 meters	0.1925 meters
Weight (kg)	56.0 kg	4.25 kg	80.5 kg	4.0 kg	71.0 kg	23.75 kg
BMI (kg/m2)	21.21	1.68	24.75	0.78	22.77	3.90

Age, height, weight, and BMI are expressed in years, meters, kilograms, and kilograms/meters^2.

Table 2. Cumulative mean and standard deviation of all measurements.

Measurement	Cumulative Mean	Cumulative Std Dev	Observer 1 Mean	Observer 1 Std Dev	Observer 2 Mean	Observer 2 Std Dev
TFL thickness	1.07	0.16	1.03	0.20	1.11	0.19
TFL velocity	2.87	0.34	2.94	0.43	2.8	0.44
TFL stiffness	27.88	5.83	29.48	7.60	26.28	7.15
GMed thickness	2.43	0.35	2.23	0.46	2.64	0.31
GMed velocity	2.34	0.55	2.39	1.08	2.28	0.31
GMed stiffness	18.08	4.53	18.01	8.08	18.16	4.68
ITBP thickness	0.27	0.06	0.25	0.06	0.3	0.09
ITBP velocity	2.28	0.41	2.53	0.55	2.0	0.4
ITBP stiffness	18.21	6.46	23.16	9.55	13.27	5.14
ITBD thickness	0.36	0.24	0.22	0.01	0.50	0.47
ITBD velocity	2.95	0.62	3.17	0.67	2.73	0.81
ITBD stiffness	28.04	8.30	27.16	7.80	28.92	14.07

TFL: tensor fascia latae, GMed: gluteus medius, ITBP: iliotibial band proximal, ITBD: iliotibial band distal. Thickness is expressed in cm, velocity is expressed in m/s, and stiffness is expressed in kPA.

Table 3. Shapiro wilks test

Group	Column	Shapiro Statistic	Shapiro P-value
O1	ztTLFthickness	0.932	0.406
O1	ztTLFvelocity	0.942	0.525
O1	ztTLFstiffness	0.965	0.851
O1	ztGMedthickness	0.955	0.706
O1	ztGMedvelocity	0.953	0.677
O1	ztGMedstiffness	0.945	0.565
O1	ztITBPthickness	0.972	0.932
O1	ztITBPvelocity	0.874	0.073
O1	ztITBPstiffness	0.844	0.031
O1	ztITBDthickness	0.875	0.076
O1	ztITBDvelocity	0.974	0.948
O1	ztITBDstiffness	0.951	0.647
O1*	sztTLFthickness	0.966	0.869
O1*	sztTLFvelocity	0.917	0.259
O1*	sztTLFstiffness	0.927	0.347
O1*	sztGMedthickness	0.911	0.222
O1*	sztGMedvelocity	0.884	0.100
O1*	sztGMedstiffness	0.834	0.023
O1*	sztITBPthickness	0.935	0.441
O1*	sztITBPvelocity	0.922	0.301
O1*	sztITBPstiffness	0.891	0.121
O1*	sztITBDthickness	0.615	0.000
O1*	sztITBDvelocity	0.972	0.926
O1*	sztITBDstiffness	0.949	0.622
O2	mtTLFthickness	0.890	0.119

O2	mtTLFvelocity	0.913	0.234
O2	mtTLFstiffness	0.921	0.291
O2	mtGMedthickness	0.975	0.953
O2	mtGMedvelocity	0.950	0.636
O2	mtGMedstiffness	0.966	0.862
O2	mtITBPthickness	0.771	0.004
O2	mtITBPvelocity	0.942	0.518
O2	mtITBPstiffness	0.934	0.424
O2	mtITBDthickness	0.938	0.468
O2	mtITBDvelocity	0.828	0.020
O2	mtITBDstiffness	0.898	0.151

O1: Observer 1, O1*: Observer 1 Second Measurement, O2: Observer 2

Table 4. Reliability of measurements with %95 Lower Confidence Interval (lCI) and Upper Confidence Interval (uCI)

	Intra-observer				Inter-observer			
Measurement	**IIC**	**lCI**	**uCI**	**P**	**IIC**	**lCI**	**uCI**	**P**
TFL Thickness	0.733	0.311	0.915	0.002	0.379	-0.243	0.773	0.107
TFL Velocity	0.436	-0.195	0.801	0.078	0.396	-0.216	0.781	0.094
TFL Stiffness	0.631	0.157	0.875	0.007	0.167	-0.469	0.667	0.301
GMed Thickness	0.441	-0.118	0.796	0.057	0.412	-0.11	0.781	0.072
GMed Velocity	0.401	-0.132	0.773	0.068	-0.032	-0.63	0.546	0.539
Gmed Stiffness	0.427	-0.17	0.793	0.074	-0.082	-0.686	0.518	0.597
ITBP Thickness	0.592	0.05	0.863	0.018	0.191	-0.403	0.672	0.264
ITBP Velocity	0.325	-0.319	0.75	0.151	0.258	-0.125	0.667	0.137
ITBP Stiffness	0.25	-0.406	0.714	0.219	0.17	-0.13	0.57	0.181
ITBD Thickness	-0.03	-0.453	0.487	0.548	0.167	-0.311	0.632	0.259
ITBD Velocity	0.634	0.147	0.877	0.008	0.364	-0.167	0.754	0.088
ITBD Stiffness	0.701	0.272	0.902	0.002	0.151	-0.496	0.661	0.322

TFL: tensor fascia latae, GMed: gluteus medius, ITBP: iliotibial band, proximal attachment, and ITBD: iliotibial band, distal attachment. The ICC reliability scores are graded as poor (< 0.4), fair (0.4-0.59), good (0.6-0.74), and excellent (>0.75).

The mean and standard deviation based on measurements cumulatively across the entire cohort and across observers are depicted in Table 2. Results from Shapiro-Wilk Test are shown in Table 3. All measurements except for Observer 1's first ITBP stiffness, Observer 1's second GMed stiffness and ITBD thickness, and Observer 2's ITBP thickness and ITBD velocity were found to be normally distributed. ICC coefficients and %95 Confidence Intervals for intra- and inter-observer measurements are displayed in Table 4.

For Inter-observer measurements, all measurements were found to be poorly reliable, except for GMed thickness, which was found to be moderately reliable, and GMed velocity and stiffness, which were found to be not reliable. Intra-observer results showed varying degrees of reliability except for ITBD thickness, which was found to be not reliable. TFL thickness, ITBP thickness, ITBD velocity, and ITBD stiffness yielded moderately reliable results, whereas the rest of the measurements showed poor intra-observer reliability.

DISCUSSION

Based on the current sample size, our findings show no excellent ICC reliability scores across both inter-, and intra-observer measurements. The analysis of first and second measurements after one week of observer 2 shows findings reliable to variable extent, except for the thickness measurement of distal part of iliotibial band. It should be important to note that ICC is sensitive to the ratio of between-group variance to total variance. A group with less variation (like healthy volunteers in our case) might show a lower ICC because of a smaller between-group variance relative to a total variance. Inclusion of pathological measurements might lead to higher ICC reliability scores as the range of total measurements (therefore higher inter-group variability potential) and heterogeneity.

The inter-observer reliability of GMed shows a distinct situation in which thickness was found to be fairly reliable, yet velocity and stiffness were found to be unreliable. This highlights the complicated nature of the relationship between thickness and velocity/stiffness measurements, which might warrant further research.

Previous studies showed no significant difference in GMed thickness measurements between two sides in young female soccer players[11]. Whittaker's study, which has the same measurement protocol as our study, reported a mean thickness of 2.02 (±0.4) cm. A similar mean of 2.43 (±0.35) cm was observed in our study. However, Whittaker reported an ICC score of 0.98 in contrast to our 0.45. This stark difference might be due to different population sizes (n=29 vs n=12). In Besomi et al.'s assessment of pain-free runners' ITBs[7], the mean velocity was higher than in our study, with measurements of 9.7 (±2.2) m/s proximally and 8.5 (±2.5) m/s distally, compared to 2.28 (±0.41) and 2.9 (±0.62) m/s in our cohort, respectively.

Umehara et al. previously showed that knee angle significantly increased the shear elastic modulus on TFL at 90° and 135° as opposed to those at 0° and 45° [16]. In our study, the hip was at normal position and the knee was at 0°, hence no additional tension was exerted on TFL. At 0°, Umerhara et al reported mean shear-elastic modulus to be 24.6 (± 8.0) kPa, similarly our findings show mean measurements of TFL to be 27.88 (±5.83) kPa. The substantial difference in terms of ICC reliability score between Umehara's, where most ICC scores were found to be highly reliable, and our study, where most scores were found to be poorly and moderately reliable, can be attributed to the different biomechanical profiles and resulting overall TFL tension based on participants.

Limitations of our study include the unilateral assessment of these structures, which may not capture bilateral variability or asymmetry. Additionally, the exclusion of elderly and pathological groups restricts the study's applicability to clinical populations with known musculoskeletal conditions. Moreover, the absence of pathological controls makes it challenging to determine the diagnostic accuracy of SWE for these conditions.

Further research involving larger sample sizes, standardized patient groups with comprehensive measurement protocols, and inclusion of pathological control groups is needed to better understand the viability and feasibility of SWE in outpatient settings. Comparative studies examining reliability in both healthy and pathological groups will help establish the clinical relevance and diagnostic potential of SWE for assessing hip stabilizers.

Our study found that ultrasonographic evaluation of hip stabilizers using SWE showed mostly poor reliability for measurements of thickness, stiffness, and velocity in healthy individuals, with some moderate reliability observed for certain parameters. The differing nature of biomechanical profiles between individuals and varying reliability of SWE suggest that further studies comparing pathological groups with healthy individuals are needed to further cement a scientific basis for the use of SWE in out-patient diagnostic settings.

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