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Evaluation of Sonoelastography Compatibility on the Achilles Tendon Between Different Devices and Observers

Aşil Tendonunun Sonoelastografisinde Farklı Cihazlar ve Gözleyiciler Arasındaki Uyumluluğun Değerlendirilmesi

Özlem ÜNAL[1]
0000-0003-4297-4930
Şule GÜZEL[2]
0000-0002-0692-3952
Sinem ŞİĞİT İKİZ[3]
0000-0001-5342-9589
Ayşenur ŞİRİN ÖZCAN[4]
0000-0003-0019-8515

[1]Yıldırım Beyazıt University Faculty of Medicine Department of Radiology, Ankara, Turkey

[2]Yenimahalle Training and Research Hospital Department of Radiology, Ankara, Turkey

[3]Dr. Burhan Nalbantoğlu State Hospital Radiology Clinic, Lefkoşa/Nicosia, Cyprus

[4]Ankara City Hospital Radiology Clinic, Ankara, Turkey

Sorumlu Yazar
Corresponding Author
Özlem ÜNAL
drozlemsarici@gmail.com

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ABSTRACT

Aim: To investigate the reliability of sonoelastography by comparing the Achilles tendon strain ratio obtained in healthy volunteers by different observers with different sonoelastography devices working on the same principle.
Material and Methods: A total of 80 Achilles tendons in 40 volunteers without chronic disease were evaluated using Toshiba and Hitachi devices using real-time elastography principle. The Kager fat pad was selected for strain ratio measurement. Each tendon was evaluated with both devices twice by both observers. The intraobserver and interobserver agreement were examined by intraclass correlation coefficient (ICC) obtained by two-way mixed ANOVA model for absolute agreement and interpreted as Ko and Li (11) suggested.
Results: Interobserver agreement in the first and second measurements of the Hitachi device and in the second measurements of the Toshiba device was found to be good (average ICC>0.75). The interobserver agreement in the first measurements made on the Toshiba device was found to be lower (average ICC=0.729, p<0.001). The intraobserver agreement was found to be excellent (ICC>0.90) for both device. The interobserver agreement for the Toshiba device was found lower than for the Hitachi device. Mean strain ratio was 2.96±1.07 for the Hitachi device and 3.54±1.03 for the Toshiba device. Measurements obtained from the Toshiba device were determined as significantly higher than those from the Hitachi device.
Conclusion: There may be differences in strain rates depending on the compression application limits of the devices, in studies carried out using different devices. Therefore, intraobserver and interobserver agreement should be evaluated separately for each device.
Keywords: Sonoelastography; strain ratio; achilles tendon.

ÖZ

Amaç: Aynı prensiple çalışan farklı sonoelastografi cihazlarında, farklı gözleyiciler tarafından sağlıklı gönüllülerden elde edilen aşil tendonu gerinim oranlarını karşılaştırarak sonoelastografinin güvenilirliğini araştırmak.
Gereç ve Yöntemler: Kronik hastalığı olmayan 40 gönüllüde toplam 80 aşil tendonu, real-time elastografi prensibi ile çalışan Toshiba ve Hitachi marka cihazlar kullanılarak değerlendirildi. Gerinim oranı ölçümü için Kager yağ planı seçildi. Her bir tendon, her iki cihazda her iki gözleyici tarafından iki kez değerlendirildi. Gözleyici içi ve gözleyiciler arası uyum, iki yönlü ANOVA modelinden mutlak uyum için elde edilen sınıf içi korelasyon katsayısı (SKK) ile incelenerek Ko ve Li'nin (11) önerdiği sınıflandırmaya göre yorumlandı.
Bulgular: Hitachi marka cihazda yapılan birinci ve ikinci ölçümlerde, Toshiba marka cihazda yapılan ikinci ölçümde gözleyiciler arası uyumun iyi seviyede olduğu tespit edildi. (ortalama SKK>0,75). Toshiba marka cihazda yapılan birinci ölçümde ise gözleyiciler arası uyumun daha düşük olduğu saptandı (ortalama SKK=0,729, p<0,001). Her iki cihazda da gözleyiciler içi uyumun mükemmel seviyede olduğu izlendi (SKK>0,90). Toshiba marka cihaz için gözleyiciler arası uyumun Hitachi marka cihaza göre daha düşük olduğu görüldü. Gerinim oranlarının ortalaması Hitachi marka cihaz için 2.96±1.07 ve Toshiba marka cihaz için 3.54±1.03 idi. Toshiba marka cihazdan elde edilen ölçümlerin, Hitachi marka cihazdan elde edilen ölçümlere göre anlamlı düzeyde yüksek olduğu belirlendi.
Sonuç: Farklı cihazlarla yapılan çalışmalarda cihazların kompresyon uygulama sınırlarına bağlı olarak gerinim oranlarında farklılıklar olabilir. Bu nedenle her cihaz için gözleyici içi ve gözleyiciler arası uyum ayrı ayrı değerlendirilmelidir.
Anahtar kelimeler: Sonoelastografi; gerinim oranı; aşil tendonu.

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INTRODUCTION

Sonoelastography is an imaging method based on ultrasonography (US), which uses conventional US devices to semi-quantitatively measure the degree of localisation change according to the deformation characteristic proportional to the hardness of the tissue on which pressure is applied (1-6).

That tissue elasticity can be revealed with elastography has been known since the beginning of the 1980s. Rapid developments in computer and US technology in recent years has enabled the widespread use of sonoelastography. With studies showing that sonoelastography can be successfully applied in the diagnosis of breast, prostate, thyroid, lymph node, muscle and tendon lesions, it has become more frequently used in current routine practice (4,5,7,8).

In addition to the evaluation of tumoral lesions in various organs, there is increasing application of sonoelastography in the musculoskeletal system. There are studies in literature that have described it for the evaluation of the Achilles tendon in particular. Elasticity patterns have been defined and findings of tendinitis and similar pathologies have been reported in healthy individuals with elastography of the Achilles tendon (9).

Although many clinicians currently prefer magnetic resonance imaging (MRI) for the evaluation of the musculoskeletal system following physical examination, US is an alternative imaging method to MRI in several situations. Especially in the evaluation of superficially located structures in the musculoskeletal system, US examination can be made comfortably using linear high-frequency probes. Furthermore, as US is inexpensive, repeatable and easily available, it can be superior to MRI in daily practice.

There are currently different sonoelastography devices available and different methods are used. To the best of our knowledge, there is no study in literature that has investigated the compatibility between devices and between the practitioners examining and interpreting the sonoelastography, which is a subjective method.

Therefore, the aim of this study was to determine the intra and interobserver compatibility of Achilles tendon strain ratio using sonoelastography devices with similar mechanisms produced by different firms.

MATERIAL AND METHODS

Patients and Study Protocol

By evaluating normal Achilles tendon strain ratios (SR) on 2 different devices by 2 different researchers at 2 different times, it was investigated whether or not the same values were given by the researchers and the devices at different times.

Volunteers included in this study were selected by random sampling method. The sample size was calculated using GPower 3.1 software (10). The sample of the study was calculated as 80 with a 95% confidence interval and an expected interobserver agreement of 0.7. The study included 42 volunteers selected from staff and their relatives at Ankara Atatürk Training and Research Hospital. Informed consent was obtained from all participants and approval for the study was granted by the Clinical Research Ethics Committee of Ankara Atatürk Training and Research Hospital (decision no: 27, dated: 14.01.2015). All procedures were conducted in compliance with the principles of the Helsinki Declaration. Two volunteers were excluded from the study because there was little Kager fat tissue and a negative effect of compression. Thus, the study was applied to 80 tendons of the remaining 40 volunteers. The study participants comprised 16 males with a mean age of 28.69±7.09 years and 24 females with a mean age of 31.88±6.00 years.

All the participants had no history of trauma to the Achilles tendon, no surgery and no episodes of pain. In all cases, systemic inflammatory diseases such as rheumatoid arthritis, spondyloarthropathy and hypercholesterolemia, which could be associated with tendon abnormalities, were discounted.

Imaging

The Applio 500 (Toshiba Medical Systems, Co Ltd Otowara, Japan) and Hitachi Vision Preirus Colour Doppler US devices (Hitachi Medical Systems, Tokyo, Japan) were used for imaging.

For the acquisition of the images on both devices, the subject was positioned prone with the ankles at the lower end of the gurney (Figure 1). Evaluation was made from the mid level 2-6 cm proximal to the attachment point of the Achilles tendon to the calcaneus.

The tendons were imaged twice on both devices by both researchers at an interval of approximately 10 days. On the Hitachi device, an EUB-54 MA 13x6 Mhz microcomposite linear probe was used at 13 MHz frequency, and on the Toshiba device, a Toshiba PLT-1204 BX linear probe at 12 MHz frequency. The musculoskeletal pre-settings were fixed by the devices and the elastograpy evaluation and measurements of the SR were taken using the integrated software (Figures 2, 3).

To avoid anisotropy, care was taken that the probe was placed vertically on the tendon and the compression ratios were symmetrical on consecutive images. For the strain ratio (SR) measurement, the region of interest (ROI) was standardised at a dimension of 20x5 mm. The ROI was first placed on the centre of the Achilles tendon (A), then on the Kager fat pad (B), which was accepted as reference tissue. The SR was automatically calculated by the devices as B/A values.

Figure 1. Positioning of the subject on the examination table

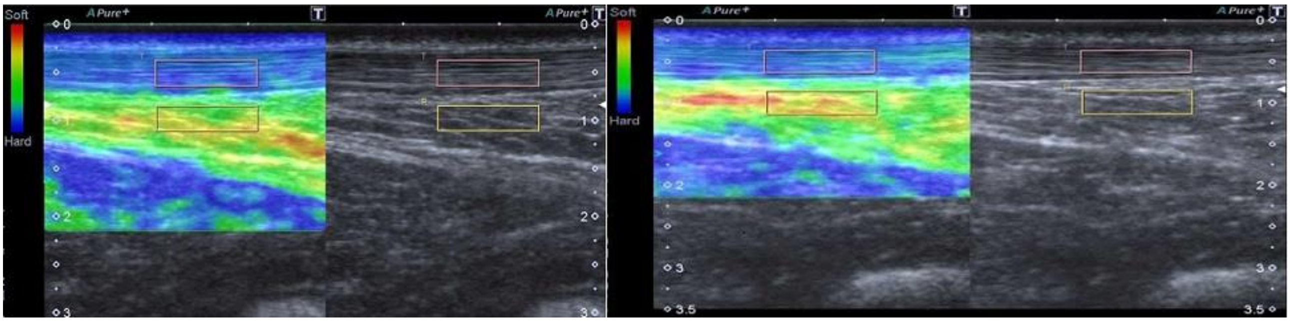

Figure 2. Images of the 1st and 2nd examinations of the same subject by Observer 1 on the Toshiba device

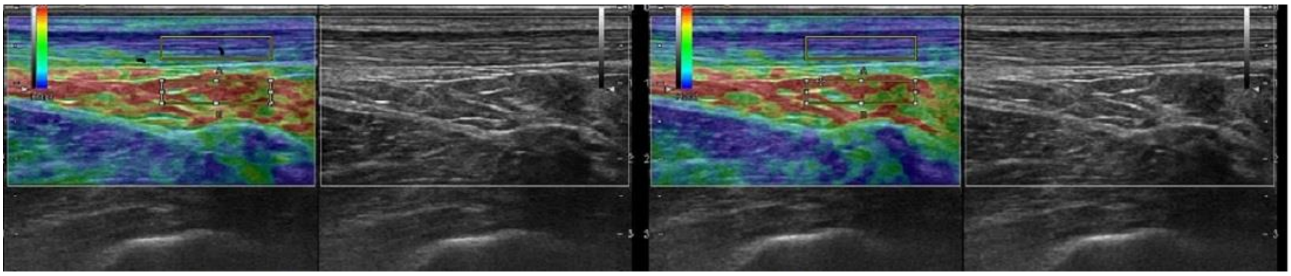

Figure 3. Images of the 1st and 2nd examinations of the same subject by Observer 2 on the Hitachi device

Statistical Analysis

Data obtained in this study were analyzed via IBM SPSS Statistics 21.0 software. The distribution of age, height, weight and SR values were examined by the Shapiro Wilks test. Variables with normal distribution were stated as mean±standard deviation (SD) and those not showing normal distribution as median and interquartile range (IQR) values. Gender was summarized as frequency and percentage. The males and females were compared with respect to the age, height and weight values by the Independent Samples t test, and the device measurements were compared by the Wilcoxon test. The intraobserver and interobserver agreement was assessed by Intraclass Correlation Coefficient (ICC) obtained by two-way mixed ANOVA model for absolute agreement, and its 95% confidence interval (CI). Since the intraobserver agreement was extremely high (ICC>0.90), the mean of each pair of measurements for each observer was calculated and the interobserver agreement was re-evaluated for each device. As the interobserver agreement was good (average ICC>0.75), the mean of the measurements of each observer was calculated and one measurement was obtained for each device. To evaluate the agreement of the measurements obtained from the devices, the ICC value was calculated using two-way mixed ANOVA model. The ICC was interpreted as suggested by Ko and Li (11): <0.5 as poor, 0.50-0.74 as fair, 0.75-0.90 as good and >0.90 as excellent. A value of $p<0.05$ was accepted as statistically significant.

RESULTS

The 40 subjects included in the study comprised 16 (40%) males with a mean age of 28.69±7.09 years and 24 (60%) females with a mean age of 31.88±6.00 years (Table 1). The age of the male and female subjects was seen to be similar (p=0.134). The height and weight values of the male subjects were statistically significantly higher than those of the females (p<0.001 and p=0.015, respectively).

The interobserver agreement was observed to be good for the first and second measurements on the Hitachi device and for the second measurement on the Toshiba device (average ICC>0.75, Table 2). The interobserver agreement for the first measurement on the Toshiba device was determined to be lower (average ICC=0.729, p<0.001).

When the repeated measurements of each observer were evaluated, the intraobserver agreement was determined as excellent for both devices (ICC>0.90, Table 3).

As the intraobserver agreement was high, the mean of the repeated measurements made by each observer for each device was taken and the interobserver agreement was re-evaluated for each device separately. The interobserver agreement was seen to be good for each device, with a slightly lower level for the Toshiba device than the Hitachi (Table 4).

As the interobserver agreeement was good, a single measurement value was obtained for each device by calculating the mean of the measurements of the observers. The agreement between the devices was determined at a good level (average ICC=0.852), but at 95%CI, the ICC fell to 0.258 (Table 5).

The SR values were determined to range 1.22-5.51 for the Hitachi device and 1.74-5.97 for the Toshiba device (Table 6). The mean SR values were calculated as 2.96±1.07 for the Hitachi device and 3.54±1.03 for the Toshiba device, and the difference was statistically significant (Z=6.884, p<0.001, Figure 4).

Table 1. Demographic characteristics

	Male (n=16)	Female (n=24)	p
Age (years)	28.69±7.09	31.88±6.00	0.134
Height (cm)	178.50±6.02	164.46±6.05	**<0.001**
Weight (kg)	73.75±13.55	63.88±7.42	**0.015**

cm: centimeter, kg: kilogram

Table 2. Interobserver agreement

Device	ICC type	1st Measurement ICC (95% CI)	2nd Measurement ICC (95% CI)
Hitachi	Single	0.716 (0.590-0.808)	0.680 (0.541-0.782)
	Average	0.835 (0.742-0.894)	0.809 (0.703-0.878)
Toshiba	Single	0.573 (0.395-0.708)	0.602 (0.438-0.727)
	Average	0.729 (0.567-0.829)	0.752 (0.609-0.842)

ICC: Intraclass correlation coefficient, CI: Confidence interval, p<0.001 for all ICC

Table 3. Intraobserver agreement

Observer	ICC type	Hitachi ICC (95% CI)	Toshiba ICC (95% CI)
1	Single	0.958 (0.909-0.978)	0.942 (0.848-0.972)
	Average	0.979 (0.952-0.989)	0.970 (0.917-0.986)
2	Single	0.954 (0.915-0.973)	0.923 (0.868-0.954)
	Average	0.976 (0.955-0.986)	0.960 (0.929-0.976)

ICC: Intraclass correlation coefficient, CI: Confidence interval, p<0.001 for all ICC

Table 4. Interobserver agreement of the mean of the repeated measurements

Observer	ICC type	Hitachi ICC (95% CI)	Toshiba ICC (95% CI)
1 - 2	Single	0.710 (0.582-0.804)	0.604 (0.435-0.730)
	Average	0.830 (0.735-0.891)	0.753 (0.607-0.844)

ICC: Intraclass correlation coefficient, CI: Confidence interval, p<0.001 for all ICC

Table 5. Compatibility between devices

Devices	ICC type	ICC (95% CI)
Hitachi - Toshiba	Single	0.742 (0.148-0.897)
	Average	0.852 (0.258-0.946)

ICC: Intraclass correlation coefficient, CI: Confidence interval, p<0.001 for all ICC

Table 6. Comparison of the measurements obtained from the devices

Device	Min - Max	Mean±SD	Median (IQR)	p
Hitachi	1.22 - 5.51	2.96±1.07	2.85 (1.55)	**<0.001**
Toshiba	1.74 - 5.97	3.54±1.03	3.31 (1.54)	

Min: minimum, Max: maximum, SD: Standard deviation, IQR: Interquartile range

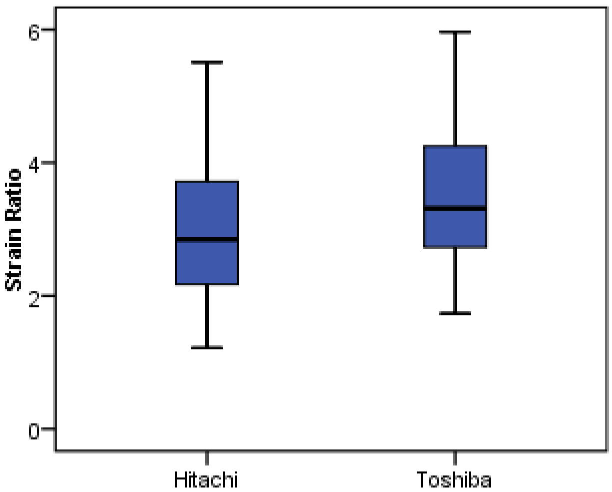

Figure 4. Strain ratio values obtained from the devices

DISCUSSION

This is the first study to have been conducted to determine the compatibility of elastography SR measurements on different sonoelastography devices. In the study, the Achilles tendon, which is the thickest and most superficially located tendon in the body, was evaluated in respect of strain ratio (SR) with separate inter and intraobserver evaluations and on different devices. While the excellent compatibility was determined in the intraobserver evaluations, the compatibility between the researchers was good but showed a lower correlation. The intraobserver evaluation showed excellent for both devices, while the interobserver agreement was good for both devices. However, the first measurement of the Toshiba device showed lower interobserver agreement. In the comparison of the devices, generally higher numerical SR values were provided by the Toshiba device.

Using sonoelastography devices produced by different companies but working on the same principle, the compatibility was investigated of interobserver and intraobserver elastography examinations of the strain ratio (SR) between the Kager fat pad and the Achilles tendon, which is easy to examine because of its superficial localisation. When the repeated measurements of each observer were evaluated, the intraobserver agreement was determined to be excellent for both devices. The interobserver agreement was found to be good for each device and slightly lower for the Toshiba device than for Hitachi.

Elastography is a technique based on the hypothesis that under external force, there is greater deformation of soft tissues than hard tissues, and the strain of the deformation is stated numerically (12,5).

Several researchers have reported the benefits of elastography according to the elasticity points, colour map and SR. In the colour map method, sub-groups, which are dependent on the user and therefore not objective, are coded according to the effect of the compression applied associated with the examined tissue. Therefore, although the sonoelastography colour scoring system is widely used in clinics, it does not provide an objective evaluation as it is practitioner dependent. In a study evaluating thyroid nodules, Wang et al. (13) reported that semi-quantitative analysis was provided with SR and this method was less user dependent. In the same study, in the tissue hardness evaluation between SR and the elastography scoring system, a statistically significant correlation was observed. With the colour scoring system, 15 thyroid nodules with deep localisation gave a false positive result and the pathological results of benign for the same nodules were found to be consistent with the SR values.

In literature, interobserver studies have been conducted previously with a single device using colour scoring in elastography for different pathologies. In a study which evaluated malignant thyroid nodules, although significant agreement was found between 3 researchers using B mode US, the same agreement could not be determined with sonoelastography colour scoring (14).

Sonoelastography cannot provide correct information about calcified benign lesions. Wang et al. (15) reported that with blue colour coding in the colour scale on sonoelastography, follicular adenoma containing calcifications could mimic thyroid cancer. Ning et al. (3)

reported that in nodules with SR>4.2, malignancy could be determined with 81% sensitivity and 83% specificity.

Although a change is seen depending on whether or not the stress applied is homogenous, SR is an important parameter showing tissue stiffness. However, there are studies showing that the addition of SR to colour coding did not increase the diagnostic performance compared to colour coding only (16).

In the current study, as it was considered that the objectivity of the colour scoring system could be low between users, it was decided to compare SRs with the aim of being more quantitative, taking into consideration whether different devices could be used in the future for the differentiation of benign and malignant lesions. Achilles tendon elasticity studies have been previously conducted on experimental models in the laboratory, or in vivo when excised from animals (17,18). Just as studies have been conducted in many areas with sonoelastography, it also has the advantage of low cost and ease of application in Achilles tendon elasticity evaluation. In the current study, a wide range of Achilles tendon SR values were determined; 1.22-5.51 on the Hitachi device and 1.74-5.97 on the Toshiba device. The difference between the SRs could be related to the fact that the mid third of the tendon was examined. This level is known as the critical zone, as it is the most defenceless section of the tendon (19). Therefore, there may not be homogeneity in asymptomatic individuals.

A difference in mechanical characteristics between various tissue components within a normal tendon may be an early indication of disease for which no clinical or sonographic signs have yet emerged. Babic et al. (20) demonstrated that the soleus and gastrocnemius components of the triceps surae complex have different viscoelasticity.

To date, no standard values have been defined in literature for SR of the Achilles tendon. In a study by Drokonaki et al. (21), no significant correlation was determined between Achilles tendon appearance and age or gender. However, in biomechanical studies, differences between individuals have been determined in the viscoelastic properties of the Achilles tendon depending on age, gender and the level of physical activity (20,22). Turan et al. (23) compared a young population with an elderly population, and as a result of colour scoring, the tendons in the elderly group were determined to have been coded as harder. In the currrent study, the subjects were not separated into subgroups according to age, gender or body mass index.

The ROI used in the current study to evaluate the SR was placed over the longitudinal axis. Previous studies that have investigated tendon strain in the axial plane have determined higher SRs compared to longitudinal measurements (24). It was decided to examine the SR in the longitudinal axis in the current study as it is difficult to apply stable, repeated pressure to the Achilles tendon surface in the axial axis and the compressions may not be standardised, especially in the peripheral sections of the tendon.

Although real-time sonoelastography is a less expensive and more widely used technique than "shear wave" technology, the fact that it is user-dependent is a limiting factor. As there is no standard for the pressure applied with the probe, elasticity values can show great variability. Therefore, in some devices, scales have been established warning the user to standardise the amount of compression applied (25).

The mean SR values obtained from the Hitachi and Toshiba devices used in this study were calculated as 2.96±1.07 and 3.54±1.03 respectively. The measurements obtained from the Toshiba device were significantly higher than those obtained from the Hitachi device. For standardization of the compressions, there are upper and lower limit lines on the Hitachi device, and so during application, less compression force is applied to avoid going outside these limits. However, on the Toshiba device there are no limit lines and it was seen that more evident compression force was applied to avoid colour confusion. If the rule is followed during application that at least 3 consecutive waves are homogenous on the compression graph, then the intraobserver agreement was found to be lower, related to the experience of the observer, especially in the first examinations.

The Kager fat pad, used as the reference tissue, is a heterogenous tissue secondary to the vascular structures, fibrous septa and fatty lobules it contains, and it shows differences between individuals depending on the body mass index, as was the case for the two subjects excluded from the study. With an increase in compression force, it is normal for more movement and deformation to develop in the Kager fat pad than in the tendon, which is a harder structure, and in parallel, the SR will be higher.

There were some limitations to this study. The healthy volunteers were only evaluated according to oral statements about chronic diseases, trauma anamnesis, and levels of activity, no patients were excluded from additional laboratory tests, and the tendons were not evaluated with MRI. Previous studies in literature using MRI have reported that on sagittal T1W examinations of the normal Achilles tendon, the reason for a non-homogenous appearance in the distal part of the tendon in 45% of cases is septations between collagen bundles forming linear and focal high signals (26).

CONCLUSION

Sonoelastography is an imaging method based on ultrasonography, which shows tissue elasticity and is being increasingly used in clinics. The results of the current study showed that in applications made by the same person at different times, the SRs showed excellent agreement. When a standard was established in compressions, the results in the evaluations made by the different researchers showed significant agreement. In studies made on different devices, there may be a difference in SRs associated with the compression application limits of the device. Therefore, intra and interobserver agreement should be evaluated separately for each device.

Finance

The study received no financial suppot from any individual or institution.

Conflict of Interests

The authors have no conflict of interests to declare.

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