

Variations in the insertion of the extensor hallucis longus muscle

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Reports that describe abnormalities of the muscles and tendons of the leg and foot are important with regard to understanding the function of the lower limb and correlating these abnormalities with the clinical aspects. Variations in the insertion of the extensor hallucis longus muscle were studied in 60 adult human cadavers. Three different patterns of insertion were noticed. Pattern I (65%): the extensor hallucis longus muscle had a single tendinous insertion on the dorsal aspect of the base of the distal phalanx of the big toe. Pattern II (26.67%): the muscle terminated in two tendons. Pattern III (8.33%): the muscle terminated in three tendinous slips. Various sites of insertion of the extensor hallucis longus muscle were recorded other than the dorsal aspect of the base of the distal phalanx of the big toe. These were the dorsal aspect of the base of the proximal phalanx of the big toe and the capsule of the first metatarso-phalangeal joint or a connection with the tendon of the extensor hallucis brevis. The frequency of occurrence of lateral deviation of the big toe at the metatarsophalangeal joint (hallux valgus) was recorded. It is suggested that the presence of these variations in the insertion of the extensor hallucis longus muscle may have a role in explaining its association with hallux valgus.

key words: anomalous muscle, extensor hallucis longus, variation, hallux valgus

INTRODUCTION

The extensor hallucis longus muscle is classically described as originating from the middle half of the anterior surface of the fibula and from the interosseous membrane. It is inserted into the base of the distal phalanx of the big toe. Its action is to extend the big toe and to extend the foot at the ankle joint. It also assists in inversion of the foot at the subtalar and transverse tarsal joints [9, 16].

Hallux valgus is a common condition in which there is lateral deviation of the big toe, at the metatarso-phalangeal joint. Once the deformity is established, it is progressively worsened by the pull of the flexor hallucis longus and the extensor hallucis lon-

gus muscles. Later osteoarthritic changes occur in the metatarso-phalangeal joint, which then becomes stiff and painful; the condition is then known as hallux rigidus [12].

Numerous operations have been devised to cure the condition of hallux valgus. The extensor hallucis longus tendon is displaced medially and maintained in position by suturing, so that by its contraction the big toe is kept in alignment [13].

A description of the variations in the insertion of extensor hallucis longus bears great significance with regard to the explanation of the functional aspects of the foot and its correlation with clinical aspects.

MATERIAL AND METHODS

The study was performed on 60 lower extremities of adult human cadavers that were used in our laboratory for educational gross anatomy at the Faculty of Medicine, King Abdulaziz University, Saudi Arabia.

The insertion of the extensor hallucis longus muscle was dissected in order to study accurately the different forms of its attachment. The number and the sites of attachment of the tendinous termination on which the extensor hallucis longus muscle gained insertion, as well as the incidence of each type of insertion, was recorded. The frequency of occurrence of hallux valgus with each type of insertion was also recorded.

RESULTS

The dissection of 60 lower extremities of human cadavers showed that the extensor hallucis longus insertion was found as a single tendon in 39 cases (65%) (Fig. 1, 2), or two tendons in 16 cases (26.67%) (Fig. 3–7), while in five cases it was three tendinous slips (8.33%) (Fig. 8, 9). Three different patterns of variation in the insertion of the extensor hallucis longus were noticed (Fig. 10, Table 1).

Pattern I: was found in 39 cases (65%), in which the extensor hallucis longus muscle had a single ten-

dinous insertion on the dorsal aspect of the base of the distal phalanx of the big toe (Fig. 1). Association with lateral deviation of the big toe at the metatarsophalangeal joint (hallux valgus) was seen in three cases (5%) (Fig. 2).

Pattern II: was observed in 16 cases (26.67%), in which extensor hallucis longus terminated in two tendons (main and accessory). The distribution of the variations in this pattern is as follows:

— In nine cases (15%) the main tendon was inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon was smaller and passed medial to the main tendon and was inserted separately into the dorsal aspect of the base of the proximal phalanx of the big toe, just distal to the insertion of extensor hallucis brevis (Fig. 3).

— In three cases (5%) the main tendon was inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon was smaller and passed medial to the main tendon to join the termination of the extensor hallucis brevis into the dorsal aspect of the base of the proximal phalanx of the big toe (Fig. 4).

— In two cases (3.33%) the main tendon was inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon



Figure 1. A photograph showing single tendinous insertion (T) of the extensor hallucis longus muscle on the dorsal aspect of the base of the distal phalanx of the big toe.



Figure 2. A photograph showing a single tendinous insertion (T) of the extensor hallucis longus muscle on the dorsal aspect of the base of the distal phalanx of the big toe. Note the lateral deviation of the big toe at the metatarso-phalangeal joint. The head (H) of the first metatarsal bone is seen to be deviated medially.

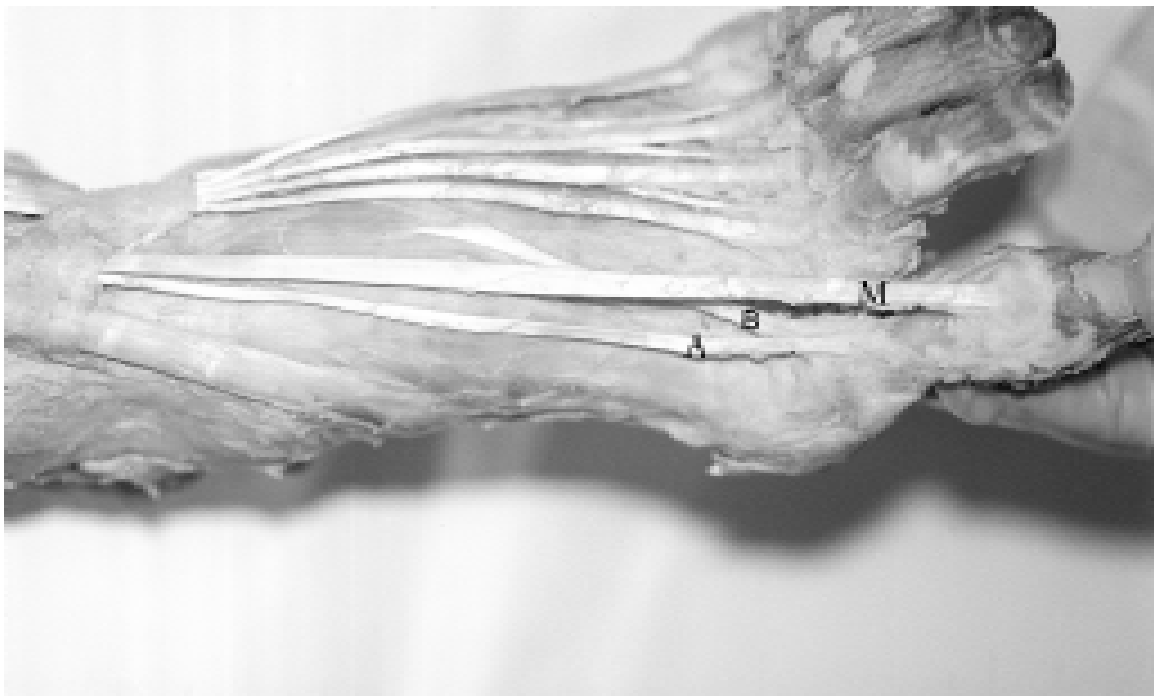


Figure 3. A photograph showing the two tendons of the extensor hallucis longus muscle. The main tendon (M) is inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon (A) is smaller and passes medial to the main tendon and is inserted separately into the dorsal aspect of the base of the proximal phalanx of the big toe; just distal to the insertion of extensor hallucis brevis (B). Note the slight lateral deviation of the big toe.



Figure 4. A photograph showing the two tendons of extensor hallucis longus muscle. The main tendon (M) is inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon (A) is smaller and passes medial to the main tendon and joins the termination of extensor hallucis brevis (B) into the dorsal aspect of the base of the proximal phalanx of the big toe. Note the slight lateral deviation of the big toe at the metatarso-phalangeal joint.



Figure 5. A photograph showing the two tendons of extensor hallucis longus muscle. The main tendon (M) is inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon (A) is smaller and passes medial to the main tendon and is inserted separately into the dorsal aspect of the proximal phalanx of the big toe medial to the attachment of extensor hallucis brevis tendon (B).



Figure 6. A photograph showing the two tendons of extensor hallucis longus muscle. The main tendon (M) is inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon (A) is smaller and passes lateral to the main tendon and joins the middle of extensor hallucis brevis tendon (B) forming a common tendon (C). The common tendon is inserted into the dorsal aspect of the base of the proximal phalanx of the big toe. Note the slight lateral deviation of the big toe.



Figure 7. A photograph of the same specimen as in Figure 3 showing the 2 tendons (arrows) of the extensor hallucis longus muscle arising from separate fleshy bellies (arrowheads).

was smaller and passed medial to the main tendon and was inserted separately into the dorsal aspect of the proximal phalanx of the big toe medial to the attachment of the extensor hallucis brevis tendon (Fig. 5).

— In two cases (3.33%) the main tendon was inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon was smaller and passed lateral to the main tendon and joined the middle of extensor hallucis brevis tendon forming a common tendon which was inserted into the dorsal aspect of the base of the proximal phalanx of the big toe (Fig. 6).

In Pattern II an association with various grades of lateral deviation of the big toe at the metatarsophalangeal joint was seen in 10 cases (16.67%) (Fig. 3, 4, 6). In one case (1.67%), the same case as in Figure 3, the two tendons of the extensor hallucis longus were seen arising from separate fleshy bellies (Fig. 7). In the remaining 59 cases (98.33%) the muscle was formed of one fleshy belly (unipennate muscle).

Pattern III was observed in five cases (8.33%), in which the extensor hallucis longus terminated in three tendinous slips (one main and two accessory) The distribution of the variations in this pattern is as follows:



Figure 8. A photograph showing the three tendinous slips of extensor hallucis longus. The main tendon (M) is inserted into the dorsal aspect of the base of the distal phalanx of the big toe. Two accessory tendons (A) arise from the medial side of the main tendon proximal to the first metatarso-phalangeal joint. The accessory tendons are attached to the capsule (P) of the first metatarso-phalangeal joint. Note the marked lateral deviation of the big toe at the metatarso-phalangeal joint and the medial deviation of the head (H) of the first metatarsal bone. The extensor hallucis brevis tendon (B) is seen.



Figure 9. A photograph showing the three tendinous terminations of the extensor hallucis longus muscle. The main tendon (M) is inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The medial and lateral accessory tendons (A1 and A2) are attached to the capsule (P) of the first metatarso-phalangeal joint. Note the marked lateral deviation of the big toe at the metatarso-phalangeal joint and the medial deviation of the head (H) of first metatarsal bone.

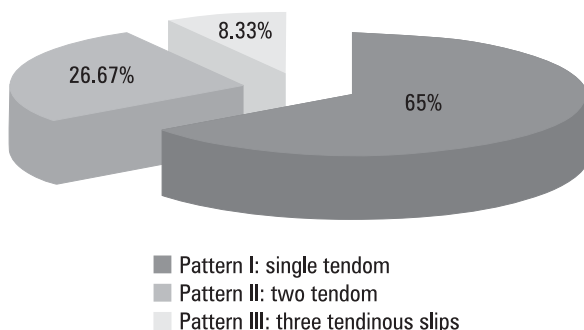


Figure 10. Shows the three different patterns of the variations in the insertion of the extensor hallucis longus muscle.

Table 1. Patterns of insertion of the extensor hallucis longus

| Pattern | No. of tendinous slips | No. of cases | (%) |
|---------|------------------------|--------------|-------|
| I | One | 39 | 65 |
| II | Two | 16 | 26.67 |
| III | Three | 5 | 8.33 |
| Total | | 60 | 100 |

— In three cases (5%) the main tendon was inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The two accessory tendons arose from the medial side of the main tendon proximal to the first metatarso-phalangeal joint and gained insertion into the capsule of the joint. (Fig. 8).

— In two cases (3.33%) the main tendon was inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The two accessory tendons (medial and lateral) arose from the medial and lateral sides of the main tendon respectively and gained insertion into the capsule of the first metatarso-phalangeal joint (Fig. 9).

— Hallux valgus was seen in the five cases (8.33%) of pattern III, with marked lateral deviation of the big toe at the metatarso-phalangeal joint and medial deviation of the head of the first metatarsal bone (Fig. 8, 9).

The accessory tendons were, seen in 21 cases (35%). The distribution is as follows: Pattern I has no accessory tendons. Medial accessory tendons were seen in 17 cases (28.33%), 14 cases (23.33%) appeared in Pattern II and 3 cases (5%) in Pattern III. A lateral accessory tendon was seen in Pattern II in two cases (3.33%). Both lateral and medial accessory tendons were seen in Pattern III in two cases (3.33%) (Table 2).

Table 2. Incidence of accessory tendons in patterns II and III

| Pattern | Accessory tendons (AT) | | | | | |
|---------|------------------------|-------|--------------|------|-----------------------|------|
| | Medial AT | | Lateral AT | | Medial and lateral AT | |
| | No. of cases | (%) | No. of cases | (%) | No. of cases | (%) |
| II | 14 | 23.33 | 2 | 3.33 | — | — |
| III | 3 | 5 | — | — | 2 | 3.33 |
| Total | 17 | 28.33 | 2 | 3.33 | 2 | 3.33 |

Hallux valgus was seen in 18 cases (30%). The cases are distributed as follows: 3 cases (5%) in Pattern I, 10 cases (16.67%) in Pattern II, 5 cases (8.33%) in Pattern III.

A normal big toe was seen in the remaining 42 cases (70%). The cases are distributed as follows: 36 cases (60%) in Pattern I, 6 cases (10%) in Pattern II. No case of Pattern III showed a normal big toe (Table 3).

DISCUSSION

Most of the available anatomical texts have described the insertion of the extensor hallucis longus muscle into the dorsal aspect of the base of the distal phalanx of the big toe [9, 12, 16].

In the present work the extensor hallucis longus muscle was seen in 65% of cases with a single tendinous insertion on the dorsal aspect of the base of the distal phalanx of the big toe. The same observation was made by Kaneff [4] in 51.12% of the cases examined by him.

In the present work accessory tendons of the extensor hallucis longus muscle were seen in 35% of cases. In 26.67% of cases the extensor hallucis longus muscle terminated in two tendons. The main tendon is inserted into the dorsal aspect of the base of the distal phalanx of the big toe. The accessory tendon is inserted into the base of the proximal phalanx of the big toe either directly or through its con-

Table 3. Incidence of hallux valgus and normal big toe in different patterns

| Pattern | Hallux valgus | | Normal big toe | |
|---------|---------------|-------|----------------|-----|
| | No. of cases | (%) | No. of cases | (%) |
| I | 3 | 5 | 36 | 60 |
| II | 10 | 16.67 | 6 | 10 |
| III | 5 | 8.33 | 0 | 0 |
| Total | 18 | 30 | 42 | 70 |

nection to the tendon of extensor hallucis brevis .

In 8.33% of cases extensor hallucis longus was seen to terminate in 3 tendinous slips (one main and two accessory). The main tendon is inserted into the dorsal aspect of the distal phalanx of the big toe, the accessory tendons into the capsule of the first metatarso-phalangeal joint.

Only in one case (1.67%) in this work were the two tendons of the extensor hallucis longus seen arising from separate fleshy bellies, while the muscle was unipennate in the remaining cases. The presence of accessory tendons for the extensor hallucis longus muscle described in the present study is in agreement with the work of Kaneff [4], who described additional tendons of the musculus extensor hallucis longus in 48.88% of the cases examined by him. Williams et al. [14] stated that at the metatarso-phalangeal articulation a slip from each side of the extensor hallucis longus tendon covers the joint's dorsal aspect. An expansion from its medial side to the proximal phalangeal base is also usually present and it may send a slip to the second toe.

Wood [15] mentioned that doubling of the muscle may occur anywhere along its length with the extramuscle (extensor primi internodii hallucis longus) running parallel and lateral to the main muscle. It may be joined to the tendon of extensor hallucis brevis distally or inserted independently onto the first metatarsal, the proximal part of the first phalanx, or both phalanges of the big toe. It arises rarely below the usual extensor, or it may arise from the tendon of the extensor at the ankle, or three inches above it.

Macalister [7] found that the muscle may be doubled, may have a common muscular slip between it and extensor digitorum; or a slip to the extensor hallucis brevis at the junction of its muscle and tendon.

Gruber [2] mentioned that occasionally this muscle, which is usually unipennate, has three bellies and three tendons and is named extensor hallucis longus tricaudatus. When one of these three bellies is represented as a separate (and usually smaller) muscle, it is named extensor hallucis longus minor.

In the present study, the accessory tendon was seen arising from the medial side of the main tendon in 28.33% of the examined cases, while in only 3.33% it arose from the lateral side. In addition, in 3.33% of cases both the medial and lateral accessory tendons were found. This finding is in agreement with that described by Kaneff [4], who said that most of these supplements (additional tendons and muscles) are positioned on the medial side of the main tendons with only a few on the lateral side.

The presence of accessory tendons for the extensor hallucis longus muscle as described in the present study is in agreement with previous reports in the literature. However, the coexistence of an additional insertion of the extensor hallucis longus muscle associated with hallux valgus has not been reported in the available literature. While Gunal et al. [3] described the anomalous tibialis posterior muscle as an etiological factor of hallux valgus, Brenner [1] stated that this deformity (hallux valgus) developed as a result of a specific type of insertion of the tendon of the tibialis anterior muscle.

In the present study, hallux valgus was seen in 30% of cases; in Pattern II, in which the muscle has two tendinous insertions, various degrees of hallux valgus were seen in 16.67% of the cases, while in Pattern III, in which the muscle has three tendinous insertions, hallux valgus was seen with marked lateral deviation of the big toe and medial deviation of the head of the metatarsal in all cases (8.33%). In Pattern I, in contrast, in which the muscle has a single tendinous insertion, hallux valgus is seen in only 5% of cases.

The presence of an additional insertion of the extensor hallucis longus muscle, described in this work has functional and clinical implications. From a functional viewpoint, the accessory tendon of extensor hallucis longus with its insertion into the base of the proximal phalanx of the big toe either directly or through its connection to the extensor hallucis brevis tendon and also to the capsule of the first metatarso-phalangeal joint would help to extend the joint irrespective of the position of the interphalangeal joint. This would add flexibility to the movement of extension of the big toe that usually accompanies the mechanism of walking and running. The clinical significance of the accessory tendons of extensor hallucis longus muscle is its possible association with deformity of the big toe, such as hallux valgus. It is expected that the presence of accessory tendons, particularly those on the medial side of the main tendon, may exert a medial pull on the base of the proximal phalanx, in addition to extending it. This would counteract the lateral pull exerted on the distal phalanx of the big toe caused by the pull of the main tendon of the muscle, which increases the predisposition to the development of hallux valgus.

Hallux valgus has been attributed to the wearing of high-fashion women's shoes [5, 8]. The causes also include hereditary conditions, pes planus (flat-foot), and hyper elasticity disorders. In active individuals, however, the development of hallux valgus

depends on a number of factors, such as the type of sport practised and its degree of rigour.

It is known that different sports put varied pressures on the foot. Walking generates a force in the forefoot equal to 80% of the body's weight; running increases it to 250% of body weight [5]. The severity and progression of the hallux valgus deformity depend on the particular sport involved. For instance, dancers develop hallux valgus at a younger age than is seen in the general population [10, 11]. A deformity may affect one patient differently from another because various sports make different demands on the foot. For example, sprinters require an extended range of motion in both dorsiflexion and plantarflexion of the first metatarso-phalangeal joint, while middle- and long-distance runners do not [6]. The presence of multiple tendons of the extensor hallucis longus muscle, as reported in the present work, could be added as a predisposing factor for the development of hallux valgus. This is probably due to the imbalance created by the accessory tendons, with different attachments along the axis of pull of the joints of the big toe.

It is concluded that this study emphasises the importance of realising the functional and clinical significance of detecting variations in the muscles of the lower limb. These variations may have a significant correlation with the clinical aspects.

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