Number of fiber bundles in the fetal anterior talofibular ligament

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Research

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Abstract

Background

For the anterior talofibular ligament (ATFL), a three-fiber bundle has recently been suggested to be weaker than a single or double fiber bundle in terms of ankle plantarflexion and inversion braking function. However, the studies leading to those results all used elderly specimens. Whether the difference in fiber bundles is a congenital or an acquired morphology is important when considering methods to prevent ATFL damage. The purpose of this study was to classify the number of fiber bundles in the ATFL of fetuses.

Methods

This study was conducted using 30 legs from 15 Japanese fetuses (mean weight, 1764.6 ± 616.9 g; mean crown-rump length, 283.5 ± 38.7 mm; 8 males, 7 females). The ATFL was then classified by the number of fiber bundles: Type I, one fiber bundle; Type II, two fiber bundles; and Type III, three fiber bundles.

Results

Ligament type was Type I in 5 legs (16.7%), Type II in 21 legs (70%), and Type III in 4 legs (13.3%).

Conclusions

The present results suggest that the three fiber bundles of the structure of the ATFL may be an innate structure.

Background

Injury to the lateral ligaments of the ankle is one of the most frequent sports injuries in both competitive and recreational sports. Roughly 70% involve injuries to the anterior talofibular ligament (ATFL) alone [1–3]. The morphological features of the lateral ligaments of the ankle are thought to be heavily involved in these injuries, and many anatomical studies of the ATFL in particular have been reported [4].

The main morphological features of the ATFL that have been investigated are the number of fiber bundles, fiber bundle length, fiber bundle width, and fiber bundle angle. However, differences in the number of fiber bundles have yet to be clarified. ATFL types with one, two, or three fiber bundles have been reported [5, 6], but other reports have suggested that types with three bundles do not exist [7–14]. On the contrary, many recent reports using a large number of specimens have described three fiber bundles [15–18].

The ATFL is reported to serve a major function in ankle plantarflexion and inversion control [19]. During plantarflexion, the superior fiber bundle tenses and the inferior fiber bundle relaxes, while during dorsiflexion, the superior fiber bundle relaxes and the inferior fiber bundle tenses [20]. In earlier studies, the ATFL was mainly described as the two fiber bundle type, and functions of the superior and inferior fiber bundles differed. In other earlier studies, however, fiber bundle length and total fiber bundle width were the same even when the number of fiber bundles differed, so functional differences were considered unlikely [20]. In all of these reports, the effects of differences in ATFL number of fiber bundles on function remained speculative. In recent studies, three-dimensional reconstructions of single, double, and triple fiber bundles of ATFL have been created. These were used to simulate and calculate ATFL strain during dorsiflexion (20°) and plantarflexion (30°) on the talocrural joint axis and inversion (20°) on the subtalar joint axis. The results suggested that an ATFL with three fiber bundles was weaker than those with single or double fiber bundles in terms of ankle plantarflexion and inversion braking function [21].

However, all specimens used in those previous studies were from elderly individuals. Whether the difference in fiber bundles represents a congenital or an acquired morphology is important when considering the prevention of ATFL damage. The purpose of this study was therefore to classify the number of fiber bundles of the ATFL in fetuses.

Materials And Methods

Cadavers

The ligaments investigated were obtained from 30 legs of 15 Japanese fetuses (mean weight, 1764.6 ± 616.9 g; mean crown-rump length, 283.5 ± 38.7 mm; 8 males, 7 females). All specimens were fixed and preserved in 10% formalin and placed in water for 24 h before dissection. The human fetuses used in the present study belong to the Kyoto Collection of Human Embryos [22, 23] and all were Japanese. They were obtained through collaborating obstetricians and in accord with the Japanese Eugenic Protection Law (the present Law for the Protection of Mothers' Bodies), mainly from healthy parents, rather than due to any clinical reasons of either embryos/fetuses or parents. Therefore, these embryos/fetuses can be considered to be representative of the normal Japanese intrauterine population. There were no congenital disorders in the central nervous system in the present cases. Mean gestational age of specimens was 23 weeks (range, 21–25 weeks; all in the second trimester) as calculated from the crown-rump length [24]. This study was approved by the ethics committee at our institution (approval no. 4881).

Methods

In the ATFL dissection procedure, the skin, subcutaneous tissue, and crural fascia were removed, and the ATFL was carefully dissected (Fig. 1). The ATFL was then classified by the number of fiber bundles: Type I, one fiber bundle; Type II, two fiber bundles; and Type III, three fiber bundles.

Results

Classification by number of ATFL fiber bundles

The ligament type was Type I in 5 legs (16.7%), Type II in 21 legs (70%), and Type III in 4 legs (13.3%) (Fig. 2).

Discussion

This study examined differences in the number of ATFL fiber bundles in the fetus. To the best of our knowledge, no previous anatomical studies have reported on the number of ATFL fiber bundles in the fetus.

The classification based on differences in ATFL fiber bundles was Type I in 5 legs (16.7%), Type II in 21 legs (70%), and Type III in 4 legs (13.3%). Previous studies have reported Type I in 23%-100% [5, 6, 8–18], and Type II in 0–75% [5, 6, 8–18], and Type III in 2-100% [5–18], and absent in 5% [11, 12]. Findings have clearly been inconsistent. One major reason for this is thought to be differences in sample size, with 4-152 legs being examined [5–18] in the previous studies (Table 1). The results of the present study were similar to reports using a large number of specimens. The three bundles in the structure of the ATFL are already visible as early as the second trimester and resemble those seen in adults. The present results therefore suggest that the three fiber bundles in the ATFL may represent innate structures.

Table 1
Summary of studies assessing ATFL morphology

Study	Number of feet	Type I (%)	Type II (%)	Type III (%)	Absence (%)
Burks et al. (1994)	39	Inferior band seen in some specimens			
Milner et al. (1997)	26	38	50	12	0
Delfaut et al. (2003)	4	25	75	0	0
Taser et al. (2006)	42	93	2	0	5
Ugurlu et al. (2010)	22	23	59	18	0
Raheen et al. (2011)	20	25	70	0	5
Neuschwander et al. (2013)	8	25	75	0	0
Yieldiz et al. (2013)	46	75.6	24.4	0	0
Clanton et al. (2014)	14	50	50	0	0
Wenny et al. (2015)	17	100	0	0	0
Edama et al. (2018)	81	33	57	10	0
Kakegawa et al. (2019)	60	23.3	70	6.7	0
Edama et al. (2019)	110	31	60	9	0
Kobayashi et al. (2020)	152	43.4	54.6	2	0
Present study	30	16.7	70	13.3	0

The ATFL is reported to serve a major function in ankle plantarflexion and inversion control [19]. One previous study [21] created three-dimensional reconstructions of the single, double, and triple fiber bundles of ATFL. The results suggested that a structure with three fiber bundles yielded an ATFL that was weaker than single or double fiber bundles in terms of ankle plantarflexion and inversion braking function. Our findings indicate that the three fiber bundles of the structure of ATFL may represent innate structural characteristics of the ligament. We therefore suggest that the presence of three fiber bundles in the ATFL may represent a risk factor for ATFL injury. In the future, we believe it will be necessary to perform biomechanical research using our basic data with in vivo samples, which may lead to development of the prevention of the ATFL injuries.

Some limitations to this study need to be considered. First, this study investigated only fetal ATFL in the second trimester. Investigations of fetal ATFL in the first trimester have also been attempted, but dissections proved difficult. Second, this study focused solely on differences in the number of ATFL fiber bundles and did not include quantitative analyses.

Conclusions

This study examined differences in the number of ATFL fiber bundles in fetuses. ATFL fiber bundles were classified as Type I in 5 legs (16.7%) Type II in 21 legs (70%), and Type III in 4 legs (13.3%). These results suggest that the three fiber bundles of the structure of the ATFL may be an innate structure.

Declarations

Ethics approval and consent to participate

Informed consent was obtained from the families of all subjects. All methods were carried out in accordance with the 1964 Declaration of Helsinki, and all cadavers used in the present study were legally donated for research purposes to the Kyoto University, Kyoto, and later transferred to the Shimane University, Izumo, Japan.

Consent for publication

Not applicable

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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None.

Authors' contributions

ME and TT contributed to the study design and data collection, and drafted the manuscript; HY, RH contributed to the data analysis and made critical revisions to the manuscript; CS, SM, RT, and YY made critical revisions to the manuscript; HO supervised the study, contributed to the analysis and interpretation of data, and made critical revisions to the manuscript. All authors read and approved the final manuscript prior to submission.

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Figures

Figure 1

Method of fetal dissection. Skin from the surface of the leg, subcutaneous tissue, and crural fascia are removed. a) Medial view, b) Lateral view

Figure 2

Classification of number of fiber bundles in the anterior talofibular ligament: right side, anterolateral. Type I: Ligament with one fiber bundle, Type II: Ligament with two fiber bundles showing complete separation, Type III: Ligament with three fiber bundles. 1: anterior talofibular ligament; 2: superior fiber bundle; 3: inferior fiber bundle; 4: intermediate fiber bundle; 5: calcaneofibular ligament; A: anterior; P: posterior