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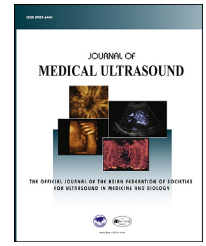

ORIGINAL ARTICLE

Assessment of the Anterior Talofibular Ligament Thickness in Patients with Chronic Stroke: An Ultrasonographic Study

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Abstract *Background:* Patients with equinovarus deformity have an increased risk of fall and ankle ligament injury, because of inappropriate prepositioning of the ankle at the end of the swing phase, and inadequate leg and ankle stability during the stance phase. Accordingly, the aim of this study is to compare anterior talofibular ligament (ATFL) thickness of chronic stroke patients with that of healthy individuals using ultrasonography.
Methods: This was a case-control study conducted in a university hospital between July 2015 and July 2016. We included 38 patients [study group; mean age, 59.0 ± 11.1 years; mean body mass index (BMI), 25.4 ± 4.3 kg/m^2] and a control group of age-, sex-, and BMI-matched healthy individuals. Demographic and clinical characteristics of the patients (i.e., age, weight, height, Brunnstrom motor recovery stage, Functional Ambulation Scale, Ashworth Scale, and duration of hemiplegia) were recorded during their visits. Furthermore, ultrasound image of the ATFL was obtained from each ankle. The thickness of the ATFL was measured at the midpoint of the ligament between the attachments on the lateral malleolus and the talus using ultrasonography.
Results: In the study group, the mean thickness of the ATFLs of the affected side (2.75 ± 0.41 mm) was thicker than both the unaffected side (2.42 ± 0.30 mm) and the healthy controls (2.35 ± 0.19 mm; $p = 0.007$, $p < 0.001$, respectively). No differences were seen between the two sides of the control group.
Conclusion: Chronic stroke patients have a thicker ATFL on both the affected and unaffected sides, compared with healthy individuals. This architectural feature of the ATFL may be a

Conflicts of interest: The authors have no conflicts of interest to declare.

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result of equinovarus deformity together with spastic muscles. For this reason, early treatment of deformed ligaments and spastic muscles is needed to prevent equinovarus deformity in patients with stroke.

Introduction

Following a stroke event, patients with hemiparesis may develop walking disabilities. On the affected side, muscular imbalance usually causes ankle and foot deformities. Inadequate ankle dorsiflexion and spasticity of the plantar flexors or invertors following stroke have been described [1]. Ankle equinus deformities are seen in up to 20% of stroke patients, and of these, equinovarus deformity is the most characteristic and the most frequently seen [2,3]. Increased tone of the plantar flexors and invertors together with weakness of the dorsal flexors and evertors may explain the development of equinovarus deformity [4,5]. Although hemiplegia is primarily associated with unilateral motor involvement, evident changes in almost all of the parameters used to assess walking have been seen on both the affected and unaffected sides of the body [6].

A ligament is soft connective tissue that transmits tensile force from bone to bone and undertakes an essential role in musculoskeletal biomechanical function by stabilizing and guiding the motion of diarthrodial joints. It tends to remodel according to the applied motion and stress [7,8]. Ligaments supporting the lateral complex of the ankle include the anterior talofibular ligament (ATFL), calcaneofibular ligament, and posterior talofibular ligament. The ATFL is a flat ligament that attaches from the anterior border of the lateral malleolus to the talus, just anterior to the lateral malleolus articular surface. The ATFL limits plantar flexion and inversion, which are the movements coinciding with the most common mechanism of injury [9]. As a result, the ATFL becomes vulnerable in a plantar-flexed and inverted position and is most susceptible to damage during walking in stroke patients. Equinovarus deformity results in an abnormal alignment of the ankle joint, causing the talus to be directed downward and the forefoot to be deviated medially and rotated into supination [10]. Patients with equinovarus deformity have an increased risk of fall and ankle ligament injury, because of inappropriate prepositioning of the ankle at the end of the swing phase, and inadequate leg and ankle stability during the stance phase [11]. However, to the best of our knowledge, the effects of equinovarus deformity on the ATFL have not been investigated in patients with poststroke hemiplegia. Accordingly, the aim of this study was to compare the ATFL thickness in the affected and unaffected sides of chronic stroke patients with that of healthy individuals using ultrasonography.

Materials and Methods

Study design and patients

The study included 38 chronic ischemic or hemorrhagic stroke patients (26 male and 12 female patients) with walking disability. Chronic stroke was defined as the open-ended period starting 6 months after the initial stroke. A control group was formed of 38 sex-, age-, and body mass index (BMI)-matched healthy individuals without ankle disorder or a history of lower limb surgery. Sex, age, BMI, Brunnstrom motor recovery stage, Functional Ambulation Scale (FAS), and duration of hemiplegia were recorded. The Ashworth Scale was used in hemiplegic tonus evaluation. Inclusion criteria were as follows: (1) a stroke event at least 6 months prior to the study and (2) a walking disability with equinovarus of the ankle. Exclusion criteria were as follows: (1) patients with an ankle injury in the poststroke period, (2) previous botulinum toxin injection to gastrosoleus muscles, (3) previous surgery on the lower limbs, (4) fixed ankle contracture, and (5) any reason for pes planus. All patients were informed about the study procedure and informed consent was obtained. The Local Ethics Committee approved the study protocol.

Ultrasonographic measurements

The ATFL measurement was taken using a linear probe (7-12 MHz, Logiq P5, GE Medical Systems, Waukesha, WI, USA) by a physiatrist (M.T.Y.), with the patient in a supine position with the ankles in neutral or slight plantar flexion. A longitudinal image of the ATFL was scanned with the transducer placed in a slightly oblique direction from the anterolateral aspect of the lateral malleolus to the peak of the talus using a previously described method [5]. The peak of the talus represents the anterior aspect of the lateral talar articular cartilage and the lateral neck of the talus. The two bony landmarks were easily identified because of their hyperechogenicity on sonography. The normal ATFL was depicted as hyperechoic bundles on sonography. The thickness of the ATFL was measured halfway between the two bony landmarks of the ankle (Figure 1).

All sonographic measurements were taken in the plane perpendicular to the long axis of the ligaments for standardization and reproducibility of the measurements. Sonographic measurements for the thickness of the ligaments were taken two times, and the mean values were recorded. The reliability of the thickness measurements

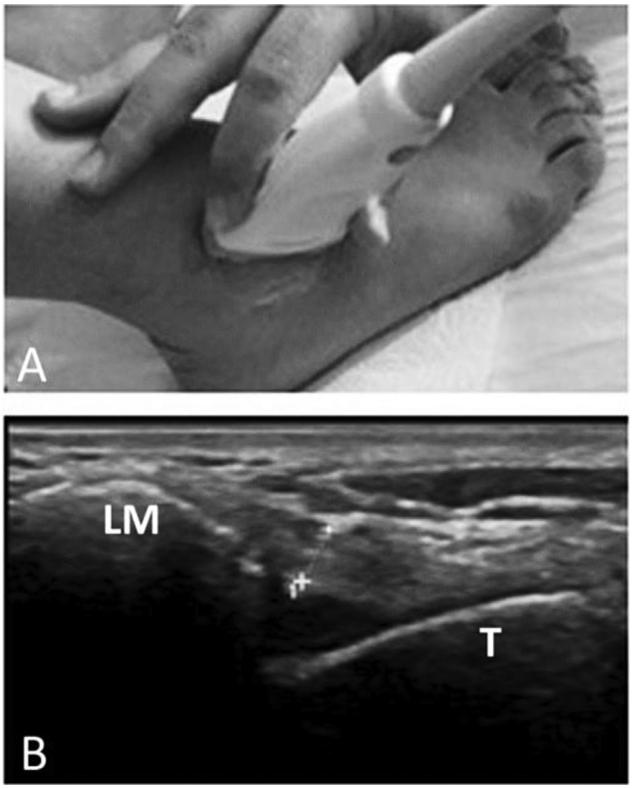

Figure 1 A longitudinal ultrasonographic image of the anterior talofibular ligament. (A) The linear probe positioned in a slightly oblique position from the lateral malleolus (LM) to the talus (T). (B) The ligament thickness measured halfway between the two bony landmarks of the ankle.

was analyzed by calculating intraclass correlation coefficients between the two measurements (intraclass correlation coefficient = 0.92).

Statistical analysis

Statistical analysis was performed with SPSS version 20.0 (SPSS, Chicago, IL, USA). Data were presented as mean with standard deviation and frequency. The one-way analysis of variance or paired *t* test was used to examine the difference between the affected sides, unaffected sides, and the control group. The correlation between the Ashworth Scale, FAS, Brunnstrom motor recovery stage, disease duration, and the ATFL thickness in the affected ankle was analyzed with the Spearman rank test. Statistical significance was set at $p < 0.05$.

Results

Thirty-eight (26 males and 12 females) consecutive patients (mean age, 59.04 ± 11.1 years; range, 38–75 years) who were admitted to our outpatient clinic with a diagnosis of chronic stroke between July 2015 and July 2016, and 38 (26 male and 12 female) sex-, age-, and BMI-matched healthy individuals (mean age, 59.0 ± 10.3 years; range, 40–72 years) were enrolled.

The demographic characteristics of the individuals in both groups are presented in Table 1. The comparison of the ATFL thickness measurements is also shown in Table 1. No statistically significant differences were observed between the groups with respect to sex, age, and BMI. The clinical characteristics of all 38 stroke patients are shown in Table 2.

The ATFL thickness of the affected side for the study group was measured as 2.75 ± 0.41 mm, 2.42 ± 0.30 mm for the unaffected side of the study group, and 2.35 ± 0.19 mm for the healthy control group. A statistically significant difference was determined between the ATFL measurements of the affected and unaffected sides of the study group ($p = 0.001$). A statistically significant difference was also determined between the ATFL thickness of the affected side of the study group and the ATFL thickness of the healthy control group ($p < 0.001$). No statistically significant difference was determined between the ATFL thickness measurement of the unaffected side of the study group and that of the healthy control group ($p = 0.530$). There was no statistically significant correlation between Brunnstrom recovery stage ($p = 0.466$; $r = 0.144$), Ashworth Scale ($p = 0.750$; $r = 0.063$), FAS ($p = 0.699$; $r = 0.076$), and the ATFL thickness of the affected side.

Table 1 Demographic features of the groups and comparison of the results of the ATFL measurements.

	Study ($n = 38$)		Control ($n = 38$)		p
Age, y	59.04 ± 11.19		59.07 ± 10.38		NS
Sex (male/female)	26/12		26/12		NS
BMI, g/cm^2	25.46 ± 4.37		25.72 ± 4.19		NS
Disease duration, mo	12 (6–60)		—		—
Affected side (R/L)	10/28		—		—
Inversion (Yes/No)	38/0		—		—
Equinus (Yes/No)	38/0		—		—
Calcaneal varus (Yes/No)	8/30		—		—
	Affected side	Unaffected side	Right side	Left side	
ATFL thickness, mm	2.75 ± 0.41 [a,b]	2.42 ± 0.30 [c]	2.35 ± 0.19	2.35 ± 0.19	

ATFL = anterior talofibular ligament; BMI = body mass index; mo = month; NS = no significant; y = years.
[a] $p = 0.001$ versus unaffected side.
[b] $p < 0.001$ versus normal side.
[c] $p = 0.530$ versus normal side.

Table 2 Clinical characteristics of the study group.

	Study group, *n* (%)
Ashworth Scale	
0	—
1	27 (71.0)
2	9 (23.6)
3	2 (5.2)
4	—
Brunnstrom motor recovery stage	
1	—
2	—
3	8 (21.0)
4	14 (36.8)
5	16 (42.1)
6	—
Functional Ambulatory Scale	
0	—
1	—
2	6 (15.7)
3	8 (21.0)
4	16 (42.1)
5	8 (21.0)

Discussion

In this study, the ATFL thickness of chronic stroke patients was evaluated, which, to the best of our knowledge, is the first time in literature. The results showed that chronic stroke patients have a thicker ATFL on the affected side. In the healthy control group, there was no difference between the thickness of the ATFL on the both sides. It can be postulated that these findings may be due to several factors. Hemiplegic patients often have inadequate ankle dorsiflexion due to loss of motor control, spasticity of the gastrocnemius soleus or the invertor group, and/or ankle contracture [1]. These muscle changes affect functional ambulation, thereby resulting in an increased falling risk and mechanical stress on the lateral column of the foot while walking [8]. Because a ligament is a highly organized fibrous tissue, its mechanical properties are directionally dependent on stress. The ATFL has an average of 7 mm wide, 20 mm long, and 2 mm thickness [12]. An increased thickness of the ATFL reflects morphologic changes that occurred secondary to the ankle injury [13]. Thus, in equinovarus deformity, the ATFL is stretched. The viscoelastic characteristic of ligaments is the gradual increase in ligament deformation over time under a constant load [14,15]. Recruitment of collagen fibers may be important for resisting gradual deformation of the ATFL under a constant load, and the ATFL is thickened on the affected side [15]. The use of ultrasonography can aid in early detection of the affected ligaments, thus helping to prevent ankle deformity. Jang et al [16] showed that inverted foot of stroke patients had a high score on a modified Ashworth Scale. In other words, the higher degree of spasticity, the more supinated the foot. In our study, 70.4% of patients had an Ashworth Scale score of 1. However, the Ashworth Scale score of the spastic ankle was not significantly correlated with the ATFL thickness. Furthermore, Brunnstrom stage, FAS, and disease duration were not correlated with the ATFL thickness. These results suggest that there may be other factors affecting the ATFL thickness. In chronic stroke patients, stretching and strengthening exercises directed at the spastic muscles, botulinum toxin injections, and solid ankle—foot orthoses aim to provide more balanced and close-to-normal gait by stabilizing the ankle in a neutral position. The stabilization of the ankle in a neutral position reduces the load on the ATFL and prevents ankle torsion.

There are some limitations to this study. The small sample size and lack of further gait/functional parameters prevent the generalization of the study results.

In conclusion, chronic stroke patients have a thicker ATFL on both the affected and unaffected sides, compared with healthy individuals. The development of equinovarus deformity due to spastic muscles may contribute to this architectural feature of the ATFL.

Author Disclosures

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