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Reliability of Measuring the Medial Knee Joint Space using Ultrasound Imaging

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Abstract

***Background**: The use of ultrasound to perform quantitative musculoskeletal (MSK) measurements requires reliability among different providers with varied levels of experience and training. Recent studies have shown that physical therapists (PT) can reliably measure the glenohumeral joint space using ultrasound imaging (USI) and operator experience or well-defined training protocols influences the reliability. Few studies have reported the reliability of medial knee gap measurements with USI.*

***Objective**: Evaluate inter- and intra-rater reliability of a novel approach to measuring knee gapping using experienced and trained novice clinicians.*

***Design:** Inter-rater and intra-rater reliability study*

***Setting:** Physical therapy program*

***Participants**: Novice researchers were three upper-year Doctor of Physical Therapy students. Experienced researchers were two PTs certified in MSK USI with eight years of experience.*

***Methods**: A total of 166 images of two subjects© medial knee joint gaps were captured in resting by a single experienced researcher. Three novice researchers, who underwent a three-hour training protocol and two experienced researchers measured the images individually. Measurements were taken using standardized bony landmarks and internal calipers. All researchers were blinded to the subjects and results.*

***Main Outcome Measures:** Data was analyzed using two-way ICC mixed-model single measurement, SEM was run for all reesarcher in comparision to experienced researcher one.*

***Results**: An excellent degree of reliability was found for both intra-rater and inter-rater measurements for Novice One and a good degree of reliability was found between Experienced One and Novice Two and Three.*

***Conclusions**: Both experienced and novice researchers attained a clinically significant ICC when compared to Experienced One. An accurate and reliable measurement of the medial knee joint gap maybe useful for further studies and help with diagnosis of joint pathologies.*

***Level of Study**: IIB*

Keywords: Measurement; Physical Therapy; Ultrasound Imaging

Abbreviations

musculoskeletal (MSK)
physical therapists (PT)
ultrasound imaging (USI)
cross sectional area (CSA)
intraclass correlation coefficients (ICC)
brightness mode (B-mode)
standard error of measurement (SEM)

In the field of healthcare, ultrasound imaging has a number of advantages. These advantages include "high axial resolution, short time to conduct the test, real-time image capture, lack of ionizing radiation, wide availability, and relatively low cost [1]. Ultrasound Imaging (USI) is an effective, economical, and noninvasive method that can provide visual feedback of the musculoskeletal system [2]. USI creates imaging of both superficial and deep anatomy of static muscles and joint structures. This technology has the ability to use internal calipers to measure distance between targeted structures in the body [1]. As technology has advanced, ultrasound imaging has become more accurate and accessible.

Ultrasound imaging has been shown to be a reliable measure for muscles and joints in the field of physical therapy. Recent studies have shown that physical therapists can reliably measure the shoulder (glenohumeral) joint space using USI [2,3,4]. Furthermore, ultrasound has been shown to be as effective as fluoroscopy, the current gold standard, in measuring medial knee gap width [5]. However, few studies have been reported that demonstrate the reliability of medial knee gap measurements with USI. Ultrasound, for the purpose of measurements, can lack inter-rater reliability because it is considered operator-dependent [6]. This potential lack of reliability is further illustrated by the fact that "few studies have evaluated the inter-rater and intra-rater reliability of quantitative ultrasound-based measurements of the musculoskeletal system [1]. Additionally, operator experience with ultrasound influences the reliability of the measurements. In a study done by Gellhorn inter-rater and intra-rater reliability were examined between novice and experienced ultrasound technicians measuring patellar tendon lengths. The study found that "inter-rater reliability in measuring both tendon Cross Sectional Area (CSA) and tendon length was excellent, with Intraclass Correlation Coefficients (ICC) between 0.90 and 0.96. Intra-rater reliability for tendon CSA was also generally excellent, with ICC between 0.87 and 0.96 [1]". The results of this study illustrate that "a well-defined protocol using bony anatomic landmarks as reference points from which to base soft tissue measurements can have excellent inter-rater reliability, even when performed by a relatively novice clinician [1]".

Some degree of training is essential for novice clinicians to reliably perform measurements. The extent of this training, how ever, is another variable that still needs more research. In a study conducted by Knobe et. al, they determined that a two-and-one-half hour course/lab in ultrasound was sufficient to prepare novice clinicians for the basics of using ultrasound to identify structures [7]. With regard to the experienced/expert designation, a study conducted by Gutierrez et al determined that rheumatologists with six years of experience with the ultrasound were considered experts [6]. However, no studies have examined novice versus experienced clinicians with regard to measuring knee joint gap. More research on the intra- and inter-reliability between novice versus experienced clinicians can make USI a powerful therapeutic tool for confirming the underlying anatomy for all therapists, particularly entry-level ones. Reliability of measuring anatomical structures can provide therapists with confidence in determining anatomical issues that could potentially contribute to a patient's musculoskeletal impairments. once© ability to reliably measure the medial knee gap can prove worthy in ruling in/out anatomical causes and strengthen diagnoses.

The purpose of this study is to determine if ultrasound imaging is reliable for both experienced and novice clinicians to measure the medial knee gap in a static position. This study examined inter-rater and intra-rater reliability, as well as experienced versus novice reliability. We hypothesize that the novel protocol used in this study will train novice therapists to reliably measure the medial knee joint space.

Methods

Study Design

This research study was designed as an inter-rater and intra-rater reliability study that examined reliability between both experienced and novice researchers. Participants included two PTs, certified in MSK USI, with eight years of experience using in USI usage. The three novice researchers were three upper-year Doctor of Physical Therapy students without USI experience.

The methods were broken down into image acquisition, novice education protocol, and the image measurement. All data was captured in January 2018.

Image acquisition

Two subjects volunteered to have their medial knee gap measured using ultrasound. Each subject had no prior history of a knee injury and were assessed for general laxity using the Beighton scale. The instrument used to both obtain the images and measure the gap between the joint surfaces of the femur and tibia was the XP700 GE Ultrasound unit. The subjects were positioned in hook-lying with their legs positioned on a wedge. The wedge ensured that subjects© knees remained in 55° of flexion, an ideal position to measure medial knee gap [8]. A single researcher, who is a physical therapist certified in musculoskeletal ultrasound, captured two ultrasound images of the subjects resting knee joint for each trial. A 12 MHz linear ultrasound probe was placed in an oblique sagittal orientation on the medial knee joint line (tibio-femoral gap) to allow images of the femur and tibia to be captured [9]. Internal bony landmarks (medial femoral and tibial condyles) were used to reproduce images, and image presets remained constant throughout the study. The Brightness Mode (B-mode) was utilized for the ultrasound imaging, which displayed the ultrasound echo as a cross-sectional grey-scale image. B-mode allowed viewing in real time to depict the positional relationship of several structures including bones and muscles [10].

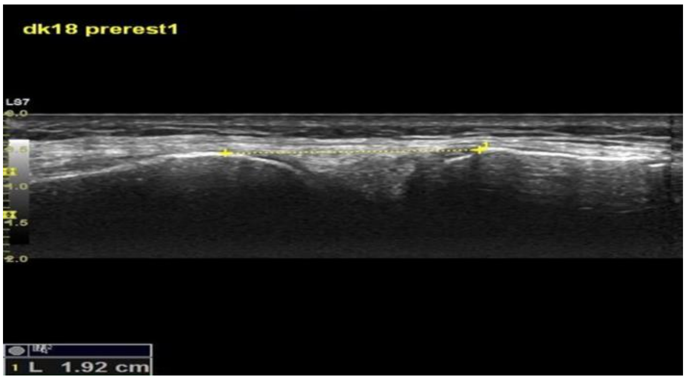
The researcher captured two images of the resting knee space a total of 86 times between the two subjects within a three-hour period, while physical therapy students practiced performing traction on the subjects between trials. This created a total of 76 images for subject one and 96 images for subject two.

Image measurement

In order to measure the joint space, internal calipers on the ultrasound machine were used to measure it in centimeters. (Figure 1) The calipers where be placed on the last horizontal hyper-echoic bone reflection of the femur and tibia (most distal femur to most proximal tibia) to standardize the measurement [5,11]. (Figure 2) The images were coded to blind all researchers to the subject.

Measuring ultrasound images using internal calipers.

Each of the five researchers independently measured the 166 images using internal calipers by following the protocol outlined above. Experienced One measured all of the images on two separate occasions one week apart in order to have data for intra-rater reliability. All measurements done by other researchers in the study were kept confidential to prevent bias.



Ultrasound image of medial femur and tibia joint line with internal calipers used to measure joint space.

Novice Education Protocol

The novice researchers received a uniform education according to a specific protocol. Each received three hours of training; how to capture and measure images on an ultrasound machine, mirroring a protocol developed for student sonographers to perform scans and identify structures [12]. This first consisted of an hour-long didactic lecture about using a real time ultrasound machine. They learned how to turn the machine on, choose the correct setting, and orient the probe and image. After that, they 75 minutes of observation where they learned about patient positioning, scanning techniques, labeling, measuring using calipers, and acquiring an image of the medial knee joint. Finally, they performed 45 minutes of capturing and measuring the images themselves, and all three were proficient in reproducing and measuring an image of the medial knee joint line with the bony landmarks used above.

Data analysis

Three sets of images had to be thrown out during post-processing because they were poor quality and the bony landmarks could not be identified. This led to a final total of 166 images to be measured among 172 images that were taken. The statistical software package SPSS 23 was used to analyze the data. Descriptive statistics were calculated and compared for each subject and for each of the researchers (table 1). The reliability in measuring the medial knee gap was analyzed by a mix model two-way ICC and a Standard Error of Measurement (SEM) (table 2). The inter-rater reliability was analyzed the ICC [3,1] using a two-way mixed effects model and single measures with a 95% confidence interval. Intra-rater reliability compared each of the novice researchers to Experienced One. An ICC value closer to 1.0 indicates better reliability. The SEM was calculated using the equation: SEM = SD x (√1-ICC) where SD is the standard deviation. SEM is expressed in millimeters, with a smaller SEM indicating less absolute error and a more reliable measurement [13].

TABLE 1

	Mean (cm)	Range (cm)	SD (cm)
Experienced 1A	1.745	1.150	0.227
Experienced 1B	1.719	1.200	0.219
Experienced 2	1.642	1.290	0.223
Novice 1	1.576	1.280	0.211
Novice 2	1.519	1.310	0.218
Novice 3	1.451	1.040	0.194

TABLE 2

Intra-rater Reliability	ICC	ICC (95%) Confidence interval	SEM (cm)
Experienced 1A vs Experienced 1B	0.919	.891 to .940	0.124
Inter-rater Reliability			
Experienced 1A vs Experienced 2	0.885	.847 to .914	0.148
Novice vs Expert Reliability			
Experienced 1A vs Novice 1	0.911	.882 to .934	0.127
Experienced 1A vs Novice 2	0.892	.856 to .919	0.142
Experienced 1A vs Novice 3	0.863	.819 to .898	0.151

Results

Subject one had a Beighton score of 0/9, while subject two had a Beighton score of need a period after 9/9 statistics calculated the First resting state measurement of the knee joint space for each subject, resulting in 82 images. Subject 1 at rest had a mean gap of 1.76mm SD 0.23mm (min 1.40- max 2.43). Subject 2 at rest had a mean gap of 1.73 SD 0.22mm (min 1.38- max 2.28). There was no significant difference between subject 1 and 2 at rest (82) = 0.16, p=0.54.

A total of 172 images of the knee at rest were captured. Three sets of images had to be thrown out during post-processing because they were poor quality and the bony landmarks could not be identified. This led to a final total of 166 images to be measured. A good degree of reliability was found between experienced inter-rater measurements. The ICC was 0.885 with a 95% confidence interval and a SEM of 0.148cm. An excellent degree of reliability was found between Novice One and Experienced One inter-rater measurements. Experienced One and Novice One had an ICC of 0.911 with a 95% confidence and a SEM of 0.127cm. A good degree of reliability was found between both Novice Two and Novice Three when comparing to Experienced One inter-rater measurements. Experienced One and Novice Two had an ICC of 0.892 with experienced one compared to experienced two result 95% confidence and a SEM of 0.142cm. Experienced One and Novice Three had an ICC of 0.863 with a 95% confidence and a SEM of 0.150cm. An excellent degree of reliability was also found between

Experienced One intra-rater measurements. Experienced One had an ICC of 0.919 with a 95% confidence and a SEM of 0.124cm.

Discussion

There were no significant differences in the first resting state measurement of the knee joint space between subject one and subject two (p=.54). This indicates consistent baseline results between subjects. Despite these findings subject two tested positive for 9/9 criteria on the Beighton score, indicating general joint hypermobility. This is in line with systematic review by Remvig in 2007, suggesting variability in the reliability and validity of the Beighton scale [14].

An excellent degree of reliability was found for both intra-rater and inter-rater measurements for Novice One and a good degree of reliability was found between Experienced One and Novice Two and Three. These findings may have clinical value. According to Larese et al. and Atkinson et al., an ICC >0.75 was considered good, an ICC >0.9 was considered excellent and an ICC > 0.92 is considered an accurate clinical measurement [15,16]. There is a small decrease in the mean measurements between the experts and the novice researchers. The difference is not significant, but the trend may suggest novice practitioners may be more conservative in identifying the limits of the knee gap. The consistency across measurements by the novice researchers supports the training protocol [17].

The positive results of reliability between the experienced clinician and novice clinicians indicate that the training protocol utilized by the novice researchers may be effective. The training protocol by Knobe et al. was referenced and modified to include didactic learning and hands-on practice [7]. During the hands-on practice, novice participants received knowledge of performance and knowledge of results from an experienced clinician to verify and confirm findings. This enhanced the learning for image acquisition and image measurement needed for this study.

More research on the intra- and inter-reliability between novice versus experienced clinicians can make USI a powerful therapeutic tool for confirming the underlying anatomy for all therapists, particularly entry-level ones. The comparison of experienced versus novice clinicians is aimed to prove that entry-level therapists can enter the field with the knowledge and ability to accurately measure anatomical structures in their patients. Reliability of measuring anatomical structures can give therapists confidence in determining anatomical issues that could potentially play a role in the patient's diagnosis. Although there are many etiologies that could cause dysfunction, anatomy should be a consideration of any therapist in diagnosis. Reliably measuring an anatomical structure can prove worthy in ruling in/out anatomical causes. The acuity of the images acquired from ultrasound in general can show issues such as dysplasia, dislocation, deep venous thromboses and aortic aneurisms [18,19,20]. For our purposes, an accurate and reliable measurement of the medial knee joint gap can help all therapists in the diagnosis of ligamentous injuries, bursitis, tendinopathies, osteoarthritis and other joint pathologies [21,22]. As more and more therapists become competent in measuring knee gaps in a variety of patient populations, the concepts of static measurements in ultrasound may be applied to dynamic movement in the future, catered to such things as sports performance and other areas of functional physical therapy.

The strengths of our study include having each measurer use the same static images, a strong sample size of images, a longer novice training than other research methods, and use of bony landmarks for standardization [7]. An additional strength of our study is that the novice training was not provided by the experienced clinician we were comparing our measurements with. Therefore, there is less potential for bias.

One limitation of our study is illustrated in the clinical application of our research. The reliability is unknown for image acquisition among novice measurers and could warrant further studies. An additional limitation of this study was the limited existence of evidence regarding novice-training protocol. Finally, while numerous images were used subjects©knees were measured. Each individual has slight variations in their knee anatomy. Therefore, there is potential for anatomic joint space variations in the rest of the population, which could make measurements more difficult for novice measurers.

Conclusions

The novice measurers in this study were at tained a high ICC when compared with experienced measurement data. Therefore, following a training, novice measurers in this study accuratetly measured anatomical structures with ultrasound. Proficiency with ultrasound will be a fairly important skill in a field that is increasing its use of the technology for its diagnostic purposes. This novel approach to examining ultrasound reliability will be a basis for future studies regarding ultrasound proficiency in novice clinicians.

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