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Validity and Reliability of Ultrasound Measurement of Knee Joint Space Width in Individuals With Knee Osteoarthritis

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Abstract

Background: Knee osteoarthritis (OA) is a single most arthritic disease. Knee joint space width (JSW) is commonly used for grading severity of knee OA. However, previous studies did not established criterion validity and test-retest reliability of ultrasound (US) image for measuring JSW.

Objects: The aim of this study was to establish criterion validity and test-retest reliability of US measurement of medial and lateral knee JSW.

Methods: Twenty-nine subjects with knee OA were participated. The US and X-ray were used to measure knee JSW. One sample Kolmogorov-Smirnov test was used to confirm the data normal distribution. Pearson correlation coefficient and ICC were used to calculated and establish criterion validity and test-retest reliability, respectively.

Results: US measurement of medial and lateral knee JSW was highly correlated with radiographic imaging measure (r=.714 and .704, respectively). Test-retest reliabilities of medial and lateral knee JSW were excellent correlated (ICC=.959 for medial side and .988 for lateral side, respectively).

Conclusion: US may be valid tool to measure knee JSW.

Key Words: Knee joint space width; Knee osteoarthritis; Reliability; Ultrasound; Validity.

Introduction

Knee osteoarthritis (OA) is a most common degenerative arthritic condition in the elderly population as characterized by degenerative articular cartilage and associated reduction in the joint space width, as well as persistent pain (Guermazi et al, 2012). Recent epidemic evidence suggests that approximately 25% of people aged over 60 years suffer from knee OA, which leads to chronic disability (Allen and Golightly, 2015; Dillon et al, 2006). Pain and other musculoskeletal symptoms in knee OA may have a detrimental impact on the quality of life compromising both physical and psychological functions (Urquhart et al, 2015). Although the etiology of knee OA is still controversial, it has been postulated that biomechanically, the narrowing of the knee joint space width (JSW) may be an important biomarker to predict the severity of the knee OA. The narrowing of the knee joint space are believed to be related with knee joint muscle imbalance, weakness, altered joint alignment (varus, valgus) deformity, and excessive external loading affecting articular cartilage erosion (Fernandez et al, 2016; Hubley-Kozey et al, 2009; Segal et al, 2010; Shull et al, 2013). Biomechanical evidence documented that the anatomical configuration of the medial compartment of the knee joint space is relatively larger and concave-shaped than the lateral compartment to embrace as large as 10 times load distribution during dynamic gait (Ahlback, 1968; Schipplein and Andriacchi, 1991). Such inherent biomechanical load distribution may predispose aged

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population to the progressive narrowing or deterioration of the medial compartment of the knee (JSW, approximately 3.35 ㎜) in knee OA when compared to healthy controls (JSW 4.21 ㎜) (Anas et al, 2013; Buckland-Wright et al, 1995).

A safe and accurate assessment of knee joint morphology is important for clinical diagnosis and progression prediction for individuals with knee OA (Wolfe and Lane, 2002). Conventionally, radiographic measurement for Kellgren and Lawrence (K-L) grade has been considered as a gold standard for classifying the levels of severity in knee OA (Kellgren and Lawrence, 1957; Hart and Spector, 2003). Previous studies have established reliability and validity of the radiographic measurement (MacKay et al, 2018; Riddle et al, 2013; Sheehy et al, 2015). Previous radiographic image study assessed reliability of JSW in individuals with knee OA. In the study, in assessments performed by a trained researcher, the intraclass coefficient (ICC) was >.8, indicating excellent measurement reliability of radiographic imaging of the medial JSW (MJSW) based on the K-L grading system (Günther and Sun, 1999). Albeit radiographic images' superior spatial resolution, ultrasound has the greater advantage over X-ray in that it is inexpensive and easy to perform, with US easier to maneuver than radiographic equipment. This allows dynamic and real-time data acquisitions without unwanted contraindications (Iagnocco 2010). Furthermore, US does not pose a biohazard radiation unlike radiographic imaging, and multiple-plane views for visualizations of soft tissue structures implicated in the pathophysiological progression of knee OA can be obtained during static dynamic movements (Berthiaume et al, 2005; Grassi et al, 1999; Hunter et al, 2006; Ko et al, 2007; Lijuan et al, 2017; McCune et al, 1990; Möller et al, 2008). A previous study reported good reliability in US measurement of femoral condylar cartilage thickness, with inter-rate reliability of between .75 and .96 (Naredo et al, 2009). Abraham et al (2011) investigated reliability and validity of ultrasound measured features in individuals with knee OA. In this study, reliability of ultrasound measured effusion size were .70 and .85 for right and left knee, respectively. Futhermore, in terms of US imaging of osteophytes, the authors reported moderate to excellent validity (.52 and .75 for right and left knee, respectively). Nevertheless, to the best of our knowledge, the test-retest reliability and validity of ultrasound imaging measurement, particularly for further evidence of specific biomarker of JSW in knee OA remains unknown. Therefore, the specific aim of the present study was to establish the test-retest reliability and validity of ultrasound imaging measurement as compared with the conventional radiographic measurement technique as developed by Kellgren and Lawrence. We hypothesized that the validity of ultrasound imaging measurement would be high to very high and test-retest reliability would be good to excellent to determine JSW in older adults with mild to moderate knee OA.

Methods

Subjects

Twenty-nine elderly subjects (5 men, 24 women; 76.2±5.3 years; 156.8±7.1 ㎝; 56.2±6.4 ㎏) with knee OA were recruited in the present study. All informed consent was given before they participated in the study. The present experimental protocol was approved by Yonsei University (approval number: 1041849-201712-BM-145-02).

Inclusion criteria were: (1) 65-85 years old; (2) able to walk 30 min without taking rest and climb up a stairway with reciprocal pattern; (3) complaining knee pain during normal activities of daily living; (4) diagnosed as mild-to-moderate knee OA (K-L grades II or III) in 1 or both knees using radiographic measurement; (5) diagnosed as medial knee OA. Exclusion criteria were: (1) Rheumatoid arthritis; (2) lower extremity surgical history (3) any exercise training history for knee OA (4) any neurological or

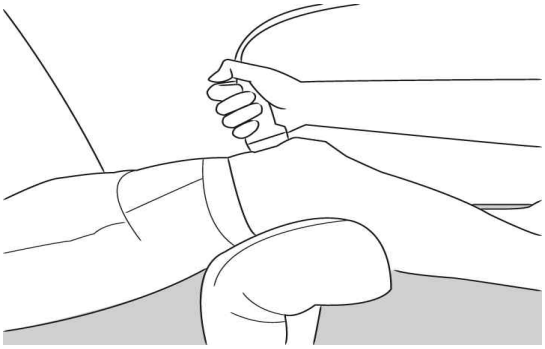

Figure 1. Ultrasound measurement of medial knee joint width.

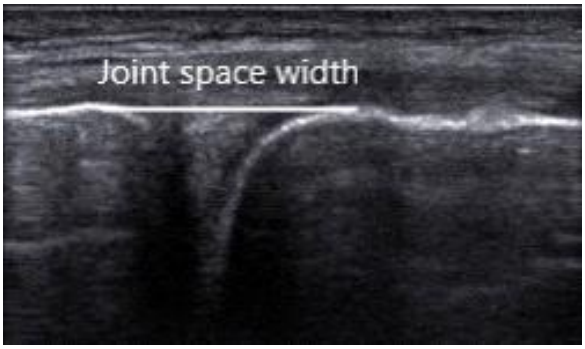

Figure 2. Example of medial knee joint space width.

cardiopulmonary disorder (5) any history of orthopedic disorders in the lower limbs including severe knee OA (> K-L grade III) or joint contracture; (6) any history of lower limb injury in 1 year; (7) lateral knee OA.

Experimental procedure

A physical health screening and survey were used to examine health status for all subjects before they participated in the study. Ultrasonographic medial and lateral knee JSW were obtained by using Ultrasound unit (The SonoAce, X8, Medison Co., Ltd, Seoul, Korea) and linear transducer (L5-12EC) in B-mode with a 10 MHz. X-ray system (REX-525RF XRAY SYSTEM, LISTEM, Inchon, Korea) was used to measure knee JSW in both knees. Every single radiograph was taken by the same radiologist with the consistent procedure using the same X-ray system and fluoroscopic table. All sonographic images were obtained from a single physical therapist (CYJ) with the same ultrasound unit.

Criterion validity

The validity of the ultrasound measurement was determined by comparing the JSW data obtained from the radiographic measurement.

(1) Radiographic measurement

The participant was sat on the fluoroscopic table with both knee full extension. The X-ray tube was placed in front of the knee cap which is parallel to at the knee joint line using 40 inches tube-film. In this position, the anteroposterior radiograph image of both knees was taken and the smallest medial and lateral compartment JSWs from all X-ray image were computed using the PacsPlus analysis software system (PacsPlusCV, Medical standard Co., Ltd. South Korea) (Koh et al, 2010).

(2) Ultrasound measurement

The participant was asked to sit with 20° bilateral knee flexion (Möller et al. 2008; Thorborg et al. 2010). A small bolster or rolled towel were placed under both knees to make her or him comfortable (Figure 1). The ultrasound measurement was recorded using the standardized landmarks and measurement procedure. Medial knee JSW (MJSW) was measured with the transducer which was placed on the medial collateral ligament and parallel to long-axis. On the other hand, lateral knee JSW (LJSW) was measured when the participant's knee 20° flexion and slight internal rotation. The optimal image scanning was performed by probing the anatomical landmark of the iliotibial band along the longitudinal axis, reaching down to the lateral tubercle of the tibia. The transducer was manually manipulated to obtain the clearest image. The JSW was is operationally defined as the length between the closest point to the skin of distal femur and proximal tibia (Möller et al. 2008), which was consistently taken 3 times by the identical investigator (CYJ), who is well-trained physical therapist, to calculate test-retest reliability (Figure 2).

Table 1. Demographic data of subjects (N=29)

Parameter	
Gender (men/women)	5/24
Age (years)	75.9±5.3[a]
Height (㎝)	156.8±7.0
Weight (㎏)	56.1±6.3
BMI[b] (㎏/㎡)	22.8±1.2

[a]mean±standard deviation, [b]body mass index.

Test-retest reliability

The test-retest reliability of US measurement was defined by test-retest JSW measurement consistency using real-time US data. A single investigator measured all US image of JSW with maintaining consistent testing conditions including experimental procedures such as verbal instruction, testing position, and testing environment. To calculate test-retest reliability, the same investigator (CYJ) measured the JSW three times.

Statistics

The descriptive statistics including means and standard deviation were conducted. All statistical analyses were computed using SPSS ver. 24.0 software (IBM Corp., Armonk, NY, USA). One-sample Kolmogorov-Smirnov test was used to confirm normal distribution of data. The criterion validity and test-retest reliability were computed using Pearson correlation coefficient (r) and intraclass correlation coefficients [ICC(3,1)] respectively. A significance level was set at $p<.05$.

Results

The subjects' demographic data were presented in Table 1. The criterion validity was defined by comparing the measurements obtained using the radiographic measuremet and US measurement. The correlation values (r) of the US measurement of MJSW and LJSW were found to be .714 and .704, respectively (Table 2). Table 3 represents test-retest reliability of US measurement of JSW. Test-retest reliability was found to be .959 (95%CI=.927-.979) for MJSW and .988 (95%CI=.978-.994) for LJSW.

Table 3. Test-retest reliability of ultrasound measurement of knee joint space width

	ICC(3,1)[a]	p-value
Medial side	.959	<.01*
Lateral side	.988	<.01*

[a]Intraclass correlation coefficient, *p<.01.

Discussion

While the US has recently gained a wide spread acceptance for determining articular features among the clinicians, the present study was to the first clinical study which establish the criterion validity and test-retest reliability of US measurement of JSW in individuals with knee OA. As anticipated, the criterion validity and test-retest reliability of US measurement were moderate to high and good to excellent, respectively, when compared to the conventional (gold standard) method. Most importantly, these novel findings provide important diagnostic implication for clinicians when making accurate clinical decision making for in individuals with knee OA who often exhibit degenerative erosion of knee joint and associated JSW loss.

In the present study, the correlational analysis of US measurements versus the radiographic measurements showed high criterion validity (r=.714 for me-

Table 2. Criterion validity of ultrasound measurement of knee joint space width

	Radiographic measurement (㎜)	Ultrasound measurement (㎜)	r	p-value
Medial side	.30±.09[a]	.50±.10	.714	<.01*
Lateral side	.60±.13	.80±.12	.704	<.01*

[a]mean±standard deviation, *p<.01.

dial side and .704 for lateral side). This validity data indicates that the accuracy of the ultrasound measurement is compatible to the conventional radiographic measurement of JSW in individuals with knee OA. This finding is consistent with that of an earlier study on intraobserver variability in US measurements. Tarhan and Unlu (2003) concluded that US measurement showed significant correlation with MRI findings for measuring cartilage and soft tissue changes. For cadevaric study, Naredo et al. (2008) found that US measurement showed good agreement with anatomic specimens for articualr cartilage on medial condyle. Unlike the previous studies, the present study measured criterion validity and test-retest reliability of US measurement for measuring JSW. It is important to establish the accuracy and reliability of US measurement in image acquisition, especially considering the dynamic nature of the US imaging technique. The results of the present study are therefore likely to be paralleled to the actual image value. Nevertheless, the clinical evidence associated with validity and reliability of US measurement of JSW is yet to be determined. JSW has been identified as a strong predictable factor for progression of knee OA (Wolfe and Lane, 2002). In particular, lateral knee joint space was found to be negatively correlated with patellar cartilage volume while medial knee joint space was inversely related with patellar and tibial cartilage erosion (Hunter et al, 2011).

The test-retest reliability analysis showed excellent correlations between the repeated measures, ranging from .959 (95%CI=.927-.979) for MJSW and .988 (95%CI=.978-.994) for LJSW, respectively. Certainly, this finding suggest that the ultrasound measurement is consistent or reproducible when determining the JSW in individuals with knee OA. This result supports Günther and Sun (1999) who examined reproducibility of radiographic measurement in knee OA using ICC. Intra-rater ICC ranged from .86 and .92 in medial and lateral knee JSW respectively. Similarly, Jonsson et al (1992) scanned cartilage thickness of six patients and four controls, which were repeated once within one to four weeks using the identical initial imaging procedure and found the radiographs, being the most consistent imaging modality (co-efficient of variation; CV=6.5%), followed by ultrasound (CV=8.4%) and magnetic resonance imaging (CV=12%).

Taken together, the present study suggest that US measurement may be valid tool to measure JSW and to determine the K-L grade in individuals with knee OA because it is well correlated with radiographic image. However, a couple of study limitations should be considered for future investigation. One limitation was that the gender was not matched since the prevalence of OA is much higher in female than male, which reflected the gender ratio of the community population from which the subjects of the present study were recruited. Another limitation was that the initial measurement position of JSW between the US and radiographic measurements were not identical due to a mechanical limitation of the radiographic measurement tool. This discrepancy of initial measurement position may affect our data. The future study should use a compatible radiographic tool with ultrasound imaging equipment to better equate the initial position of measurement.

Conclusion

The present ultrasound validity and reliability test established good validity and excellent test-retest reliability in the in individuals with mild to moderate knee OA. Clinically, the US measurement is useful tool to accurately and consistently quantify the JSW, which better assist in diagnosing the OA.

References

Abraham AM, Goff I, Pearce MS, et al. Reliability and validity of ultrasound imaging of features of knee osteoarthritis in the community. BMC Musculo-

skelet Disord. 2011;12:70. https://doi.org/10.1186/1471-2474-12-70

Ahlback S. Osteoarthrosis of the knee. A radiographic investigation. Acta Radiol. 1968;Suppl 277:7-72.

Allen KD, Golightly YM. Epidemiology of osteoarthritis: State of the evidence. Curr Opin Rheumatol. 2015;27(3):276-283. https://doi.org/10.1097/BOR.0000000000000161

Anas I, Musa TA, Kabiru I, et al. Digital radiographic measurement of normal knee joint space in adults at Kano, Nigeria. The Egyptian Journal of Radiology and Nuclear Medicine. 2013;44(2):253-258.

Berthiaume MJ, Raynauld JP, Martel-Pelletier J, et al. Meniscal tear and extrusion are strongly associated with progression of symptomatic knee osteoarthritis as assessed by quantitative magnetic resonance imaging. Ann Rheum Dis. 2005;64(4):556-563. https://doi.org/10.1136/and.2004.023796

Buckland-Wright JC, Macfarlane DG, Lynch JA, et al. Joint space width measures cartilage thickness in osteoarthritis of the knee: high resolution plain film and double contrast macroradiographic investigation. Ann Rheum Dis. 1995;54(4):263-268.

Dillon CF, Rasch EK, Gu Q, et al. Prevalence of knee osteoarthritis in the United States: arthritis data from the third national health and nutrition examination survey 1991-94. J Rheumatol 2006;33(11):2271-2279.

Fernandez C, Cleland J, Dommerholt J. Manual Therapy for Musculoskeletal Pain Syndrome: An evidence- and clinical informed approach. Philadelphia, Churchill livingstone, Elsevier. 2015:482-489.

Guermazi A, Niu J, Hayashi D, et al. Prevalence of abnormalities in knees detected by MRI in adults without knee osteoarthritis: Population based observational study (Framingham osteoarthritis study). BMJ. 2012;345:e5339. https://doi.org/10.1136/bmj.e5339

Günther KP, Sun Y. Reliability of radiographic assessment in hip and knee osteoarthritis. Osteoarthr Cartilage. 1999;7(2):239-246.

Grassi W, Lamanna G, Farina A, et al. Sonographic imaging of normal and osteoarthritic cartilage. Semin Arthritis Rheum. 1999;28(6):398-403.

Hart DJ, Spector TD. Kellgren & Lawrence grade 1 osteophytes in the knee-doubtful or definite? Osteoarthritis Cartilage. 2003;11(2):149-150.

He L, Qi Y, Wang Q, et al. The correlation between ultrasonographic findings and the Lysholm scores in knee osteoarthritis. Journal of Traditional Chinese Medical Sciences. 2017;4(2):141-148. https://doi.org/10.1016/j.jtcms.2017.08.007

Hubley-Kozey CL, Hill NA, Rutherford DJ, et al. Co-activation differences in lower limb muscles between asymptomatic controls and those with varying degrees of knee osteoarthritis during walking. Clin Biomech (Bristol, Avon). 2009;24(5):407-414. https://doi.org/10.1016/j.clinbiomech.2009.02.005

Hunter DJ, Zhang W, Conaghan PG, et al. Systematic review of the concurrent and predictive validity of MRI biomarkers in OA. Osteoarthritis Cartilage. 2011;19(5):557-588. https://doi.org/10.1016/j.joca.2010.10.029

Hunter DJ, Zhang YQ, Niu JB, et al. The association of meniscal pathologic changes with cartilage loss in symptomatic knee osteoarthritis. Arthritis Rheum. 2006;54(3):795-801. https://doi.org/10.1002/art.21724

Iagnocco A. Imaging the joint in osteoarthritis: A place for ultrasound? Best Pract Res Clin Rheumatol. 2010;24(1):27-38. https://doi.org/10.1016/j.berh.2009.08.012

Jonsson K, Buckwalter K, Helvie M, et al. Precision of Hyaline Cartilage Thickness Measurements. Acta Radiol. 1992;33(3):234-239

Kellgren JH and Lawrence JS, Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957;16(4):494-502.

Ko CH, Chan KK, Peng HL. Sonographic imaging of meniscal subluxation in patients with radiographic knee osteoarthritis. J Formos Med Assoc.

2007;106(9):700-707. https://doi.org/10.1016/S0929-6646(08)60031-5

Koh YH, Hong SH, Kang HS, et al. The effects of bone turnover rate on subchondral trabecular bone structure and cartilage damage in the osteoarthritis rat model. Rheumatol Int. 2010;30(9):1165-1171. https://doi.org/10.1007/s00296-009-1118-x

MacKay JW, Low SBL, Smith TO, et al. Systematic review and meta-analysis of the reliability and discriminative validity of cartilage compositional MRI in knee osteoarthritis. Osteoarthritis Cartilage. 2018;26(9):1140-1152. https://doi.org/10.1016/j.joca.2017.11.018

McCune WJ, Dedrick DK, Aisen AM, et al. Sonographic evaluation of osteoarthritic femoral condylar cartilage: Correlation with operative findings. Clin Orthop Relat Res. 1990;254:230-235.

Möller I, Bong D, Naredo E, et al. Ultrasound in the study and monitoring of osteoarthritis. Osteoarthritis Cartilage. 2008;16 Suppl 3:S4-S7. https://doi.org/10.1016/j.joca.2008.06.005

Naredo E, Acebes C, Möller I, et al. Ultrasound validity in the measurement of knee cartilage thickness. Ann Rheum Dis. 2009;68(8):1322-1327. https://doi.org/10.1136/ard.2008.090738

Riddle DL, Jiranek WA, Hull JR. Validity and reliability of radiographic knee osteoarthritis measures by arthroplasty surgeons. Orthopedics. 2013;36(1):e25-32. https://doi.org/10.3928/01477447-20121217-14

Schipplein OD, Andriacchi TP. Interaction between active and passive knee stabilizers during level walking. J Orthop Res. 1991;9(1):113-119.

Segal NA, Glass NA, Torner J, et al. Quadriceps weakness predicts risk for knee joint space narrowing in women in the MOST cohort. Osteoarthritis Cartilage. 2010;18(6):769-775. https://doi.org/10.1016/j.joca.2010.02.002

Sheehy L, Culham E, McLean L, et al. Validity and sensitivity to change of three scales for the radiographic assessment of knee osteoarthritis using images from the Multicenter Osteoarthritis Study (MOST). Osteoarthritis Cartilage. 2015;23(9):1491-1498. https://doi.org/10.1016/j.joca.2015.05.003

Shull PB, Silder A, Shultz R, et al. Six-week gait retraining program reduces knee adduction moment, reduces pain, and improves function for individuals with medial compartment knee osteoarthritis. J Orthop Res. 2013;31(7):1020-1025. https://doi.org/10.1002/jor.22340

Tarhan S, Unlu Z. Magnetic resonance imaging and ultrasonographic evaluation of the patients with knee osteoarthritis: a comparative study. Clin Rheumatol. 2003;22(3):181-188. https://doi.org/10.1007/s10067-002-0694-x

Thorborg K, Petersen J, Magnusson SP, et al. Clinical assessment of hip strength using a hand-held dynamometer is reliable. Scand J Med Sci Sports. 2010;20(3):493-501. https://doi.org/10.1111/j.1600-0838.2009.00958.x

Urquhart DM, Phyomaung PP, Dubowitz J, et al. Are cognitive and behavioural factors associated with knee pain? A systematic review. Semin Arthritis Rheum 2015;44(4):445-455. https://doi.org/10.1016/j.semarthrit.2014.07.005

Wolfe F, Lane NE. The longterm outcome of osteoarthritis: Rates and predictors of joint space narrowing in symptomatic patients with knee osteoarthritis. J Rheumatol. 2002;29(1):139-146.

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