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Tibiofibular relationships of the normal syndesmosis differ by age on axial computed tomography—Anterior fibular translation with age

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ABSTRACT

Introduction: This study aimed to assess the tibiofibular relationships of normal syndesmosis on axial computed tomography (CT) images and evaluate the measurement differences by gender, age, and body sides.

Patients and Methods: The cases of 120 volunteers who underwent bilateral ankle CT were retrospectively reviewed. Volunteers were divided into three groups of 40 (20 men and 20 women) as follows: 20–40, 40–60, and 60–80 years old. Radiographic evaluation included the anterior tibiofibular clear space (ATFCS), posterior tibiofibular clear space (PTFCS), anterior tibiofibular interval (ATFI), length of incisura (LI), depth of incisura (DI), and fibular width (FW). Each measured parameter was compared based on gender, age, and body sides. To calibrate anatomical variations among the volunteers, ATFCS, PTFCA, and ATFI were expressed as ratios of FW.

Results: PTFCS and ATFI were significantly larger in the men ($p = 0.001$, 0.001). LI and FW were significantly smaller in the women ($p < 0.001$, < 0.001). Calibrated ATFCS, PTFCS, and ATFI did not differ between the genders. ATFCS, PTFCS, and ATFI were significantly different among the age groups ($p = 0.001$, 0.001, and < 0.001, respectively). These calibrated parameters showed significant differences according to age ($p = 0.009$, 0.006, and < 0.001, respectively). There were no significant differences between sides. All CT measurements, except DI, showed high intra- and inter-observer reliabilities.

Conclusions: Axial CT images of the normal syndesmosis showed significant differences according to gender and age, but not between sides. In light of the anatomical variation, narrowing of the syndesmotic joint due to anterior translation of the fibula following aging may represent the most significant finding.

Level of Evidence: : Level IV, case series.

Introduction

Disruption of the distal tibiofibular syndesmosis, which has been reported in approximately 13% of all ankle fractures [1], can lead to post-traumatic arthritis and poor outcomes if not detected or properly treated [2]. Therefore, the importance of anatomical restoration and stabilization for disrupted syndesmosis has been emphasized [3–5]. Nevertheless, the optimal evaluation methods and criteria for evaluating syndesmosis integrity are controversial. Traditionally, radiographic parameters, including tibiofibular overlap and clear space on simple radiographs, have been used for the diagnosis of disrupted syndesmosis [6,7]. However, these parameters may be less reproducible according to the rotation of the ankle, and subtle diastasis of syndesmosis is difficult to diagnose using these parameters [8,9]. Accordingly, computed tomography (CT) may be a more effective diagnostic tool than simple radiography for evaluating disrupted syndesmosis [10,11].

Recent studies have introduced methods for evaluating syndesmosis using axial CT images [12,13]. However, there is no consensus on the standardized measurement methods for evaluating the normal tibiofibular relationship. In addition, the definition of malreduction of the syndesmosis has also not been well established. A previous study suggested a 2-mm difference between the anterior and posterior tibiofibular distances on axial CT scan as a criterion for malreduction of the syndesmosis [14], and to date, this definition has been widely used as the standard for malreduction in several studies [14–16]. However, this definition was set as an arbitrary threshold of "2 mm" for incongruity without scientific evidence [14]. Moreover, anatomical variations due to age and gender were not considered.

Although there have been some studies on the anatomical relationship of the normal syndesmosis on CT images [12,13], few studies have reported the tibiofibular relationships with respect to

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gender and age. To the best of our knowledge, no previous study has conducted such evaluations in an Asian population. We hypothesized that the tibiofibular relationships of the normal syndesmosis would differ by gender and age on axial CT images. The purpose of this study was to assess the tibiofibular relationships of the normal syndesmosis on axial CT images and evaluate the measurements according to gender, age, and side-to-side differences.

Patients and methods

The present study was approved by the institutional review board of our hospital, and informed consent was obtained from all the patients. From May 2014 to December 2015, healthy volunteers aged 20–80 years were recruited for this study. The inclusion criteria were as follows: absence of ankle fractures or syndesmotic injuries, chronic ankle instability, ankle arthritis, and any other surgery affecting syndesmotic integrity. Finally, 120 volunteers (60 men and 60 women) who underwent bilateral ankle CT scans were enrolled and retrospectively analyzed in this study. The enrolled volunteers were divided into three groups of 40 people (20 men and 20 women) according to age group in increments of two decades as follows: 20–40 years old (group 1), 40–60 years old (group 2), and 60–80 years old (group 3). The groups had balanced number and gender distributions. The demographic characteristics of all volunteers are shown in Table 1.

All CT scans were taken in the same facility using the same protocol. All images were obtained with SOMATOM Definition AS+ (Siemens, Germany) using a bone algorithm. Typical scan parameters were as follows: field of view, 25 cm; peak kilovoltage, 120 kVp; quality reference, 82 mAs; scan time per slice, 1 s; and slice thickness, 2 mm. Bilateral CT scans were performed with neutral rotation of the ankle joint to obtain standardized and reproducible axial images parallel to the tibial plafond. Neutral rotation was defined on the basis of the bimalleolar axis as reported in previous studies [13,17]. A single image of the syndesmosis for measurement was selected approximately 1 cm proximal to the tibia plafond, at which level the incisura could be easily recognized due to its correspondence to the deepest tibiofibular articulation [17,18]. As the interval of the CT cuts was set at 2 mm in our hospital, the fifth cut was selected above the level of the ankle joint.

All radiographic measurements were performed using a picture archiving and communication system (Maroview®, version 5.4; Marotech, Seoul, Korea) in the format of DICOM (Digital Imaging and Communicating in Medicine). The radiographic evaluation of the distal tibiofibular relationship included the anterior tibiofibular clear space (ATFCS), posterior tibiofibular clear space (PTFCS), anterior tibiofibular interval (ATFI), length of the incisura (LI), depth of the incisura (DI), and fibular width (FW). ATFCS was defined as the interval between the tip of the anterior tibial tubercle (point A) and the anterior border of the fibula (point B) [12,18]. PTFCS was the interval between the medial border of the fibula (point C) and the most lateral point of the posterior tibial tubercle (point D; Fig. 1) [12,18]. ATFI was defined as the vertical distance between the most anterior point of the tibia (point G) and the line connecting the anterior border of the fibula (line EF) [13]. LI was defined as the distance between the tip of the anterior tibial tubercle and the tip of the posterior tibial tubercle (line HI) [13], while DI was defined as the vertical distance between the line representing LI and the deepest point of the incisura (line JK; Fig. 2) [13,19]. FW was defined as the interval between the anterior and posterior fibular tubercles (line LM; Fig. 3) [13]. Each measured parameter was compared by gender, age, and side-to-side differences. In addition, to calibrate the anatomical variations among the volunteers, ATFCS, PTFCA, and ATFI were expressed as ratios of FW [13], and these calibrated parameters were also compared by gender, age, and side-to-side differences.

We randomly selected 51 CT images of the 51 patients based on the calculation of sample size according to Bonett's approximation to assess the intra- and inter-observer reliabilities of the radiographic measurements [20]. Radiographic measurements were performed by two independent board-certified orthopedic surgeons and repeated two weeks later. Reliabilities for all radiographic parameters were analyzed using intraclass correlation coefficients, and reliabilities were classified as little if any (correlation coefficient, $\leq$0.25), low (0.26–0.49), moderate (0.50–0.69), high (0.70–0.89), or very high ($\geq$0.90) [21].

The statistical evaluation was performed using the IBM SPSS software version 23 (IBM Corp., Armonk, NY, USA), and continuous data are expressed as means with standard deviation. All data are presented separately by gender, age, and side-to-side differences.

Table 1
Demographic differences by gender and age.

	Height (cm)	Weight (kg)	Body mass index
Gender			
Male (n = 60)	171.6 ± 7.6	71.6 ± 11.9	24.2 ± 3.4
Female (n = 60)	159.1 ± 5.6	61.4 ± 9.4	24.2 ± 3.2
p-Value*	<0.001	<0.001	0.964
Age (years)			
20–40 (n = 40)	170.3 ± 8.7	72.7 ± 13.3	25.0 ± 3.8
40–60 (n = 40)	165.2 ± 8.0	65.2 ± 11.0	23.9 ± 3.4
60–80 (n = 40)	161.6 ± 8.8	62.2 ± 8.4	23.8 ± 2.4
p-Value†	<0.001	<0.001	0.201
Overall (n = 120)	165.8 ± 9.2	66.8 ± 11.9	24.2 ± 3.3

Values presented as mean and standard deviation.
* An independent *t* test was used to compare the differences in demographic factors between the genders. The statistical significance was set at $p < 0.05$.
† One-way analysis of variance was used to compare the differences in demographic factors among age groups. The statistical significance was set at $p < 0.05$.

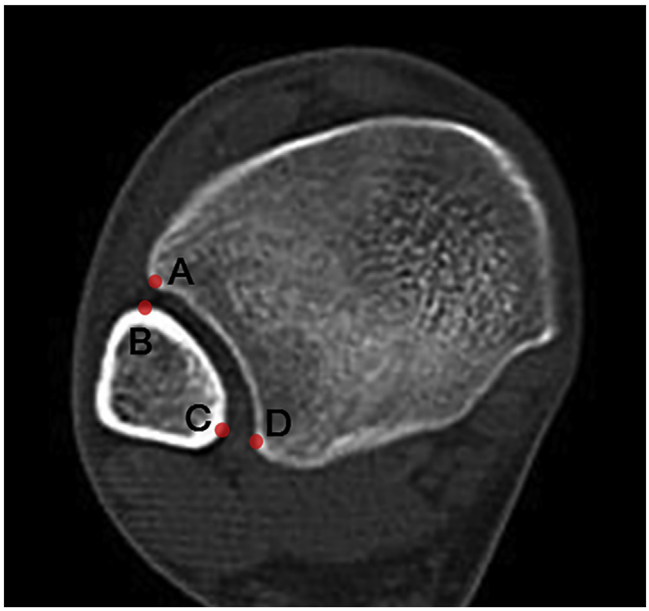

Fig. 1. Axial computed tomography image of the right ankle approximately 1 cm proximal to the tibial plafond in a normal syndesmosis in a 40-year-old man. The anterior tibiofibular clear space is the distance between points A and B, and the posterior tibiofibular clear space is the distance between points C and D.

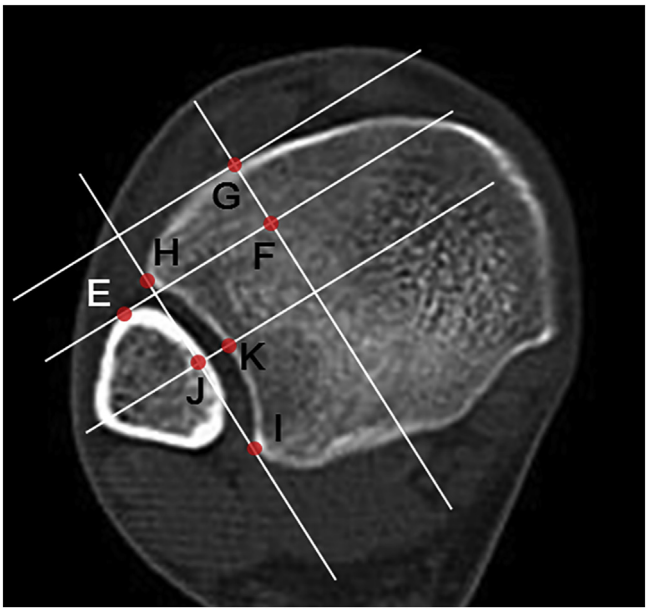

Fig. 2. Axial computed tomography image of the right ankle approximately 1 cm proximal to the tibial plafond in a normal syndesmosis in a 40-year-old man. The anterior tibiofibular interval is the distance between points F and G. The length of the incisura is the distance between points H and I (line HI), and the depth of the incisura is the distance between points *J* and K (line JK).

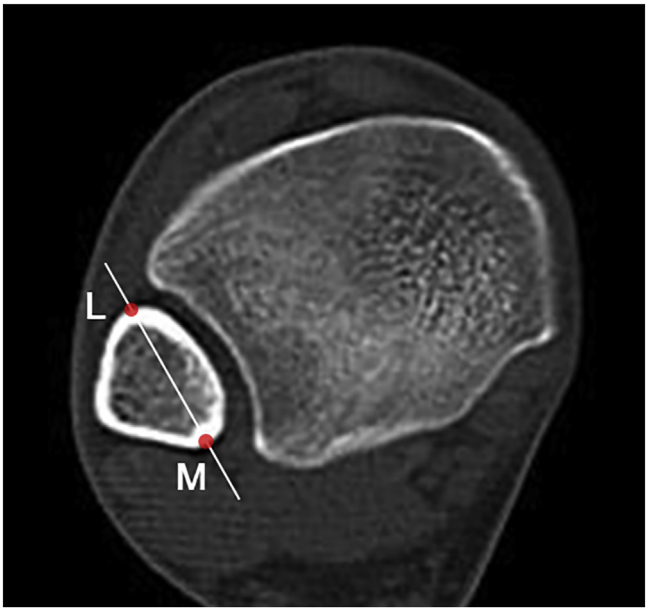

Fig. 3. Axial computed tomography image of the right ankle approximately 1 cm proximal to the tibial plafond in a normal syndesmosis in a 40-year-old man. The fibular width is the interval between the anterior fibular tubercle and the posterior fibular tubercle (line LM).

All dependent variables were tested for normality of distribution and equality of variances by using the Kolmogorov-Smirnov test and analyzed using parametric or non-parametric tests based on normality. An independent *t* test was used to analyze the differences in measured radiographic parameters according to gender and body sides. One-way analysis of variance (post-*hoc* analysis: Tukey test) was also used to compare the difference in radiographic parameters among the groups by age. *P* values of $<.05$ were considered statistically significant.

Results

Radiographic results according to gender, age, and side-to-side differences are described in Table 2, while calibrated radiographic results as a ratio of FW are described in Table 3. PTFCS ($p = 0.001$) and ATFI ($p = 0.001$) were significantly larger in the men than in the women, while LI ($p < 0.001$) and FW ($p < 0.001$) were significantly smaller in the women than in the men (Table 3). Calibrated ATFCS, PTFCS, and ATFI as a ratio of FW did not differ between the genders (Table 3). ATFCS ($p = 0.001$), PTFCS ($p = 0.001$), and ATFI ($p < 0.001$) were significantly different among the age groups (Table 2). These parameters, calibrated as ratios of FW, showed significant differences among the age groups (Table 3). No significant side-to-side differences were observed in the radiographic results (Table 2).

The intra- and inter-observer reliabilities of the radiographic measurements are shown in Table 4. All CT measurements except DI showed very high intra- and inter-observer reliabilities (Table 4).

Discussion

This study aimed to evaluate the tibiofibular relationships of the normal syndesmosis on axial CT images according to gender, age, and side-to-side differences. The most important finding of the present study was the significant differences according to age on the axial CT image of the normal syndesmosis.

Unlike the apparent diastasis of the syndesmosis in ankle fracture, occult diastasis associated with ankle sprain is likely to be overlooked [22,23]. Although it may not be considered the first-line diagnostic tool for disrupted syndesmosis, CT scan is much more sensitive than simple radiography for diagnosing subtle diastasis of $\leq$3 mm [11]. Moreover, simple radiographs may be less reproducible depending on the amount of ankle rotation [8,9]. Some studies have reported the advantages of CT scans for diagnosing the disrupted syndesmosis [11,24]. In the present study, CT revealed superior intra- and inter-observer reliabilities for all measured radiographic parameters (Table 4).

Although several studies have reported the analyses of CT images of the normal syndesmosis [11,12,14,18,25], there is a paucity of information in the literature regarding the anatomical relationship of the normal syndesmosis on CT images [12,13]. In addition, some studies were of cadaveric rather than living subjects [11,25], and most studies did not consider differences according to age [12,14,18]. The present study demonstrated differences in the tibiofibular relationships according to the gender and age. PTFCS, ATFI, LI, and FW were significantly larger in the men than in the women (Table 2). However, no significant differences were observed when these parameters were calibrated as ratios of FW, which reflect dimensional differences among the subjects. Men tend to have larger bony dimensions compared to women; thus, the absolute value of their measured parameters might be larger. This may be explained by the anatomical variations between men and women rather than the actual differences in the measured parameters [13].

In this study, ATFCS, PTFCS, and ATFI were significantly smaller in the older age group. These parameters were also significantly smaller when presented as ratios of FW. There is little information regarding the sagittal translation of the fibula in normal population. Lepojärvi et al. reported that 67% of all subjects showed anterior translation of the fibula and that the narrowest part of the incisura was located anteriorly in 94% of all the subjects [26]. They concluded that sagittal translation measurements are not affected by the size of the joint or gender, although there was no mention of sagittal translation according to age [26]. In spite of the lack of evidence of sagittal movement of the fibula with aging, we thought that the anterior

Table 2
Differences in measured CT parameters.

	ATFCS (mm)	PTFCS (mm)	ATFI (mm)	LI (mm)	DI (mm)	FW (mm)
Gender						
Male (n = 60)	2.1 ± 0.8	3.7 ± 0.9	6.5 ± 1.6	24.4 ± 2.0	4.4 ± 0.9	18.2 ± 1.9
Female (n = 60)	2.0 ± 0.6	3.1 ± 1.0	5.6 ± 1.1	22.6 ± 1.9	4.1 ± 0.9	16.8 ± 1.5
p-Value*	0.787	0.001	0.001	< 0.001	0.081	< 0.001
Age (years)						
20–40 (n = 40)	2.4 ± 0.8	3.9 ± 1.1	6.7 ± 1.1	23.8 ± 2.3	4.3 ± 1.1	17.8 ± 1.9
40–60 (n = 40)	2.0 ± 0.7	3.3 ± 1.0	6.2 ± 1.7	23.6 ± 2.2	4.4 ± 0.6	17.7 ± 1.9
60–80 (n = 40)	1.8 ± 0.6	3.1 ± 0.8	5.2 ± 1.3	23.1 ± 1.7	4.1 ± 1.0	17.1 ± 1.6
p-Value†	0.001	0.001	< 0.001	0.514	0.994	0.153
Body side						
Right (n = 60)	2.1 ± 0.8	3.6 ± 1.0	6.0 ± 1.5	23.8 ± 2.0	4.1 ± 0.9	17.6 ± 1.7
Left (n = 60)	2.0 ± 0.8	3.3 ± 1.0	6.1 ± 1.5	23.2 ± 2.1	4.4 ± 1.0	17.4 ± 1.9
p-Value*	0.765	0.092	0.624	0.123	0.172	0.570

Values presented as mean and standard deviation.
Statistical significance was set at $p < 0.05$.
CT, computed tomography; ATFCS, anterior tibiofibular clear space; PTFCS, posterior tibiofibular clear space; ATFI, anterior tibiofibular interval; LI, length of incisura; DI, depth of incisura; FW, fibular width; mm, millimeter.
* The independent *t* test was used to compare the differences in measured CT parameters between the genders and body sides.
† One-way analysis of variance was used to compare the difference in measured CT parameters among the groups according to age.

Table 3
Differences in calibrated CT parameters as ratios of FW.

	ATFCS/FW	PTFCS/FW	ATFI/FW
Gender			
Male (n = 60)	0.12 ± 0.05	0.21 ± 0.06	0.36 ± 0.09
Female (n = 60)	0.12 ± 0.04	0.19 ± 0.06	0.33 ± 0.06
p-Value*	0.430	0.062	0.074
Age (years)			
20–40 (n = 40)	0.14 ± 0.05	0.22 ± 0.06	0.38 ± 0.06
40–60 (n = 40)	0.11 ± 0.04	0.19 ± 0.06	0.35 ± 0.09
60–80 (n = 40)	0.11 ± 0.04	0.18 ± 0.05	0.31 ± 0.07
p-Value†	0.009	0.006	< 0.001

Values presented as mean and standard deviation.
CT, computed tomography; FW, fibular width; ATFCS, anterior tibiofibular clear space; PTFCS, posterior tibiofibular clear space; ATFI, anterior tibiofibular interval.
* An independent *t* test was used to compare the ratio of the measured CT parameters of the FW between the genders. Statistical significance was set at $p < 0.05$.
† One-way analysis of variance was used to compare the ratio of the measured CT parameters of the FW among the age groups. Statistical significance was set at $p < 0.05$.

Table 4
Intra- and inter-class correlation coefficients of the measured CT parameters.

	Intra-observer	Inter-observer
ATFCS	0.93	0.92
PTFCS	0.92	0.91
ATFI	0.94	0.93
LI	0.94	0.96
DI	0.90	0.87
FW	0.98	0.97

Values presented as absolute values. The data show almost perfect intra- and inter-observer agreement in the measured CT parameters.
CT, computed tomography; ATFCS, anterior tibiofibular clear space; PTFCS, posterior tibiofibular clear space; ATFI, anterior tibiofibular interval; LI, length of incisura; DI, depth of incisura; FW, fibular width.

translation of the fibula might correspond to physiologic changes and could progress with aging due to attenuation of the ligaments around the ankle joint and arthritic changes. Therefore, we considered these to be potential reasons for the significant differences in ATFCS, PTFCS, and ATFI among the age groups in the present study.

Some studies have reported that a significant number of patients showed incongruity of the syndesmosis on axial CT images, even after operative treatment [14]. They suggested the cutoff value of a '2-mm' difference between the anterior and posterior tibiofibular distances on axial CT scan as a criterion for malreduction of the syndesmosis. However, not only did they not compare the injured side with the uninjured contralateral side, the threshold of '2-mm' to indicate incongruity is also arbitrary [14]. Furthermore, since this criterion did not consider differences in subject dimensions, it could not reflect any anatomical variations. Rather, some studies have reported that this criterion is not generally applicable [27], as the differences greater than 2 mm are observed even in the normal ankle [12,18,26]. In addition, since fibular position or rotation may also affect syndesmotic congruity [13], further research is needed to determine the appropriate systematic criteria that incorporate the factors of anatomical variation and fibular rotation.

Despite its informative results, this study has some limitations. First, the clinical application might be limited by the CT scan itself. Since the condition of soft tissue is difficult to accurately assess by CT scan, other diagnostic tools such as magnetic resonance imaging may be necessary to evaluate ligament or adjacent soft tissue injuries associated with disrupted syndesmosis. Second, the number of subjects included in each group was relatively small. Forty volunteers were assigned to each group, but, we could not confirm whether this number was sufficient for each group. Nevertheless, as compared with previously reported studies on the tibiofibular relationship, the present study included a relatively larger number of ankles. Third, the association between the results of the present study and clinical outcomes was not investigated. Future research on the relevance of the clinical outcomes is warranted.

Conclusions

In conclusion, there are significant differences according to gender and age, but not between sides. Therefore, until the clinical relevance of this study has been investigated, we suggest that in patients with an injury of the distal tibiofibular joint requiring a CT investigation, the findings of the injured side should compare to those of the normal side. In light of the anatomical variation, narrowing of the syndesmotic joint due to anterior translation of the fibula following aging may represent the most significant finding.

Conflicts of interest and source of funding

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