

Shearwave elastography of the knee menisci

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Abstract

Objectives: Sonoelastography is a relatively new technique used to evaluate the musculoskeletal system, but shear wave elastography of the knee menisci has not previously been reported. The purpose of this study is to study sonoelastographic features of the knee menisci.

Methods: 34 knee joints were studied, in 17 healthy subjects. Shear wave elastography was used to evaluate the anterior horn of the medial meniscus. Normal sonoelastographic values were obtained.

Results: The mean shear elastic modulus of the anterior horn of the right medial meniscus was 24.86 kPa (range 15.3- 36.1 \pm 6.35 SD), and 23.86 kPa (range 14.6-37.6 \pm 4.49 SD) for the anterior horn of the left medial meniscus. Inverse correlation was noted between the right medial meniscus elasticity and height. Inverse correlation was noted between the left medial meniscus elasticity and age, while positive correlation was noted between left medial meniscus elasticity and BMI.

Conclusion: The elastic modulus of the knee menisci has been determined in healthy subjects and can serve as a reference when studying pathological conditions of these structures .

Background

The menisci are semicircular fibrocartilagenous structures that function within the knee joint to protect the underlying articular cartilage. They also act as weight absorbers and provide stability. ^[1,2]

Tension/compression nonlinearities are among the complex biomechanical properties of the menisci. Considering the fact that of limited ability of the menisci to heal, studying the changes of the biomechanical meniscal properties occurring with degenerative osteoarthritis can help in the prevention and treatment of degeneration. ^[1] Some studies were performed on the normal human meniscus and proved decrease of the compressive modulus with the increase in meniscal degeneration ^[1-5]

Arthroscopy is considered the gold standard for the diagnosis of meniscal pathologies, however, the price, invasive nature, and the need for high skill are among its drawbacks. Magnetic resonance imaging [MRI] is a non-invasive imaging technique, with more than 90% accuracy in the diagnosis of meniscal injuries, however, it is an expensive modality, with long acquisition time, beside claustrophobia experienced in some patients. ^[6] High resolution ultrasound is a noninvasive, cheap, and fast technique, however, its diagnostic accuracy is clearly less than arthroscopy and MRI. It has been used for more than twenty years in the assessment of soft tissues and the musculoskeletal system. ^[6] Shear wave elastography was introduced as a new era of ultrasound where the transducer induces an acoustic pulse that stimulate the target tissue and propagate transverse shear waves with particle displacement and consequent attenuation by different tissues. This displacement is measured as numerical value and related to the Young modulus formula. ^[7] The main advantage of the shear wave elastography is that it is reproducible, operator independent and quantitative. Another type of elastography exists (strain elastography) and depends on mild manual pressure on the probe that gives an impulse and measure tissue stiffness. ^[7-12] The purpose of this study is to study sonoelastographic features of the knee menisci.

Methods

Participants

34 knee joints in 17 healthy adult subjects (1 male, 16 females), mean age 27.35 ± 1.77 SD, (range 24–30), mean height $155.29 \text{ cm} \pm 5.78$ SD (range 144–165), mean weight $54.89 \text{ kg} \pm 10.03$ SD (range 43–84). After institutional review board approval, participants of the study were recruited between September 2019 and October 2019, and written consent was obtained. Exclusion criteria included: History of knee trauma, lower limb surgery, osteoarthritis, inflammatory arthritis, and rheumatic diseases. For each participant, data including sex, age, weight, BMI and height were recorded.

Technique

The anterior horn of the medial menisci of both knees was scanned in coronal view, with the L18-4, MHz linear-array transducer (EPIQ Elite SW 5.0.1, Ultrasound system: Philips, Bothell). All examinations were performed by two experienced radiologists (M.B, 19 years of experience) and (A.E, 15 years of experience). All subjects were scanned in the supine position with the knee joint in a 30 degrees flexion. Each subject was scanned three consecutive times with probe removed from the skin between measurements to assess intra-observer reliability. To increase the reliability of the reported stiffness values, a confidence map is used to mask areas below a specific confidence level. After identifying the anterior horn of the medial meniscus, the probe was held stationary for 5 seconds and a 2 mm diameter region of interest (ROI) circle was placed over the examined meniscus. After viewing the color map, real time shear wave images were recorded with color coding. The readings consisted of median elasticity (MED), maximum elasticity (MAX), and average elasticity (AVG) with standard deviation (SD) and were reported in kPa. The color scale was mapped to a 0 kPa to 200 kPa range. The spectrum of scale colors range from blue for softer tissues through red for stiffer tissues (Fig. 1).

Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 21 software (SPSS Inc., Chicago, IL, USA).

All data were presented as mean \pm standard deviation (SD) and range. Intra-observer variability was measured using Kohen's Kappatest. Independent sample test was used to assess the differences between mean elasticity of the right and left medial menisci. The correlations between the mean elasticity bilaterally and age, weight, height and BMI were calculated by Pearson correlation coefficient test.

Results

The study included 17 healthy adult subjects (16 females, 1 male), with a mean age of 27.35 ± 1.77 , mean height $155.3 \text{ cm} \pm 5.78$, mean weight $54.89 \text{ kg} \pm 10$, mean BMI 22.6 ± 3.1 . Table 1 showed descriptive statistics used in our study. The intra-observer reliability calculations resulted in an overall

intra-class correlation coefficient of 0.87. The mean shear elastic modulus of the anterior horn of the right medial meniscus was 24.86 kPa (range 15.3–36.1 ± 6.35 SD), and for the anterior horn of the left medial meniscus was 23.86 kPa (range 14.6–37.6 ± 4.49 SD). We compared the values of the mean shear wave elastic modulus at the right and left sides in each subject and no significant statistical differences were noted ($p < 0.05$). Negative correlation was found between the elasticity of the right medial meniscus and height ($p > 0.05$). No significant statistical correlation was found between the elasticity of the right medial meniscus, weight, BMI, and age. Negative correlation was found between the elasticity of the left medial meniscus and age ($p > 0.001$). Positive correlation was found between the elasticity of the left medial meniscus and BMI ($p > 0.05$). No significant statistical correlation was found between the elasticity of the left medial meniscus, weight, and height. Table 2

Discussion

We studied the anterior horn of the medial menisci bilaterally in healthy adult subjects by quantitative shearwave elastography. The relationship between elasticity and height, weight, body mass index, gender, were also studied. Significant inverse correlation was noted between the right medial meniscus elasticity and height. Other demographic factors showed no significant relation to the right medial meniscus elasticity. Significant inverse correlation was noted between the left medial meniscus elasticity and age, while significant positive correlation was noted between left medial meniscus elasticity and BMI. Some studies considered evaluation of the mean stiffness of some components of the musculoskeletal system by shearwave elastography. For example the elasticity of the Achilles tendon in the resting position was 51.5 kPa, while the elasticity of supraspinatous tendon was 29.1 kPa. The elasticity of the gastrocnemius was 16.5 kPa in the resting position and 225.4 kPa during contraction. Fewer studies involved ligaments like the transverse carpal ligaments (55.2 kPa).^[13–17] Important peripheral nerves were also evaluated by elastography like the median nerve with a mean elasticity at the carpal tunnel reaching 32 kPa.^[18] The values of mean elasticity of the menisci obtained in our study are expected to be increase or decrease in different types of pathologies according the degree of stiffness. The anatomical position of the medial meniscus was great challenge confronting our study. In order to optimize our images, minimum amount of transducer pressure was used, together with thick layer of gel in each scan, since precompression of the tissue can impact their stiffness. Some studies [Akaya et al and Cay et al] considered the knee joint by elastography, however, both dealt with the femoral condyle cartilage and both were done by the strain type.^[19, 20]

Only one study was found in the literature was reported to study the knee menisci by SWE. Park et al studied five healthy volunteers revealing comparable results to our study, with a mean stiffness of the medial meniscus (30.6 ± 3.5 kPa), and lateral meniscus stiffness (23.3 ± 3.1 kPa), compared to (24.86 kPa ± 6.35 SD) at the right anterior horn medial meniscus, and (23.86 kPa ± 4.49) at the left anterior horn medial meniscus, in our study. He also revealed correlation between stiffness measurements in the menisci and the degree of meniscal degeneration.^[21]

This study has several limitations. First, the sample size is small and this decreases the accuracy of results of elasticity measures in addition to the comparison to the demographic factors. Second, all the participants were females which limits generalization of our results. Third, The mean age was 27.35 ± 1.77 . Fourth, the study only involved the anterior horn of the medial meniscus. Future studies on larger sample size, evenly distributed on both sexes with wider age range, and evaluating the posterior horn of the medial meniscus together with both horns of the lateral meniscus could help to increase the accuracy reliability and reproducibility of these measurements. These further studies should consider the elasticity in meniscal degeneration and traumatic injuries and comparing them to the elasticity of the normal menisci.

Conclusion

Shear wave elastography, could be a useful future tool to aid in the studying change of the stiffness of the knee menisci in different pathologies for diagnostic and therapeutic purposes.

Abbreviations

shearwave elastography, SWE, body mass index, BMI, Magnetic resonance imaging, MRI

Declarations

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Author contribution MA Bedewi designed the study, conducted the searches, and was the major contributor in drafting, writing and edited the manuscript. A A Sifey assisted in interpretation of the data. A K Saleh assisted in interpretation of the data. T Alfaifi codesigned the study. All authors read and approved the final manuscript.

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Availability of data and materials All data generated or analyzed during the study are available from the first and corresponding author.

Ethics approval and consent to participate This study was approved the institutional review board of the college of medicine in Prince Sattam Bin Abdulaziz university.

Consent for Publication Consent was obtained from all study participants.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1

Overview of the descriptive statistics of the study population

	N	Mean	Minimum	Maximum	Std Deviation
Age (Years)	17	27.35	24	30	1.77
Weight (Kg)	17	54.89	43	84	10.03
Height (Cm)	17	155.29	144	165	5.78
BMI	17	22.60	18.7	30.9	3.11

BMI= Body mass index

Table 2

Correlation between Mean elasticity of the medial meniscus and demographic factors.

	RT MM	LT MM
Age	-0.264	-0.636**
Sig	0.306	0.006
Weight/kg	-0.081	0.377
Sig	0.758	0.135
Height/cm	-0.564*	-0.051
Sig	0.018	0.847
BMI	0.199	0.501*
Sig	0.443	0.040

MM= Medial meniscus

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Figures

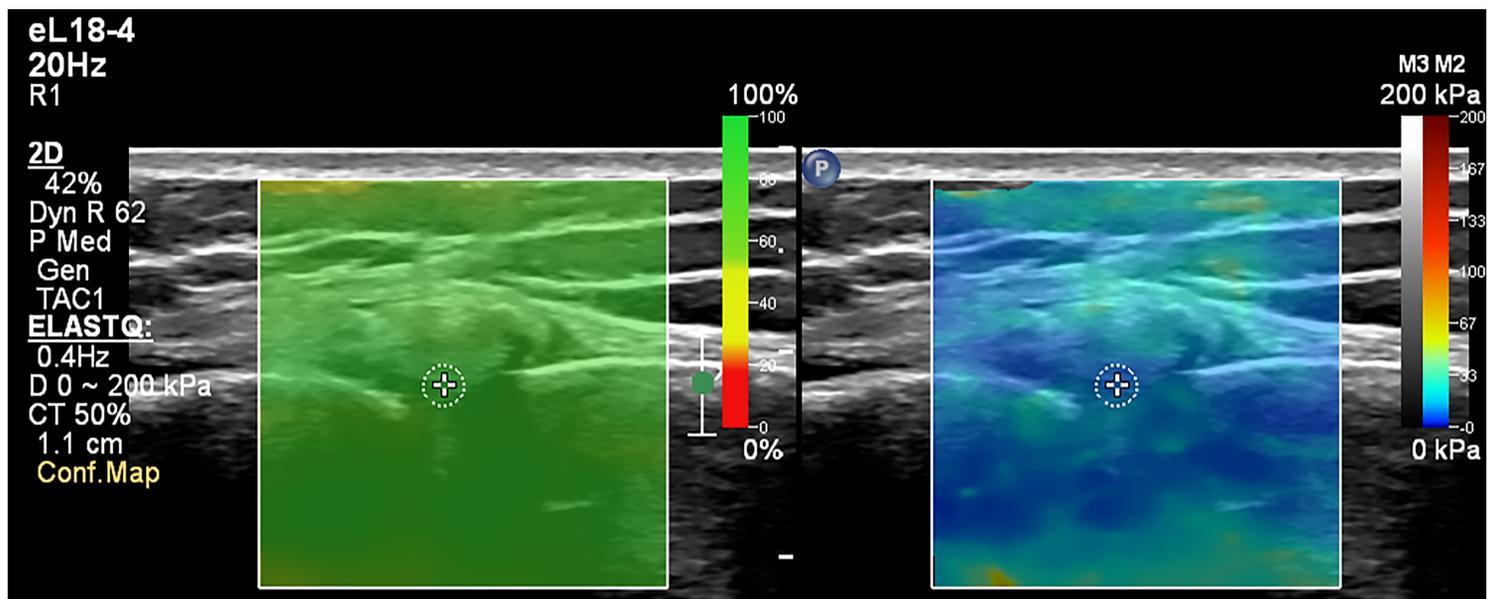


Figure 1

Elastographic measurement. Coronal view of the anterior horn medial mensicus shearwave elastography, with confidence map on the left, color map with measurement of stiffness on the right side in kPa.