The Ratio of Stress to Nonstress Anterior Talofibular Ligament Length on Ultrasonography

Normative Values

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Background: Stress ultrasonography (US) has been shown to be a valid procedure for evaluating chronic anterior talofibular ligament (ATFL) injury. The ratio of stress/nonstress ATFL length (ATFL ratio) as measured on US is clinically useful; however, there are no published normative data concerning this ratio.

Purpose: To report a normative value of the ATFL ratio on US and evaluate the relationships between sex, generalized joint laxity (GJL), and the grade of anterior drawer test (ADT).

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: The ATFL lengths were prospectively measured in the stress and nonstress positions (manual maximal anterior drawer position) for participants with noninjured ankles from March 2020 to March 2021. GJL was defined as a Beighton score $\geq$4. A manual ADT was also performed. The ATFL ratio was calculated, and the relationships between sex, GJL, and ADT grade were evaluated.

Results: A total of 333 ankles in 184 participants (mean age, 24.5 $\pm$ 2.7 years; range, 20-33 years) were eligible for the analysis. GJL was found in 69 ankles (20.7%). The mean ATFL ratio was 1.08 $\pm$ 0.04 (95% CI, 1.08-1.09; range, 1.01-1.24), and there was a significant difference between male (1.07 $\pm$ 0.04; 95% CI, 1.07-1.08; range, 1.02-1.23) and female (1.09 $\pm$ 0.04; 95% CI, 1.08-1.10; range, 1.01-1.24) ankles (P = .001). In male ankles, the ATFL ratio was significantly greater in participants with GJL (1.11 $\pm$ 0.06 vs 1.07 $\pm$ 0.03; P = .02) or a higher grade of ADT (grade 2 vs grade 1: 1.11 $\pm$ 0.06 vs 1.07 $\pm$ 0.03, P = .002). These findings were not observed in female ankles.

Conclusion: The normative value of the ATFL ratio on stress US was 1.07 $\pm$ 0.04 in men and 1.09 $\pm$ 0.04 in women. The ATFL ratio was affected by the presence of GJL in men but not in women. These findings will be useful for future studies seeking to establish the cutoff value of the ATFL ratio for diagnosing chronic lateral ankle stability on stress US.

Keywords: anterior talofibular ligament; chronic lateral ankle instability; stress ultrasonography; normative values; generalized joint laxity; sex

Lateral ankle sprain (LAS) is one of the most prevalent injuries in the general population and athletes in particular.[18,22] Patients with LAS have a high risk of recurrence, resulting in chronic lateral ankle instability (CLAI).[2,35] CLAI has been associated not only with an increased risk of secondary osteoarthritis of the ankle[21] but also a poor quality of life throughout the patient's lifetime.[1]

Clinically, the diagnosis of CLAI is made through a combination of physical examinations (anterior drawer test [ADT], inversion stress test) and imaging examinations, including stress radiography, computed tomography (CT) arthrography, magnetic resonance imaging (MRI), and stress ultrasonography (US). Oae et al[31] reported that the accuracy of diagnosing anterior talofibular ligament (ATFL) injury was highest by MRI, followed by US and stress radiography, compared with the arthroscopic findings as the gold standard. Elkaïm et al[17] showed that CT arthrography had the highest accuracy for the evaluation of chronic ATFL injuries among other imaging modalities, including MRI and US. However, CT arthrography is an invasive examination with exposure to radiation. Moreover, while MRI has a high sensitivity and specificity in detecting ATFL injuries, it is expensive.[24,31]

Stress US enables the dynamic evaluation of the lateral ankle ligaments and is noninvasive and inexpensive. Several studies[8,10,23,27,38] have recently demonstrated the usefulness of stress US for the diagnosis of CLAI. According to a recent systematic review,[8] the sensitivity and specificity for diagnosing chronic ATFL injury with US are 0.99 (95% CI, 0.96-1.00) and 0.91 (95% CI, 0.82-0.97), respectively, while the sensitivity and specificity with MRI are 0.83 (95% CI, 0.78-0.87) and 0.79 (95% CI, 0.69-0.87), respectively.

Cho et al[10] reported that a ratio of stress (maximal anterior drawer)/nonstress ATFL length (ATFL ratio) ≥ 1.2 on US could serve as a criterion in diagnosing CLAI. However, few studies have evaluated the normative value of the ATFL length as well as the ATFL ratio on US. A reference value is crucial for establishing cutoff values to discern patients with and without CLAI. In addition, it remains unclear whether the ATFL ratio is affected by patient factors such as sex or the presence of generalized joint laxity (GJL). A systematic review[13] reported that the incidence rate of ankle sprains was not significantly influenced by sex. However, there is a lack of evidence regarding sexual differences in the native laxity of the lateral ankle complex. It was demonstrated that GJL was an independent predictor of poor outcomes and recurrent instability after the modified Broström procedure for CLAI.[32,43] The main purpose of the present study was to provide the normative value of the ATFL ratio. Its secondary purpose was to evaluate its relationships with patient characteristics and the grade of ADT. We hypothesized that the ATFL ratio would be affected by sex, GJL, and the grade of ADT.

METHODS

This was a prospective study designed to provide normative data regarding US findings of ATFL. The study protocol received institutional review board approval, all procedures were performed in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Declaration of Helsinki as revised in 2013, and all participants gave informed written consent.

Selection of Participants

Volunteers ≥ 20 years of age were recruited from a single institute via an advertisement from March 2020 to March 2021. The exclusion criteria included CLAI, history of recurrent ankle sprains, episodes of giving way of the ankle, primary LAS within 3 months at the time of
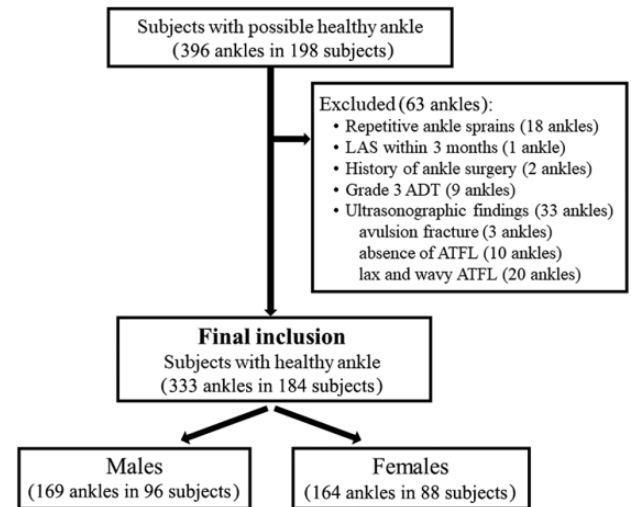
Figure 1. Flowchart showing the patient-selection process. ADT, anterior drawer test; ATFL, anterior talofibular ligament; LAS, lateral ankle sprain.

recruitment, prior surgical intervention to the foot and ankle, persistent foot and ankle pain at the time of recruitment, osteoarthritis of the ankle, inflammatory arthritis such as rheumatoid arthritis, and Ehlers-Danlos or Marfan syndrome. Considering the possibility of recall bias for a history of primary (acute) LAS, 3 months was chosen as the time period in this study.

The diagnosis of CLAI was made if the patient had a history of ≥ 1 ankle sprains and ≥ 2 episodes of giving way in the previous 6 months. In addition, patients were excluded if they answered yes to ≥ 5 questions on the Ankle Instability Instrument or scored ≤ 24 on the Cumberland Ankle Instability Tool.[19] The prevalence of undiagnosed CLAI was expected to be higher in the general population than that reported by previous studies.[20] The possibility of recall bias for history of ankle sprains was also considered. Therefore, to obtain US data from healthy ankles, participants were also excluded if (1) an ADT confirmed grade 3 laxity or (2) the absence of ATFL, lax and wavy ATFL, or avulsion fracture of the distal fibula was confirmed by US.[23,28]

Of 396 ankles in 198 initial participants, 63 ankles were excluded, leaving 333 ankles (184 participants) included in this study (Figure 1). None of the included participants had a history of primary LAS within 1 year of enrollment.

The characteristic information of the participants included age, sex, height, weight, body mass index (BMI), side of the ankle (right or left), and foot size. The foot size

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TABLE 1
Beighton Score for the Assessment of Generalized Joint Laxity[a]

1. Passive dorsiflexion of the little fingers >90°
2. Passive apposition of the thumbs to the volar aspect of the forearms
3. Hyperextension of the elbows >10°
4. Hyperextension of the knees >10°
5. Forward flexion of the trunk, with the knees straight, so that the palms of the hands rested easily on the floor

[a]Tests 1 to 4 are performed bilaterally. One point is given for each positive test (score, 0-9). Generalized joint laxity was defined as a score ≥4.

was defined as the length from the longest toe to the tip of the heel, which was measured with a tape measure in the standing position. The assessment of GJL and the manual ADT were performed before the US examination. GJL was assessed using the Beighton score.[4] The manual ADT was performed by a certified orthopaedic surgeon (S.K.). US images of the ankle were obtained in the nonstress (resting position) and stress position (manual maximal anterior drawer position) according to the procedure described by Lee et al.[27] US evaluations were performed by a certified orthopaedic surgeon (T.Y.) who was blinded to other examination results of the participant. To evaluate the interrater reliability of the US evaluation, US assessments were also performed for the first 50 patients by another blinded senior orthopaedic surgeon (S.K.).

Manual ADT

ADT of the ankle was performed with the patient in the supine position. The knee joint was flexed, and the ankle joint was sustained in 10° to 15° of plantarflexion. The patient was instructed to relax before the performance of ADT. While grasping the heel of the examined ankle with one hand and stabilizing the distal tibia with the other, the examiner drew the ankle until no further movement was recognized. The results were classified as grade 1 (stable), 2 (partially unstable), or 3 (completely unstable).[10]

Generalized Joint Laxity

GJL was evaluated using the Beighton score.[4] The Beighton score consists of 5 objective measurements of joint mobility, of which 4 are measured bilaterally (Table 1). One point is given when each joint meets the criteria (score, 0-9). GJL was defined as a score ≥4 points.

Ultrasound Evaluations of the ATFL

US examinations were performed with an Aloka Arietta 850 US apparatus (Hitachi) using a linear probe (L64 probe, 18-5 MHz). The spatial resolution of this US device was as follows: axial resolution, ≤0.8 mm; lateral resolution, ≤3.0 mm. The method reported by Lee et al[27] was used
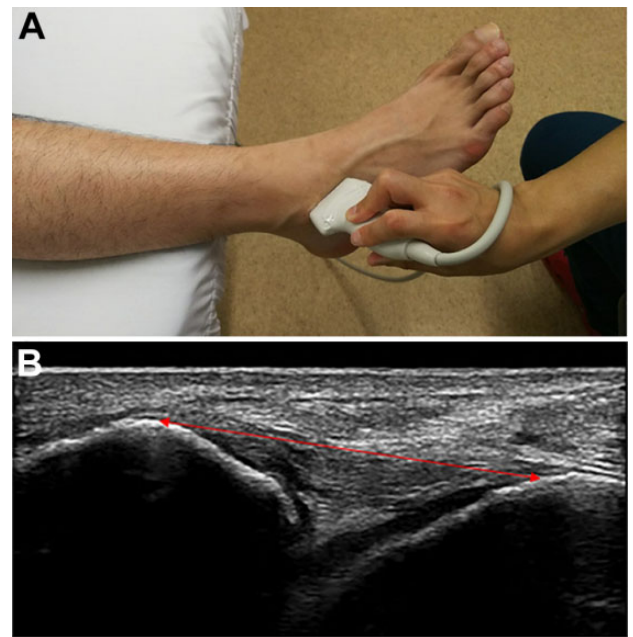
Figure 2. Measurement of nonstress anterior talofibular ligament (ATFL) length by ultrasonography. (A) The patient was relaxed in the supine position with the ankle joint in 10° to 20° of plantarflexion. The transducer was placed over the ATFL parallel to the sole of the foot. (B) An ultrasonographic image of the nonstress ATFL.

in this study, as that study demonstrated the validity of stress US for the diagnosis of CLAI.

US images were taken in 2 positions: the resting position (nonstress ATFL) and the manual maximal anterior drawer position (stress ATFL). Nonstress ATFL images were taken first (Figure 2). The patient was in a sitting position with one leg hanging from the edge of the examination table (resting position), with 10° to 15° of internal rotation of the leg. The transducer was placed over the ATFL parallel to the sole of the foot. The patient was then instructed to relax his or her ankle muscles with the ankle joint in 10° to 20° of plantarflexion. The ATFL length was measured as a linear distance from the origin to the insertion of the ATFL. The origin and insertion points of the ATFL were identified as bony landmarks during the acquisition of the US images to ensure standardization of the ATFL, in a manner previously reported.[6]

Next, a stress ATFL image was taken (Figure 3). The patient was first instructed to position himself or herself in the aforementioned resting position, and the examiner manually applied maximal medial internal rotational force to the ankle. Sisson et al[38] reported a strong positive correlation between the ATFL length on US under inversion stress and that under the ADT. The ATFL length was measured as a linear distance from the origin to the insertion of the ATFL, in the same manner as that for nonstress ATFL images. The anterolateral aspect of the lateral malleolus was identified as the ATFL origin, and the peak of the talus was used as the insertion point. The peak of the talus also

represents the anterior aspect of the lateral talar articular cartilage and the lateral neck of the talus. These bony landmarks can be identified as hyperechogenic points[14] and were confirmed to ensure that the talar insertion was consistently selected at a reference point across images.
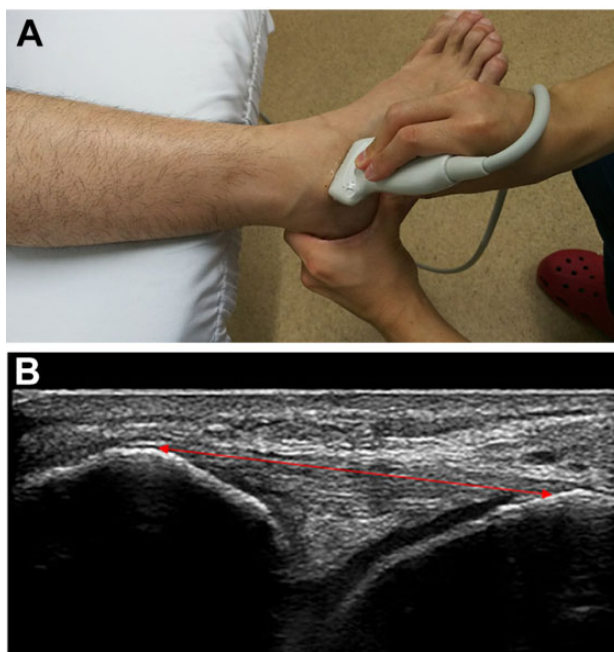
On both the nonstress and stress US images, we measured the ATFL length 3 times, and the mean of the 3 measurements was used to calculate the ATFL ratio.

Statistical Analyses

All statistical analyses were performed using SAS software (JMP Pro Version 15.2.0; SAS Institute). The results were reported as mean values with 95% CIs. The Shapiro-Wilk test was used to confirm whether the data were normally distributed. When the data showed a normal distribution, the Student t test was conducted to compare continuous data. Otherwise, the Mann-Whitney U test was performed. The chi-square test or Fisher's exact test was used to compare categorial data. The Wilcoxon signed-rank test was performed to compare US results between the right and left ankles.

The interrater reliability of the US findings was evaluated using the κ statistic. The κ coefficient for interrater agreement was graded by Landis and Koch[26] classification (slight, 0.0-0.20; fair, 0.21-0.40; moderate, 0.41-0.60; substantial, 0.61-0.80; almost perfect, 0.81-1.00). The standard error of measurement (SEM) was calculated to analyze the agreement of the US procedure.[15] For all analyses, $P < .05$ was considered statistically significant.

RESULTS

There were 169 ankles of 96 men and 164 ankles of 88 women. The mean age was 24.5 ± 2.7 years (range, 20-33 years). The patient characteristics are shown in Table 2. There were 257 ankles (77.2%) with grade 1 ADT and 76 ankles (22.8%) with grade 2 ADT. The frequency of grade 2 ADT was significantly different between male and female ankles (11.8% vs 34.1%, $P < .001$). Sixty-nine ankles (20.7%) were from patients with GJL (Beighton score ≥ 4), and there was a significant difference in the prevalence of GJL between male and female ankles (10.7% vs 31.1%, $P < .001$) (Table 3).

Normative ATFL Ratio

The κ coefficients for interobserver reliability of the US evaluations were as follows: 0.994 (95% CI, 0.990-0.996; $P < .001$) for the nonstress ATFL length, 0.990 (95% CI, 0.985-0.993; $P < .001$) for the stress ATFL length, and 0.987 (95% CI, 0.981-0.991; $P < .001$) for the ATFL ratio, indicating almost perfect agreement. The SEMs for the nonstress ATFL length, stress ATFL length, and ATFL ratio were 0.03, 0.03, and 0.002, respectively.

The ATFL ratios in the right and left ankles were 1.08 ± 0.04 (95% CI, 1.07-1.09) and 1.08 ± 0.04 (95% CI, 1.08-1.09), respectively ($P = .20$). The results of US evaluation of the

Figure 3. Measurement of stress anterior talofibular ligament (ATFL) length by ultrasonography. (A) Stress ATFL images were taken while the examiner applied maximal medial rotational force by hand. (B) An ultrasonographic image of the stress ATFL.

TABLE 2
Patient Characteristics[a]

Characteristic	All (n = 333 ankles)	Male (n = 169 ankles)	Female (n = 164 ankles)
Age, y	24.5 ± 2.7 (20-33)	24.9 ± 2.9 (21-33)	24.0 ± 2.3 (20-33)
Height, cm	165.4 ± 9.4 (147-185.2)	173.0 ± 5.2 (161-185.2)	157.6 ± 5.4 (147-167.2)
Weight, kg	59.6 ± 11.2 (41-100)	68.1 ± 8.9 (46.3-100)	50.8 ± 4.4 (41-100)
Body mass index, kg/m^2	21.6 ± 2.6 (17.2-32.7)	22.8 ± 2.9 (17.2-32.7)	20.5 ± 1.5 (17.4-25.2)
Foot size, cm	24.3 ± 1.7 (20.1-28.3)	25.6 ± 1.0 (24-28.3)	23.0 ± 1.1 (20.1-25.3)
Side of the ankle, n (%)			
Right	170 (51.1)	86 (50.9)	84 (51.2)
Left	163 (48.9)	83 (49.1)	80 (48.8)

[a]Data are shown as mean ± SD (range) unless otherwise indicated.

TABLE 3
Results of ADT, Generalized Joint Laxity, and Ultrasonographic Evaluation[a]

Variable	All (n = 333 ankles)	Male (n = 169 ankles)	Female (n = 164 ankles)	P
ADT, n (%)				<.001
Grade 1	257 (77.2)	149 (88.2)	108 (65.9)	
Grade 2	76 (22.8)	20 (11.8)	56 (34.1)	
Beighton score, n (%)				<.001
<4	264 (79.3)	151 (89.3)	113 (68.9)	
≥4	69 (20.7)	18 (10.7)	51 (31.1)	
Ultrasonographic findings				
Nonstress ATFL length, mm	19.50 ± 1.81 (15.5-24.6) [19.30-19.69]	20.41 ± 1.62 (16.8-24.6) [20.16-20.65]	18.57 ± 1.49 (15.5-23.1) [18.34-18.80]	<.001
Stress ATFL length, mm	21.08 ± 1.98 (16.4-26.8) [20.87-21.30]	21.92 ± 1.86 (17.9-26.8) [21.64-22.21]	20.22 ± 1.70 (16.4-26.0) [19.96-20.48]	<.001
ATFL ratio	1.08 ± 0.04 (1.01-1.24) [1.08-1.09]	1.07 ± 0.04 (1.02-1.23) [1.07-1.08]	1.09 ± 0.04 (1.01-1.24) [1.08-1.10]	.001

[a]Data are shown as mean ± SD (range) [95% CI] unless otherwise indicated. *P* values indicate a statistically significant difference between sexes. ADT, anterior drawer test; ATFL, anterior talofibular ligament.

TABLE 4
Relationship Between GJL and ADT[a]

Variable	ADT Grade 1	ADT Grade 2	P Value
All			<.001
GJL (−)	223	41	
GJL (+)	34	35	
Male			<.001
GJL (−)	142	9	
GJL (+)	7	11	
Female			.022
GJL (−)	81	32	
GJL (+)	27	24	

[a]GJL (+) was defined as Beighton score ≥4. *P* values indicate a statistically significant difference between ADT grades. ADT, anterior drawer test; GJL, generalized joint laxity.

ATFL are shown in Table 3. The ATFL ratio was 1.08 ± 0.04 (95% CI, 1.08-1.09; range, 1.01-1.24). The ATFL ratio in male ankles was 1.07 ± 0.04 (95% CI, 1.07-1.08; range, 1.02-1.23), while that in female ankles was 1.09 ± 0.04 (95% CI, 1.08-1.10; range, 1.01-1.24). There was a significant difference in the ATFL ratio between male and female ankles (*P* = .001).

Relationship of ATFL Ratio With GJL and ADT

Patients with GJL showed a significantly higher rate of grade 2 ADT than those without GJL (Table 4). When comparing patients with versus without GJL, there was a significant difference in the ATFL ratio for all ankles (1.10 ± 0.05 vs 1.08 ± 0.04; *P* = .003) and for male ankles (1.11 ± 0.06 vs 1.07 ± 0.03, *P* = .02). There was no significant difference in female ankles (1.10 ± 0.05 vs 1.09 ± 0.04, *P* = .24) (Table 5). When comparing patients with grade 1 versus grade 2 ADT, there was a significant difference in the ATFL ratio for all ankles (1.10 ± 0.06 vs 1.08 ± 0.03, *P* < .001) and for male ankles (1.11 ± 0.06 vs 1.07 ± 0.03, *P* = .002); there

TABLE 5
Relationship Between GJL and the ATFL Ratio[a]

	ATFL Ratio		
Variable	Mean ± SD (range)	95% CI	P
All			**.003**
GJL (−)	1.08 ± 0.04 (1.02-1.24)	1.07-1.08	
GJL (+)	1.10 ± 0.05 (1.01-1.23)	1.09-1.11	
Male			**.02**
GJL (−)	1.07 ± 0.03 (1.02-1.16)	1.07-1.08	
GJL (+)	1.10 ± 0.06 (1.04-1.23)	1.08-1.14	
Female			.24
GJL (−)	1.09 ± 0.04 (1.03-1.24)	1.08-1.10	
GJL (+)	1.10 ± 0.05 (1.01-1.20)	1.08-1.11	

[a]GJL (+) was defined as Beighton score ≥4. Bolded *P* values indicate a statistically significant difference between GJL (−) and GJL (+). ATFL, anterior talofibular ligament; GJL, generalized joint laxity.

was no significant difference in female ankles (1.10 ± 0.05 vs 1.08 ± 0.04, *P* = .12) (Table 6).

DISCUSSION

In the current study, we calculated the normative ATFL ratios on US in male and female ankles as 1.07 ± 0.04 (95% CI, 1.07-1.08; range, 1.02-1.23) and 1.09 ± 0.04 (95% CI, 1.08-1.10; range, 1.01-1.24), respectively. The ATFL ratio was affected by the presence of GJL in men (*P* = .02) but not in women (*P* = .24).

US has been demonstrated to be a valid diagnostic procedure for CLAI.[8-10,23,38] Cheng et al[9] reported that the sensitivity, specificity, and accuracy of US as a reference of surgical findings were 98.9%, 96.2%, and 84.2%, respectively. Stress US is particularly useful because clinicians can perform dynamic evaluations of the lateral ankle ligaments. However, normative data for stress US have not

TABLE 6
Relationship Between ADT and the ATFL Ratio[a]

| Variable | ATFL Ratio | | |
	Mean ± SD (range)	95% CI	*P*
All			**<.001**
ADT grade 1	1.08 ± 0.03 (1.01-1.20)	1.07-1.08	
ADT grade 2	1.10 ± 0.06 (1.02-1.24)	1.09-1.12	
Male			**.002**
ADT grade 1	1.07 ± 0.03 (1.02-1.16)	1.07-1.08	
ADT grade 2	1.11 ± 0.06 (1.04-1.23)	1.08-1.14	
Female			.12
ADT grade 1	1.08 ± 0.04 (1.01-1.20)	1.08-1.09	
ADT grade 2	1.10 ± 0.05 (1.02-1.24)	1.09-1.16	

[a]Bolded *P* values indicate a statistically significant difference between ADT grades. ADT, anterior drawer test; ATFL, anterior talofibular ligament.

been established because previously published studies[12,38] included small samples of healthy ankles. To the best of our knowledge, the present study evaluated the largest sample size of healthy ankles to provide a normative value of the ATFL ratio. Cho et al[10] reported that an ATFL ratio ≥1.2 could serve as a criterion for diagnosing CLAI through their retrospective assessment of 38 patients with CLAI. In the current study, the normative ATFL ratio was 1.08 ± 0.04 (95% CI, 1.08-1.09; range, 1.01-1.24). In addition, of the included 333 healthy ankles, 1.8% (6/333) had an ATFL ratio ≥1.2. Therefore, the cutoff value of 1.2 may be appropriate to diagnose CLAI by stress US using the method by Cho et al.[10] However, we evaluated only patients with healthy ankles. Therefore, further studies are needed to establish the optimal cutoff value of the ATFL ratio for diagnosing CLAI.

In the present study, the mean ATFL ratio in women was significantly greater than that in men ($P = .001$). Considering the results in this study, the enrollment of 333 ankles was determined to be sufficient to achieve statistical significance with >80% power via ClinCalc.com (63 required in each group). Wilkerson and Mason[42] reported that healthy women had a significantly higher talar tilt angle on stress radiography using the Telos device than healthy men. These findings were consistent with our results. Therefore, clinicians should consider sexual differences in US findings when evaluating CLAI. It remains unclear whether sex is a risk factor of LAS or CLAI.[16,40] Doherty et al[16] reported that the incidence of acute LAS was higher among women than men (13.6/1000 vs 6.9/1000 exposures). On the other hand, Waterman et al[40] did not find a significantly higher incidence of ankle sprain in men in comparison to women (incidence rate ratio, 1.04; 95% CI, 1.00-1.09).

In the present study, grade 2 ADT was detected in 34.1% of female ankles compared with 11.8% of male ankles ($P < .001$), indicating that women have greater laxity of the native ankles than men. Several intrinsic factors, such as anatomic, hormonal, and biological sexual differences, may contribute to the incidence of LAS or CLAI. It is also estimated that sexual differences in the extrinsic factors, including activity levels and sports type, may affect the incidence of LAS or CLAI.[13,16,22,40] However, there is scarce evidence regarding sexual differences in the development of LAS or CLAI. Thus, future studies will be required to evaluate sexual differences in the development of LAS or CLAI.

Another interesting finding of the present study was that the ATFL ratio was statistically greater in men with GJL than in those without GJL, although this finding was not confirmed in women. This suggests that the GJL should be considered when assessing chronic ATFL injuries specifically in men. Several studies[11,37] have shown that the prevalence of GJL is higher in women than in men in the general population, which was compatible with our findings (10.7% in men vs 31.1% in women). Furthermore, as shown in the current study, female ankles tended to have greater laxity than male ankles, suggesting that the effect of GJL on ankle injuries may differ by sex. It was confirmed that elite male soccer players with GJL were associated with a higher incidence of injuries than those without GJL.[25] However, Blokland et al[5] reported that GJL was not a risk factor for injuries in elite female soccer players. It was also reported that the presence or absence of GJL did not affect postoperative functional outcomes after arthroscopic surgery for femoroacetabular impingement in female patients.[33] These findings and the results of the present study suggest that the influence of GJL on injuries may be less significant in women than in men. Further studies are needed to evaluate the clinical importance of GJL on ankle injuries in each sex.

The relationship between GJL and the risk of injuries has been well-discussed in the shoulder[7,34,36] and knee.[29,30,39] However, few studies have evaluated the effect of GJL on the incidence of LAS or CLAI. There are a few studies[32,43,44] evaluating the effect of GJL on the results after the modified Broström procedure. Future studies need to be performed to clarify the influence of GJL on the incidence of LAS or CLAI. It was reported that the Beighton score had a poor correlation with specific shoulder laxity examinations.[41] Therefore, further studies will also be required to evaluate whether the Beighton score is an appropriate tool for assessing laxity of the ankle joint.

This study has several limitations. First, we did not evaluate the normative ATFL ratio in adolescent or preadolescent populations in this study. Therefore, we cannot provide normative data in these high-risk individuals.[13] Second, the normative value was obtained by using the stress US method reported by Lee et al[27] because the validity of this technique has been confirmed. Therefore, the normative values using other procedures are unclear. Third, US findings are affected by the examiner's experience and the spatial resolution of the US apparatus. Fourth, the intraobserver reliability of the US procedure was not assessed in this study. Fifth, we did not evaluate the possible effect of exercise on ankle ligament laxity.[3] Finally, this study included a single ethnic population. Therefore, the generalizability of the results in this study to other ethnic groups is unknown.

CONCLUSION

The normative value of the ATFL ratio on stress US was 1.07 ± 0.04 in men and 1.09 ± 0.04 in women. The ATFL ratio was affected by the presence of GJL in men but not in women. These findings provide a useful reference not only for clinicians when evaluating CLAI but also for future studies establishing cutoff values for the ATFL ratio to diagnose CLAI by stress US.

ACKNOWLEDGMENT

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