Quantitative Measurement of Achilles Tendon Elasticity using Ultrasound Elastography: Measurement Repeatability and Normative Value

Yohei Yamamoto, Satoshi Yamaguchi, MD, PhD, Takahisa Sasho, MD, PhD, Taisuke Fukawa, Yuta Muramatsu, Shunsuke Mukoyama, Yorikazu Akatsu, Jo Katsuragi, Jun Endo, Hiroko Hoshi, Kenji Takahashi, Kazuhiisa Takahashi.

1Department of Orthopaedic Surgery, Graduate School of Medical and Pharmaceutical Sciences, Chiba University, Chiba, Japan, 2Funabashi Orthopaedic Hospital, Chiba, Japan.

Disclosures:

Introduction: Degeneration of the Achilles tendon is a risk factor of Achilles tendon rupture and tendinopathy. It is assessed using MRI and conventional ultrasonography, however these are qualitative measures, and there is no quantitative method. Ultrasound elastography is an ultrasound technique to measures tissue elasticity. Studies have shown that elasticity of the Achilles tendon measured with elastography correlates with tendon degeneration, and the strain of the Achilles tendon with tendinopathy is higher (i.e. softer) than the normal tendon [1]. However, conventional elastography is also qualitative measurement, and quantitative measurement is necessary to precisely assess tendon degeneration. Recently quantitative elastography has developed. Application of the quantitative method to the Achilles tendon has not been reported. The purposes of this study were 1) to measure intraobserver and interobserver repeatability of quantitative elastography for the Achilles tendon, 2) to assess correlation between the quantitative measurement and conventional qualitative measurements and 3) to compare the elastography values among different age groups.

Methods: Each Achilles tendon was examined in a prone position with the feet hanging over the edge of the examination bed. The longitudinal image of the middle third of the tendon between the musculotendinous junction and the calcaneal insertion was evaluated with an ultrasound system and the linear probe (6~14MHz). For quantitative elastography, an acoustic coupler with a gel pad of known Young's module (22.6±2.2kPa) was attached on the probe. Color mapping of the tissue strain was superimposed on the B-mode image, ranging from red (soft), green/yellow (medium) to blue (stiff) (Fig. 1). Strain value of the tendon (B) was divided by that of the coupler (A), and the strain ratio (SR) of the tendon was calculated (B/A). For conventional B-mode image, the tendon degeneration was divided into three grades based on the shape and intratendinous signal of the tendon (Grade 1: normal, 2: enlarged and 3: hypoechoic). For qualitative elastography, the color map of the tendon strain was visually divided into three grades (Grade 1: blue-hard, 2: yellow-medium and 3: red-soft). Intraobserver repeatability was examined by one experienced orthopaedic surgeon. Subjects were 100 asymptomatic Achilles tendons of 50 healthy volunteers (25 men and 25 women; 5 men and 5 women in each decade of age from their 20s to 60s). SR measurement was repeated four times for each tendon. Intraclass correlation coefficient (ICC (1, 1)) and standard error of the mean were calculated. Interobserver repeatability was examined by two experienced orthopaedic surgeons. Subjects were 50 asymptomatic Achilles tendons of 25 healthy volunteers, who were independent of the intraobserver study. Interobserver repeatability was assessed using the ICC (2, 2). Correlations between the SR and the B-mode grading, and the SR and the qualitative elastography grading were assessed using the Wilcoxon signed-rank test. The SR values were compared among the age groups (20s to 60s) using the Kruskal-Wallis test. Statistical significance was set at p<0.05.

Results: The average SR of the 100 Achilles tendons was 0.40. The ICC (1, 1) was 0.63, and the standard error was 0.10. The ICC (2, 2) was 0.90. The average SRs were 0.39 and 0.67 for the grade 1 and 2 B-mode imaging, respectively. The SR in the grade 2 tendon was significantly higher than in the grade 1 tendon (P = 0.005) (Fig. 2). The average SRs were 0.33 and 0.49 for the qualitative elastography grade 1 and 2, respectively. The value in the grade 2 tendon was significantly higher than in the grade 1 tendon (P < 0.001) (Fig.3). The average SRs of each age group (20s-60s) were 0.38, 0.28, 0.45, 0.42 and 0.45. The SR of the 30s was significantly lower (stiffer) than those of the other groups (P < 0.001).

Discussion: Quantitative elastography is a new ultrasound technique. We showed high intraobserver and interobserver repeatability for the measurement of the Achilles tendon elasticity. We also showed significant correlations between the SR values and the conventional qualitative measurements to assess tendon degeneration. Interestingly, the tendons of 30s were significantly stiffer than those of the other age groups. Quantitative elastography can be a useful method to quantify degeneration of the Achilles tendon. The intraobserver and interobserver repeatability of the SR measurement using the acoustic coupler was substantial and almost perfect. Drakonaki et al. measured SR of the Achilles tendon with the Kager’s fat pad as a reference [2]. The ICC for intra- and interobserver repeatability of the measurements were 0.66-0.78 and 0.51,
respectively. Use of the coupler would guarantee consistency of the measurement. The SR was correlated with the conventional ultrasound evaluation to quantify degeneration of the Achilles tendon; the degenerated tendon was softer than the normal tendon. Palle et al. measured elasticity of the Achilles tendon using conventional qualitative elastography, and reported that tendons with tendinopathy were softer than normal tendons, which agreed with our results [3]. Quantitative elastography may be a useful method to more accurately quantify degeneration of the Achilles tendon than the conventional elastography which has only three grades. The Achilles tendon in the 30s was significantly stiffer than those in other age groups. Nakagawa et al. reported the Achilles tendons of young adult rabbit had higher tensile strength than the immature and old rabbits do [4]. However, the strain ratio in this study represents elasticity against the transverse compression force. Further research is necessary to clarify relationship between the strain ratio and mechanical property of the tendon.

**Significance:** Degeneration of the Achilles tendon is a risk factor of Achilles tendon rupture and tendinopathy. Quantitative elastography using the acoustic coupler can be a useful method to quantify degeneration of the Achilles tendon.

**Acknowledgments:**


![Image](image.jpg)

**Fig. 1.** B-mode (right) and elastography (left) images of the Achilles tendon. In the left image, color mapping of the tissue strain was superimposed on the B-mode image. A: region of interest in the acoustic coupler; B: region of interest in the Achilles tendon.
Fig. 2. Correlation between the strain ratio and the conventional B-mode grading for the evaluation of Achilles tendon degeneration.
Fig. 3. Correlation between the strain ratio and the qualitative elastography grading.

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