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ORIGINAL ARTICLE

Factors affecting Kager's fat pad stiffness and its normal reference value in healthy adults using 2-dimensional shear wave elastography

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ABSTRACT

Introduction: Acute ankle sprains account for 15-20% of sports-related injuries among athletes, with prolonged instability leading to gait issues, altered ankle posture, and Achilles tendon mechanics, while the adjacent Kager's fat pad (KFP) is prone to inflammation from trauma, infection, or tumors. To determine factors that affect the stiffness of KFP and establish the median stiffness in healthy individuals using two-dimensional shear wave elastography (2D SWE). **Methodology**: A total of sixty-one healthy volunteers were scanned using SWE to measure the right KFP. A single-layer gel was applied between the transducer and the posterior aspect of the ankle skin surface with the subjects in a prone position and extending their ankles. Longitudinal plane was obtained to visualize the anatomical structures of the ankle joint, with a specific focus on the right KFP. A 1 mm region of interest (ROI) was identified within the KFP. No pressure was applied during SWE image acquisition to avoid image artifact. **Results**: Chi-square test revealed no significant associations between gender and stiffness. Spearman's rho test revealed no significant difference between BMI, age, and KFP stiffness, but physical activity correlated significantly with stiffness ($\rho(59) = 0.773$, $p < .001$). Multiple linear regression reported that volunteers' demography was not significant in predicting stiffness ($p = 0.225$). Inter-observer analysis demonstrated excellent agreement, with an ICC of 0.948 (95% CI, 0.922–0.966, $p < 0.001$). **Conclusion**: SWE demonstrated excellent reliability in assessing KFP stiffness. The findings provide a valuable reference for future studies and clinical evaluations, particularly in the context of ankle pathologies.

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1. INTRODUCTION

Acute ankle sprain is one of the most common musculoskeletal (MSK) injuries, particularly among individuals participating in sports. Epidemiological studies have shown that ankle sprains account for approximately 15-20% of all sports-related injuries [1]. A systematic review reported that ankle injuries are among the most frequent sports injuries across various disciplines, especially in activities involving jumping and rapid directional changes [2]. In the United States, the annual incidence of ankle sprains has been estimated at 2.15 per 1000 person-years, representing a significant proportion of MSK injuries requiring medical attention [3]. Additionally, about 40% of all traumatic ankle injuries occur during sports participation, with an incidence of seven lateral ankle sprains per 1000 exposures in indoor sports [4]. Despite this high frequency, only around half of those affected seek medical treatment, and many later develop chronic ankle instability [4]. Prolonged ankle instability after an acute sprain has been associated with persistent gait disturbances, altered ankle posture, and changes in Achilles tendon mechanics. Because of its close anatomical relationship with the Achilles tendon, the KFP moves synchronously with tendon motion and may be involved in retrocalcaneal and hindfoot disorders [5–7]. Moreover, due to its anatomical proximity, KFP can become inflamed or oedematous secondary to trauma, infection, or local tendon pathology [8]. The distribution of loads surrounding the KFP may indirectly influence biomechanical adjustments in the ankle, potentially leading to changes in the pad's density or appearance [9].

Imaging techniques, such as magnetic resonance imaging (MRI) and conventional ultrasound, are employed for the diagnosis of MSK. MRI has several benefits in assessing ankle joint, produces comprehensive, high-resolution images that make it easy to distinguish between different soft tissues, such as muscle, fat, and tendons [5]. However, MRI has drawbacks, such as higher cost and longer scan duration, which requires patients to remain still for long periods. Additionally, MRI is less accessible than ultrasound, and its availability might be limited in certain settings compared to conventional ultrasound [10]. Conventional ultrasound is a cost-effective and high spatial resolution diagnostic tool that helps diagnose MSK ankle disorders [11]. KFP, visualized via ultrasound, is normally presented as a well-defined, ovoid, triangular and hypoechoic structure [12]. While conventional ultrasound is effective in identifying morphological changes, the assessment is, however, subjective. According to Sunding et al. [13], biomechanical properties of tissues such as stiffness have proven to be an indicator of early pathological changes not yet visible structurally [13]. Hence, given the existing limitations of conventional ultrasound, further exploration of supplementary techniques is necessary.

Shear wave elastography (SWE) is an advanced imaging modality that quantifies tissue elasticity by producing and monitoring shear waves, which in turn evaluates tissue stiffness. This non-invasive technique is frequently used to evaluate the mechanical characteristics of tissues in medical diagnostics [14]. Diseased conditions alter the mechanical properties such as the stiffness of the tissue. Previous investigators have studied SWE in human tendons, ligaments, and muscles, yielding promising outcomes [15-16].

Despite the progress made in diagnostic imaging techniques, there is still a significant gap in our knowledge about the normal biomechanical properties of KFP since conventional ultrasound does not provide quantitative data on tissue stiffness, which can be critical in distinguishing between normal and pathological conditions. Therefore, this study aims to determine factors that affect the stiffness of KFP and establish the median stiffness in healthy individuals using 2D SWE.

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2. METHODOLOGY

2.1 Participants

A total of 61 healthy volunteers were recruited based on a sample size estimation conducted using g*power version 3.1.9.7 [17]. The estimation was derived from data reported in a pilot study by Ibrahim et al. [18], which found an effect size of 2.39. According to Cohen's [1988] criteria, this effect size is considered extremely large with a significant criterion of a = 0.05 and power = 0.90. The minimum sample size needed with this effect size is 61. Volunteers were university students, lecturers, and administrative staff who were recruited via open announcements throughout the university campus to guarantee broad involvement across various demographics. Participants were selected on a voluntary basis and screened to meet the inclusion criteria representing diverse age groups, BMI, and gender. Physical activity levels were defined based on self-reported frequency of mild to moderate exercise per week and were considered during the screening process. The study protocol was designed following the declaration of Helsinki and approval was obtained from the research ethics committee (REC/08/2023 (PG/MR/282)). Written consent was obtained from all participants prior to the commencement of the study, guaranteeing confidentiality and privacy adherence. The inclusion criteria required participants with no history of ankle injuries, no prior ankle surgery, and no systemic disease affecting the MSK system. Participants with sonographic evidence of any KFP abnormality under grayscale ultrasound were excluded. Athletes were not considered for participation to minimize potential confounding variables, as regular training and repetitive loading may lead to increased stiffness in the KFP due to mechanical stress and MSK adaptations. Age groups were classified as 20-29, 30-39, and above 40 [19], and BMI groups as healthy weight, overweight, and obese.

2.2 SWE Image Acquisition

SWE was performed using ultrasound scanner (RS85, Samsung Medison Co., Seoul, Korea) equipped with S-Shear wave software. A linear array transducer (LA2-9A, frequency range of 2.0 - 9.0 MHz) was used. The subjects were asked to lie down in a prone position on the ultrasound table and extend their ankles in neutral position. A single-layer gel was applied between the transducer and the posterior aspect of the right ankle skin surface. Longitudinal plane was obtained to visualize the anatomical structures of the right ankle joint, with a specific focus on the right KFP. A 1 mm ROI was positioned within the right KFP. No pressure was applied to avoid image artifact. SWE readings were acquired once the reliability measurement index (RMI) achieved > 0.4, indicating the reliability of shear-wave velocity (SWV). A minimum of 5 consecutive measurements were obtained within the selected ROI in the KFP, in line with established SWE guidelines to enhance measurement reliability, and maximum of 10 measurements. To ensure accuracy, the probe was held steadily in place with consistent pressure and alignment throughout the measurements. The median stiffness value, recorded in meters per second (m/s), was used to measure the stiffness of KFP (Figure 1). All SWE image acquisitions were performed by the same sonographer (A. I. Aburabee. three years' experience in SWE imaging) for the right ankle.

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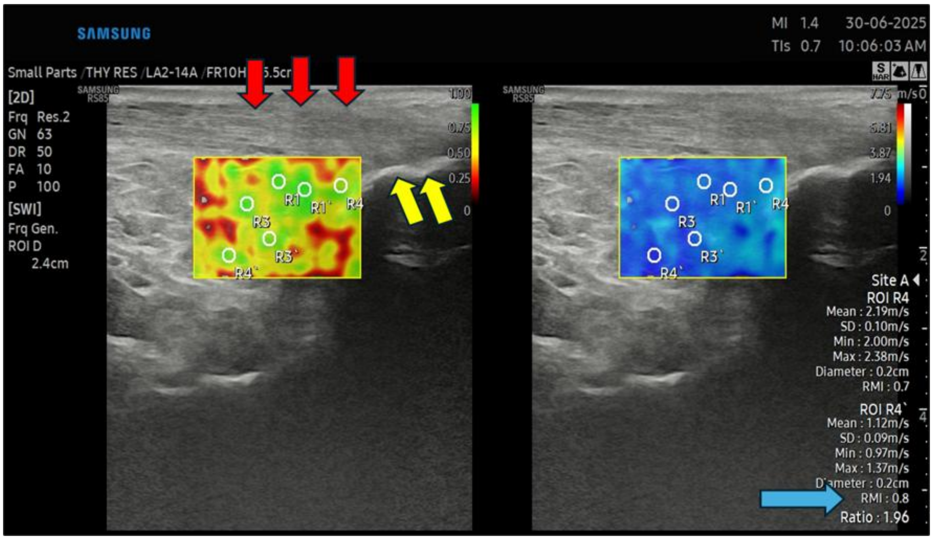

Fig.1 2D-shear wave elastography (2D-SWE) image of the right Kager's fat pad (KFP), Achilles tendon (AT) (red arrows) and Calcaneus bone (yellow arrows) in a longitudinal scanning plane. The region of interest (ROI) in the SWE image is represented by the white circle, which is set to a size of 1 mm. This ROI is used to measure the stiffness of the KFP within the selected area. A single layer of ultrasound gel was used for optimal contact. The color scale represents tissue stiffness, with green indicating areas of lower stiffness and yellow indicating areas of higher stiffness, measured in meters per second (m/s).

Source: Aburabee et al. (2026)

2.3 Inter-observer reliability

All subjects were re-scanned by a second observer (L.S.S, six years' experience in SWE imaging) for the right ankle on the same day. The second observer was blinded to the results and the number of measurements performed by the first operator, to prevent any potential bias. This blinding was ensured by specific protocol, e.g., the probe fixed in longitudinal position, 1 layer of ultrasound gel, 1 mm ROI, and neutral position, making the measurement display or conducting the measurements independently. The time interval between the first and second observer's measurements was not strictly fixed but was kept within the same imaging session to reduce potential variability due to physiological changes or measurement conditions.

2.4 Statistical Analysis

Data analysis was performed using tests contained in SPSS version 28 (SPSS Inc, Chicago, Illinois, USA). Continuous data was expressed as mean and standard deviation (SD). A Mann-Whitney U test was used to assess the association between gender and stiffness in the KFP. The correlation between KFP stiffness and demographic variables such as BMI, age, and physical activities were analyzed using Spearman correlation coefficient to assess the effect of these variables on stiffness. The Kruskal-Wallis H test was used to compare stiffness measurements across different BMI and age groups, followed by pairwise comparisons to compare stiffness measurements across different BMI age groups. Multiple linear regression test was used to investigate whether volunteers' demographic and physical activity can predict the KFP stiffness. An Inter-class Correlation Coefficient (ICC) was conducted to assess inter-observer agreement. Statistical tests were performed on the data collected and significance levels were declared at $p \leq 0.05$.

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3. RESULTS

SWE was performed on the right KFP of 61 healthy volunteers (23 males and 38 females). All participants in our study were right-leg dominant. The participants were grouped into various age categories (20–29, 30–39, and above 40) and BMI categories (healthy weight, overweight, and obese), with mean and (SD) physical activity times per week across the three age groups being 1.36 (0.42), 1.52 (0.47), and 1.38 (0.39) respectively. The demographic features of the volunteers are summarized in (Table 1)

Table 1. Demographic features of volunteers

Demographic	N	Role of participants	Male (mean ± SD)	Female (mean ± SD)
Age groups				
20-29	22	Students	21.66±1.15	22.10±1.41
30-39	19	Lecturer (10), students (9)	32.75±2.22	36.00±1.15
Above 40	20	Lecturer (10), clerical officer (10)	44.75±4.49	43.33±3.14
BMI groups				
Healthy weight	38		21.04±2.96	21.13±2.20
Overweight	14		27.74±2.16	27.17±.1.56
Obese	9		35.95±5.74	33.21±2.86

Source: Aburabee et al. (2026)

3.1 Association between gender and KFP stiffness

The descriptive statistics revealed that males had a higher mean (SD) SWV of 13.38 (4.79) m/s for right KFP stiffness compared to females, who had a mean (SD) of 11.20 (3.10) m/s. A Mann–Whitney U test was performed to compare right KFP stiffness between genders. The results showed no statistically significant difference between males and females ($U = 330.0$, $Z = -1.593$, $p = 0.111$), indicating that gender was not associated with right KFP stiffness in this cohort.

3.2 Correlation between BMI, age and physical activity with KFP stiffness

Spearman's rho test indicated no significant correlation between BMI and KFP stiffness ($\rho(59) = 0.033$, $p = 0.800$). No significant correlation was seen between age and stiffness of the KFP ($\rho(59) = 0.207$, $p = 0.110$). Additionally, physical activity levels were significantly correlated with stiffness measurements of the KFP with ($\rho(59) = 0.773$, $p < 0.001$). Kruskal-Wallis test was used to compare the stiffness of KFP between BMI and age groups. According to the results, the test indicated non-significant differences in BMI among the healthy weight, overweight, and obese groups in the in the KFP (χ^2 (2) = 5.296, $p = 0.437$). For the age groups a significant difference was seen in the KFP (χ^2 (2) = 8.573, $p = 0.014$) (Table 2). The mean rank of age group was highest in the group of 30-39 with mean rank 39.08.

Pairwise comparisons test was conducted to determine the differences between age groups of the KFP. The test indicated a significant difference between the 20-29 and 30-39 age groups (p = 0.004) as presented in (Figure 2). No significant differences were found between the 20-29 and above 40 age groups (p = 0.237) or between the 30-39 and above 40 age groups (p = 0. 679) as shown in (Table 3).

Table 2. Kruskal-Wallis test used to compare the stiffness of KFP between BMI and age groups

SWE (m/s)	Groups	Mean rank	Median stiffness m/s	P-value
Right ankle stiffness	**BMI groups**			0.437
	Healthy weight	31.96	10.90	
	Overweight	22.15	13.10	
	Obese	38.85	15.30	
Right ankle stiffness	**Age groups**			0.014
	20 to 29 years	22.93	10.20	
	30 to 39 years	39.08	14.07	
	Above 40 years	32.20	12.06	

Source: Aburabee et al. (2026)

Table 3. Pairwise comparison of right ankle stiffness between age groups using the Bonferroni-adjusted Kruskal-Wallis post hoc test

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Significance
20-29/Above 40	-9.268	5.484	-1.690	0.091
20-29/30-39	-16.147	5.559	-2.905	0.004
Above 40/30-39	6.879	5.686	1.210	0.226

Source: Aburabee et al. (2026)

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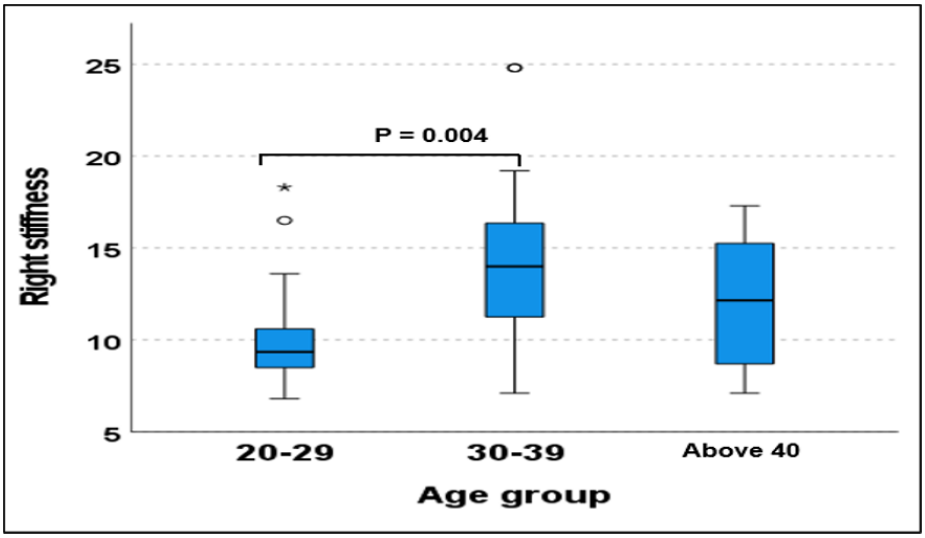

Fig 1. Pairwise comparison of mean Kager's fat pad *(*KFP*)* stiffness values (m/s) between the three age groups in the KFP. The central line represents the median, the box represents the interquartile range (IQR), and the whiskers indicate the minimum and maximum values within 1.5 times the IQR. Circles and asterisks denote outliers. The test indicated a significant difference between the 20-29 and 30-39 age groups (p = 0.004).

Source: Aburabee et al. (2026)

3.3 Multiple linear regression between KFP stiffness and age, gender, BMI, and physical activities

Multiple linear regression analysis found that 11.8% of the variation in the stiffness of KFP was explained by age, gender, BMI, and physical activities. Coefficients for age (0.883), gender (-1.758), BMI (0.016), and physical activities (1.283) were calculated. However, these factors were not statistically significant in predicting the stiffness of KFP (p = 0.128) (Table 4).

Table 4. Multiple linear regression analysis of factors associated with right ankle stiffness. The model includes age group, BMI, physical activity, and gender as independent variables. The R^2 value (0.118) suggests that the model explains 11.8% of the variance in stiffness, with an adjusted R^2 of 0.055

Coefficient							
	Unstandardized Coefficients		**Standardized Coefficients**			**Correlations**	
Model	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Partial**	**Part**
(Constant)	11.027	3.685		2.992	.004	.185	.177
Age group	.883	.626	.188	1.411	.164	.025	.023
BMI	.016	.089	.023	.185	.854	.158	.150
Physical activity	1.283	1.072	.155	1.197	.236	-.220	-.212
Gender	-1.758	1.042	-.219	-1.687	.097	.185	.177

Source: Aburabee et al. (2026)

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3.4 Inter-observer reliability of SWV measurements

The ICC was calculated to investigate the agreement between two observers of the study and their observatory measurements of KFP stiffness. The results of the ICC showed high reliability, the ICC was 0.948 (95% CI, 0.922 – 0.966) ($p < 0.001$), as well as the consistency in the KFP stiffness measurements recorded by both observers.

4. DISCUSSION

The objective of this study was to investigate or identify factors that affect the stiffness of KFP, and to establish the median stiffness in healthy individuals using 2D SWE. Our results showed physical activity correlated significantly with stiffness. We also observed stiffness variations across different age groups, with the middle-aged group exhibiting higher stiffness. Although ultrasound is operator dependent, yet the ICC test revealed excellent reliability for SWE.

Ankle pain could result from KFP diseases or conditions affecting the fat pad within the ankle joint. For instance, overuse and conditions like Achilles tendinopathy, Achilles paratenonitis, posterior ankle impingement syndrome, and Haglund's disease can cause inflammation of KFP [9]. Inflammation of KGF has also been associated with systemic diseases like rheumatoid arthritis, gout, and fat pad atrophy or hypertrophy. Several studies have applied 2D SWE in MSK imaging to quantitatively evaluate medium stiffness with promising results [20-21]. To the best of our knowledge, and based on a review of the literature, no study has employed SWE to assess the KFP. Therefore, determination of factors that affect the stiffness of KFP, and establishing the median stiffness in healthy individuals using 2D SWE is important.

Previous research has suggested that hormonal differences, muscle composition, and biomechanical loading patterns can contribute to variations in tissue stiffness between men and women [22]. Fat pad characteristics, in particular, are known to be influenced by hormonal regulation and fat distribution, where estrogen promotes greater fat deposition in the hips, thighs, and gluteal regions, while testosterone increases muscle mass and reduces fat accumulation [23].

Despite these physiological distinctions, our findings align with a number of other previous studies reporting no significant gender-related differences in musculoskeletal stiffness under healthy conditions. Gonzalez et al. [24] similarly observed no gender differences in Achilles tendon stiffness among asymptomatic athletes using SWE. This suggests that when tissues such as the KFP and surrounding structures are structurally intact and free from pathology, comparable mechanical loading during daily activities may override subtle hormonal or physiological influences [9]. The absence of a significant difference in right KFP stiffness between males and females, as confirmed by the Mann–Whitney U test, supports the view that, in a healthy population, tissue stiffness reflects functional rather than sex-specific adaptations.

The current study revealed that BMI too does not significantly impact KFP stiffness. According to Malagelada et al. [25] KFP does not play a primary role in load bearing, instead its primary functions are related to cushioning, shock absorption, and facilitating smooth movement of the Achilles tendon rather than bearing weight. In this regard, our finding is consistent with a previous study that explored the influence of BMI on the mechanical properties of periarticular structures. Gürün et al. [26] reported no statistically significant differences in knee medial collateral ligament (MCL) stiffness among patients with varying BMI. Similar to KFP, the knee MCL is not primarily responsible for load bearing but instead contributes to joint stability, specifically by providing resistance against stress at the knee joint due to valgus or varus knee alignments. These findings suggest that, for structures not directly involved in weight-bearing, BMI may have a limited effect on tissue stiffness measurements.

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The morphology of the MSK system, especially thickness and appearance, can be affected by age due to changes in tissue composition, such as decreased elasticity and increased collagen cross-linking [27]. In our study, age has no significant correlation with KFP stiffness. This is consistent, with a study by Shang et al. [28], investigating tibial nerve stiffness using SWE. They found no significant difference between legs, gender, or different age groups.

However, our study showed that the stiffness of the right ankle KFP was significantly higher in the 30-39 age group compared to the 20-29 age group. This could be attributed to the fact that many participants in this age group were lecturers, whose work predominantly involved standing and walking, leading to increased stiffness compared to the age group 20-29 who were mainly students [29]. The KFP moves frequently as a person stands and walks since it has to adapt to the dynamic variations in the ankle position and load-bearing activities. This motion improves flexibility and shock absorption by stabilizing and cushioning the Achilles tendon [6]. Our findings showing increased KFP stiffness in the middle-aged group are also consistent with those of Liu et al. [30], who reported that muscle stiffness responses to passive stretching vary with age. Specifically, they observed that middle-aged individuals exhibited greater stiffness compared to younger and older groups, suggesting age-related differences in tissue elasticity and adaptive response to mechanical loading.

In the present study, all stiffness measurements were obtained from the right ankle, thereby minimizing any potential influence of limb dominance. The middle-aged group 30-39 year demonstrated slightly higher KFP stiffness compared to both the younger and older groups. This difference is unlikely to be related to age or laterality but may instead reflect the influence of physical activity levels. Based on our results, the 30–39-year age group exhibited the highest mean physical activity level among all age groups.

Tissue adaptation is affected by the frequency and length of activities. Depending on the particular demands exerted on the tissue, regular activity over time can cause tissue hypertrophy possibly due to adaptations in response to repetitive loading [31]. This study showed a strong positive correlation between physical activity and KFP stiffness, indicating that as the frequency of physical activity increases, the stiffness of KFP increases. According to Thomas et al. [32] the intensity, type, duration of exercise, or individual physiological differences may have a more substantial impact on stiffness, implying that other factors related to physical activity may indeed play a role in influencing stiffness measurements but not as much as physical activity.

Age, gender, BMI, and physical activity combined only explained low percentage of the variation in KFP stiffness, with no statistically significant predictors. This implies that additional factors that were not considered in this model may have a greater influence on KFP stiffness in this dataset than these variables. Nevertheless, the findings of this study are consistent with a previous study by Madsen et al. [33], which stated that leg stiffness in relation to different factors was not statistically significant, which could be due to the biomechanical features as more relevant factors.

The inter-observer reliability of SWE measurements showed high reliability, with an excellent agreement between observers. This outcome was likely facilitated by the scanner SWE's RMI application, a quality control parameter built into the 2-D SWE system. The repeatability measures rise with greater RMI levels, helping operators determine which images were suitable for use in the SWE assessment and filter out inaccurate SWE acquisitions [34]. Our results are consistent with those of Berrigan et al. [35] in which they were using the same scanner to investigate the reliability of SWE in patella and Achilles tendon, demonstrating very good inter-observer reliability.

4.1 Study Limitations

This study had several limitations. First, this study only measured unilateral KFP stiffness in the dominant leg while the participant was in a prone position. Future research may include bilateral measurements to ascertain if limb dominance affects KFP stiffness and examine the potential role of BMI on stiffness during weight-bearing situations. Second, this study did not investigate the correlation between the intensity of the physical activity with stiffness change. Future research should incorporate direct assessments of physical activity levels to gain a deeper understanding of its impact on KFP characteristics. Lastly, this study did not account for diabetes mellitus (DM) and hypertension (HTN), both of which may alter the soft tissue properties of the KFP. Future studies should consider excluding or stratifying participants with DM and HTN to better understand their potential impact.

5. CONCLUSION

Despite these limitations, this study demonstrates that gender, BMI, and age have minimal influence on KFP stiffness, although physical activity may play a role. The established median stiffness values provide a useful reference for future research and clinical assessment of KFP in ankle pathologies.

6. CONFLICT OF INTEREST

Authors declare none.

7. ACKNOWLEDGEMENT

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8. GENERATIVE A.I DISCLOSURE STATEMENT

Generative AI (ChatGPT, OpenAI) was used only to assist with language refinement during manuscript preparation. All scientific content, data interpretation, revisions, and final approval were performed by the authors, who take full responsibility for the manuscript.

9. ETHICAL CLEARANCE

We obtained approval from the Research Ethics Committee (REC/08/2023), Universiti Teknologi MARA.

10. FUNDING

None.

11. AUTHORS' CONTRIBUTIONS

Conception and design, Analysis and interpretation of the data, Drafting of the article: Abdalmalek Ismail Aburabee

Critical revision of the article for important intellectual content: Sook Sam Leong

Collection and assembly of data: Mohd Shukry Khalid

Administrative, technical, or logistic support: Noor Shafini Mohamad

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12. REFERENCES

1. Zhang Y, Wang X, Wang X, Cao J, Wang H, Zhang F. Allogeneic tendons in the treatment of malunited lateral malleolar avulsion fractures with chronic lateral ankle instability. BMC Musculoskelet. Disord. 2023 Dec;24(1):1-8. https://doi.org/10.1186/s12891-023-06390-1
2. Fong DT, Hong Y, Chan LK, Yung PS, Chan KM. A systematic review on ankle injury and ankle sprain in sports. Sports medicine. 2007 Jan;37(1):73-94. https://doi.org/10.2165/00007256-200737010-00006
3. Waterman BR, Owens BD, Davey S, Zacchilli MA, Belmont Jr PJ. The epidemiology of ankle sprains in the United States. Jbjs. 2010 Oct 6;92(13):2279-84. https://doi.org/ 10.2106/JBJS.I.01537
4. Vuurberg G, Hoorntje A, Wink LM, et al. Diagnosis, treatment, and prevention of ankle sprains: update of an evidence-based clinical guideline. Br. J. Sports Med. 2018 Aug 1;52(15):956-956. https://doi.org/10.1136/bjsports-2017-098106
5. Theobald P, Bydder G, Dent C, Nokes L, Pugh N, Benjamin M. The functional anatomy of Kager's fat pad in relation to retrocalcaneal problems and other hind ankle disorders. J. Anat. 2006 Jan;208(1):91-7. https://doi.org/10.1111/j.1469-7580.2006.00510.x
6. Ghazzawi A, Theobald P, Pugh N, Byrne C, Nokes L. Quantifying the motion of Kager's fat pad. J. Orthop. Res. 2009 Nov;27(11):1457-60. https://doi.org/10.1002/jor.20900
7. Szaro P, Polaczek M, Ciszek B. The Kager's fat pad radiological anatomy revised. Surg. Radiol. Anat. 2021 Jan; 43:79-86. https://doi.org/10.1007/s00276-020-02552-1
8. Bianchi S, Martinoli C, Abdelwahab IF. Ultrasound of tendon tears. Part 1: general considerations and upper extremity. Skeletal radiology. 2005 Sep;34(9):500-12. https://doi.org/10.1007/s00256-005-0956-1
9. Pingel J, Petersen MC, Fredberg U, et al. Inflammatory and metabolic alterations of Kager's fat pad in chronic Achilles tendinopathy. PLoS One. 2015 May 21;10(5): e0127811. https://doi.org/10.1371/journal.pone.0127811
10. Motamedi D, Bauer AH, Patel R, Morgan TA. Problem solved: Integral applications of musculoskeletal ultrasound. J. Ultrasound Med. 2021 Aug;40(8):1693-704. https://doi.org/10.1002/jum.15551
11. McAuliffe S, McCreesh K, Culloty F, Purtill H, O'Sullivan K. Can ultrasound imaging predict the development of Achilles and patellar tendinopathy? A systematic review and meta-analysis. Br. J. Sports Med. 2016 Dec 1;50(24):1516-23. https://doi.org/10.1136/bjsports-2016-096288
12. Rodríguez-Sanz D, Losa-Iglesias ME, de Bengoa-Vallejo RB, et al. A New Test for Achilles Tendinopathy Based on Kager's Fat Pad Clinical Assessment Predictive Values. J. Clin. Med. 2023 Aug 9;12(16):5183. https://doi.org/10.3390/jcm12165183
13. Sunding K, Fahlström M, Werner S, Forssblad M, Willberg L. Evaluation of Achilles and patellar tendinopathy with greyscale ultrasound and color Doppler: using a four-grade scale. Knee Surgery, Sports Traumatology, Arthroscopy. 2016 Jun;24:1988-96. https://doi.org/10.1007/s00167-014-3270-4
14. Xie LT, Yan CH, Zhao QY, He MN, Jiang TA. Quantitative and non-invasive assessment of chronic liver diseases using two-dimensional shear wave elastography. World J. Gastroenterol. 2018 Mar 3;24(9):957. https://doi.org/10.3748/wjg.v24.i9.957
15. Taljanovic MS, Gimber LH, Becker GW, Latt LD, Klauser AS, Melville DM. Shear-wave elastography: basic physics and musculoskeletal applications. Radiographics. 2017 May 11;37(3):855-70. https://doi.org/10.1148/rg.2017160116
16. Heales LJ, Badya R, Ziegenfuss B, Hug F, Coombes JS, van den Hoorn. Shear-wave velocity of the patellar tendon and quadriceps muscle is increased immediately after maximal eccentric exercise. Eur. J. Appl. Physiol. 2018 Aug; 118:1715-24. https://doi.org/10.1007/s00421-018-3903-2

17. Faul F, Erdfelder E, Lang AG, Buchner A. G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior research methods. 2007 May;39(2):175-91. https://doi.org/10.3758/BF03193146
18. Ibrahim OM, Alhassanin SA, Essa ES, Mostafa TM. Metformin as an adjuvant therapy to an aromatase inhibitor in overweight and obese postmenopausal women with breast cancer: A pilot study. https://doi.org/10.21203/rs.3.rs-1365471/v1
19. Jakubowski KL, Ludvig D, Lee SS, Perreault EJ. At matched loads, aging does not alter ankle, muscle, or tendon stiffness. bioRxiv. 2023 Nov 26. https://doi.org/10.1101/2023.11.25.568676
20. Cosgrove DO, Berg WA, Doré CJ, Skyba DM, Henry JP, Gay J, et al. Shear wave elastography for breast masses is highly reproducible. Eur Radiol 2012; 22: 1023–1032. https://doi.org/10.1007/s00330-011-2340-y
21. Stiver ML, Mirjalili SA, Agur AM. Measuring shear wave velocity in adult skeletal muscle with ultrasound 2-D shear wave elastography: a scoping review. Ultrasound Med Biol. 2023 Jun 1;49(6):1353-62. https://doi.org/10.1016/j.ultrasmedbio.2023.02.005
22. Gianakos AL, Hartman H, Kerkhoffs GM, Calder J, Kennedy JG. Sex differences in biomechanical properties of the Achilles tendon may predispose men to higher risk of injury: A systematic review. Journal of ISAKOS. 2024 Apr 1;9(2):184-91. https://doi.org/10.1016/j.jisako.2023.11.001
23. Santosa S, Jensen MD. Effects of male hypogonadism on regional adipose tissue fatty acid storage and lipogenic proteins. PLoS One. 2012 Feb 20;7(2):e31473. https://doi.org/10.1371/journal.pone.0031473
24. Gonzalez FM, Gleason CA, Lee KS, et al. Shear wave elastography assessment and comparison study of the Achilles tendons in optimally conditioned asymptomatic young collegiate athletes. Skeletal Radiol. 2021 Dec;50(12):2381-92. https://doi.org/10.1007/s00256-021-03798-5
25. Malagelada F, Stephen J, Dalmau-Pastor M, Masci L, Yeh M, Vega J, Calder J. Pressure changes in the Kager fat pad at the extremes of ankle motion suggest a potential role in Achilles tendinopathy. Knee Surgery, Sports Traumatology, Arthroscopy. 2020 Jan;28:148-54. https://doi.org/10.1007/s00167-019-05585-1
26. Gürün E, Aksakal M, Akdulum İ. Measuring stiffness of normal medial collateral ligament in healthy volunteers via shear wave elastography. Surg Radiol Anat. 2021 Oct;43:1673-9. https://doi.org/10.1007/s00276-021-02749-y
27. Karanfil Y, Eşme M, Korkusuz F. Musculoskeletal physiological changes in aging. In Beauty, Aging, and Anti-Aging 2023 Jan 1 (pp. 83-108). Academic Press. https://doi.org/10.1016/B978-0-323-98804-9.00020-7
28. Shang S, Yan W, Guo Y, et al. The normal value and influencing factors of shear wave elastography in healthy tibial nerves: A cross-sectional study. Health Sci. Rep. 2023 Jul;6(7):e1412. https://doi.org/10.1002/hsr2.1412
29. Gupta A, Mulvihill E, Turner D. Is Real-Time Ultrasound Reliably Able to Determine Kager's Fat Pad Motion during Walking? Ultrasound Med Biol. 2022 Feb 1;48(2):217-22. https://doi.org/10.1016/j.ultrasmedbio.2021.09.024
30. Liu X, Yu HK, Sheng SY, et al. Quantitative evaluation of passive muscle stiffness by shear wave elastography in healthy individuals of different ages. Eur. Radiol. 2021 May;31:3187-94. https://doi.org/10.1007/s00330-020-07367-7
31. Usgu S, Uluşahin SB, Gönen T. The association between ankle mobility and Achilles tendon, plantar fascia, iliotibial band stiffness and elasticity in athletes. Spor Hekimliği Dergisi. 2023;58(1):008-14. https://doi.org/10.47447/tjsm.0701
32. Thomas E, Ficarra S, Nakamura M, et al. Effects of different long-term exercise modalities on tissue stiffness. Sports Med.-Open. 2022 Dec;8(1):71. https://doi.org/10.1186/s40798-022-00462-7
33. Madsen A, Sharififar S, Alfonso K, Vincent KR, Vincent HK. Leg Stiffness Features In Runners With Single And Multiple Stress Fracture Histories: 2512. Med. Sci. Sports Exe. 2023 Sep 1;55(9S):827. https://doi.org/10.1249/01.mss.0000987616.86537.e8

34. De-Giorgio F, Ciasca G, D'Amico R, et al. An evaluation of the objectivity and reproducibility of shear wave elastography in estimating the post-mortem interval: a tissue biomechanical perspective. Int. J. Legal Med. 2020 Sep;134:1939-48. https://doi.org/10.1007/s00414-020-02370-5
35. Berrigan W, Cipriano K, Easley K, Mautner K. Quantifying Mechanical Properties of the Patella and Achilles Tendon Using Ultrasound Shear Wave Elastography. 2023. https://doi.org/10.20944/preprints202310.1043.v1

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