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ANATOMIC VARIATIONS

The relationships between the quadratus plantae and the flexor digitorum longus and the flexor hallucis longus

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Abstract

Purpose The purpose of this research was to clarify the relationships between quadratus plantae (QP) and flexor digitorum longus (FDL) and flexor hallucis longus (FHL) using large-scale specimens.

Methods This study examined 116 legs from 62 Japanese cadavers. The QP was classified as: Type I, formed by the lateral and medial heads; Type II, the lateral head is absent; and Type III, the medial head is absent. The FHL branches to the lesser toes were classified as: Type A, connection from FHL to toe 2; Type B, connection from FHL to toes 2 and 3; Type C, connection from FHL to toes 2–4. Next, the relationships between QP and FHL and FDL were observed.

Results Type I accounted for 87%, Type II for 10%, and Type III for 3%. Type A accounted for 33%, Type B for 53%, and Type C for 14%. Regarding the relationship between QP and FDL, regardless of the classification of the connections of the FHL tendon slip to the lesser toes, QP attachments to FDL branching to toes 2, 3, and 4 were seen in 47–59%. Furthermore, QP attachments to FDL branching to toes 2, 3, 4, and 5 were seen in 41–47%.

Conclusions QP appears to function strongly to counter the oblique pull of FDL and FHL and as a lesser digit plantar flexor.

Keywords Biomechanical function · Anatomical study · Classification

Introduction

The quadratus plantae (QP) muscle is a flat, trapezoidal muscle formed by two heads: lateral and medial [5], and the various origins of the QP are reported [2]. With respect to the biomechanical function of QP, there is relatively a lack of evidence supporting any one particular theory. At least four theories of its function have been proposed. The theories are that QP counters the oblique pull of flexor digitorum longus (FDL) [4, 5], that QP is a pronator [7], that QP is a lesser digit plantar flexor [9], and that QP is a lumbrical stabilizer [10]. However, very little has been demonstrated through empirical research [10].

These theories are based on the anatomical findings of QP and FDL connections. However, the numbers of specimens have been very small. Furthermore, many of the anatomical studies involving flexor hallucis longus (FHL) have focused on the relationship (tendon connections) between FHL and FDL [3]. However, the relationships between QP and FHL and FDL have not been studied.

Therefore, the purpose of this research was to clarify the relationships between QP and FDL and FHL using large-scale specimens.

Materials and methods

Cadavers

The specimens used were from 116 legs of 62 Japanese cadavers (mean age 79.6 ± 11.2 years; 69 sides from men and 47 from women), which had been switched to alcohol after placement in 10% formalin. None showed signs of major previous surgery around the foot and ankle or

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relevant deformities. This study was approved by the Ethics Committee at our institution.

Methods

The feet were dissected by medial and plantar incisions, removing the plantar skin. The tarsal tunnel was dissected and the anatomical structures identified. The plantar aponeurosis was meticulously dissected from flexor digitorum brevis and removed; then flexor digitorum brevis, flexor hallucis brevis, and abductor hallucis were dissected and lifted to the distal side. FHL, FDL, QP, and the lumbrical muscles were then harvested. The QP was also classified as: Type I, formed by lateral and medial heads; Type II, the medial head is absent; and Type III, the lateral head is absent. Referring to an earlier report [3], FHL branches to the lesser toes were classified as: Type A, connection from FHL to toe 2; Type B, connection from FHL to toes 2 and 3; Type C, connection from FHL to toes 2–4. Next, the relationships between QP and FHL and FDL were observed.

Statistical analysis

Type comparisons between males and females and between left and right sides were done using Chi-squared tests with 5% taken as the level of significance.

Results

Classification of QP (Fig. 1)

Type I accounted for 101 cases (87%), Type II for 11 cases (10%), and Type III for 4 cases (3%). In comparison between men and women, the type in men was Type I in 60 legs (87%), Type II in 7 legs (10%), and Type III in 2 legs (3%), and the type in women was Type I in 41 legs (87%), Type II in 4 legs (9%), and Type III in 2 legs (4%). No significant differences were seen between men and women. In determining differences between left and right legs, both legs of 54 cadavers could be evaluated. In comparisons between left and right legs, the right leg was Type I in 49 legs (91%), Type II in 4 legs (7%), and Type III in 1 leg (2%). The left leg was Type I in 44 legs (81%), Type II in 7 legs (13%), and Type III in 3 legs (6%). No significant differences were seen between the right and left legs.

Classification of the connections of the FHL tendon slip to the lesser toes (Fig. 2)

Type A accounted for 38 cases (33%), Type B for 61 cases (53%), and Type C for 17 cases (15%). In comparison between men and women, the type in men was Type I in 24 legs (35%), Type II in 35 legs (51%), and Type III in 10 legs (14%), and the type in women was Type I in 14 legs (30%), Type II in 26 legs (55%), and Type III in 7 legs (15%). No significant differences were seen between men and women. In comparisons between left and right legs, the right leg was Type I in 16 legs

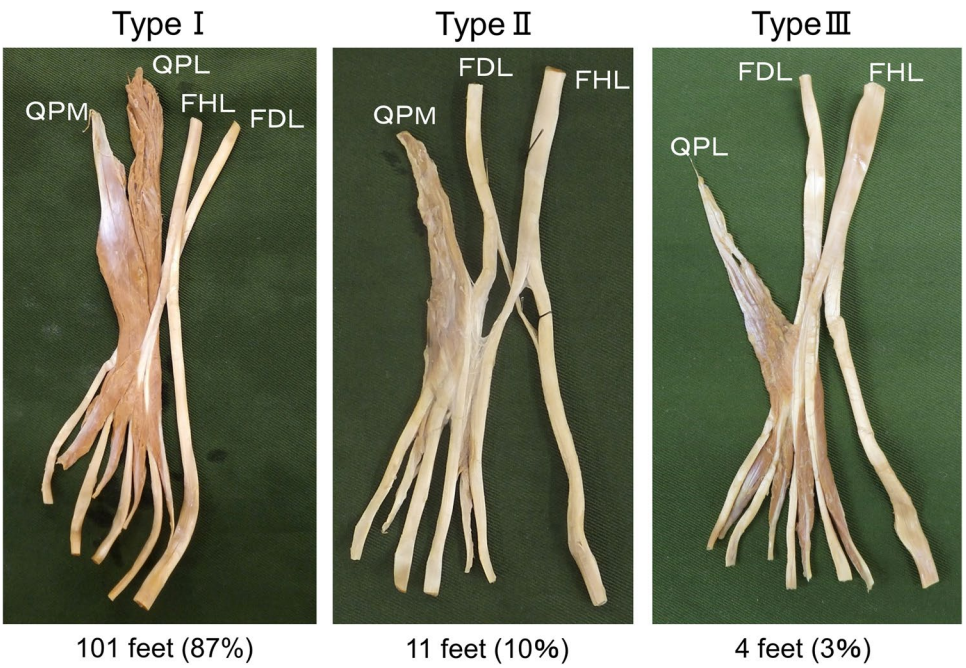

Fig. 1 Classification of QP. Type I, formed by lateral and medial heads; type II, the lateral head is absent; type III, the lateral medial is absent. *FHL* flexor hallucis longus, *FDL* flexor digitorum longus, *QPM* quadratus plantae, medial head, *QPL* quadratus plantae, lateral head

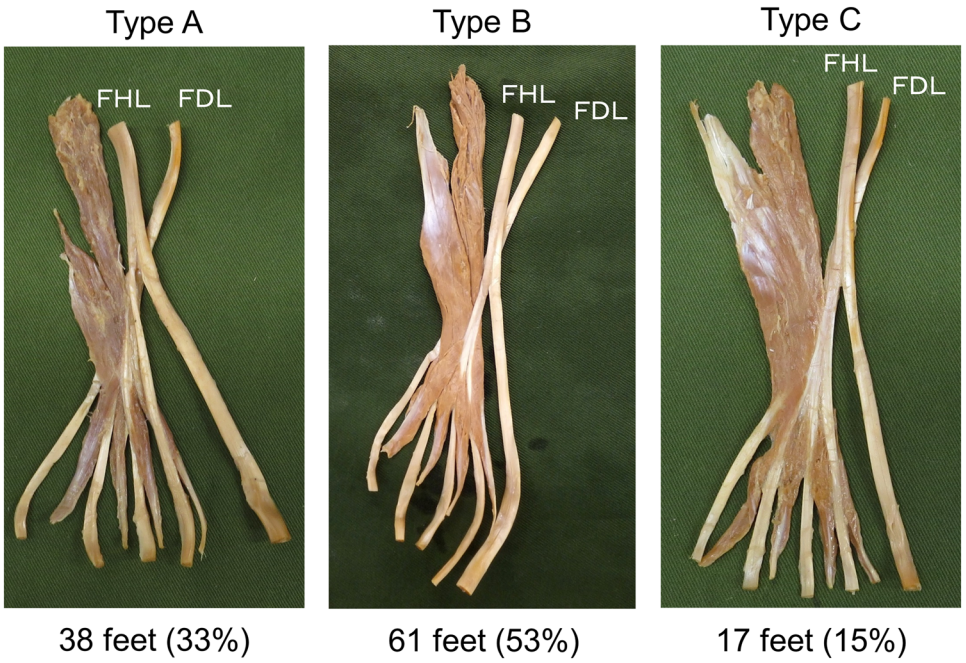

Fig. 2 Classification of the connections of the FHL tendon slip to the lesser toes. Type A, connection from FHL to toe 2; Type B, connection from FHL to toes 2 and 3; Type C, connection from FHL to toes 2–4. *FHL* flexor hallucis longus, *FDL* flexor digitorum longus

(30%), Type II in 29 legs (54%), and Type III in 9 legs (17%). The left leg was Type I in 18 legs (33%), Type II in 28 legs (52%), and Type III in 8 legs (15%). No significant differences were seen between the right and left legs.

Relationships between QP and FDL and FHL (Table 1)

Regarding the relationship between QP and FDL, regardless of the classification of the connections of the FHL tendon slip to the lesser toes, QP attachments to FDL branching to toes 2, 3, and 4 were seen in 47–59%. Furthermore, QP attachments to FDL branching to toes 2, 3, 4, and 5 were seen in 41–47%. Regarding the relationship between QP and FHL, QP attachments to all tendons where FHL branched to FDL were seen at rates of 100% in Type A, 97% in Type B, and 94% in Type C.

Table 1 Relationships between QP and FHL and FDL

	QP			
	Attachment of the FDL		Attachment of the FHL	
Type A (*N*: 36)	II, III, IV	20 (53)	II	20 (53)
	II, III, IV, V	16 (47)	II	16 (47)
Type B (*N*: 61)	II, III, IV	36 (59)	II, III	34 (56)
			III	2 (3)
	II, III, IV, V	25 (41)	II, III	25 (41)
Type C (*N*: 17)	II, III	1 (6)	II, III, IV	1 (6)
	II, III, IV	8 (47)	II, III, IV	7 (41)
			II, IV	1 (6)
	II, III, IV, V	8 (47)	II, III, IV	8 (47)

Type A, connection from the FHL to toe 2; Type B, connection from FHL to toes 2 and 3; Type C, connection from FHL to toes 2–4. Number (%)

FHL flexor hallucis longus, *FDL* flexor digitorum longus, *QP* quadratus plantae

Discussion

The present study found 11 feet (10%) of Type II (the lateral head of QP is absent), and 4 feet (3%) of Type III (the medial head of QP is absent). Pretterklieber [8] reported the lateral head was absent 31% (31/100), and Hur [6] reported 10% (5/50). Also, Hur [6] reported the medial head was absent 8% (4/50), and Athavale [1] reported 11% (5/47). Since there have been few previous large-scale anatomical studies of the classification of QP, the present results provide very important basic data.

In the present study, regardless of the classification of the connections of the FHL tendon slip to the lesser toes, QP attachments to FDL branching to toes 2, 3, and 4 were seen in about 50%. Furthermore, QP attachments to FDL branching to toes 2, 3, 4, and 5 were seen in about 50%. Therefore, QP appears to strongly function to counter the oblique pull of the FDL and as a lesser digit plantar flexor.

Also, the QP attachments to all tendons where FHL branched to FDL were seen at rates of 100% in Type A, 97% in Type B, and 94% in Type C. There have been no previous reports of the relationship between QP and FHL. In the

present results, QP appeared to function strongly to counter the oblique pull of FHL, and as a hallucis plantar flexor.

The results of the present study provide useful basic data for understanding the biomechanical function of QP. In the future, in vivo studies based on the present study data will be necessary.

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Author contributions ME and TT contributed to study design and data collection, and drafted the manuscript; TI and TK contributed to data analysis and made critical revisions to the manuscript; WI, EN, RH, MI, and FK made critical revisions to the manuscript; IK supervised the study, contributed to 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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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Availability of data and material The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical approval The methods were carried out in accordance with the 1964 Declaration of Helsinki, and the cadavers were legally donated for the research by the Nippon Dental University of Life Dentistry at Niigata in Japan.

Informed consent Informed consent was obtained from the families of all subjects.

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