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A Review of Extensor Hallucis Longus Variants Featuring a Novel Extensor Primi Internodii Hallucis Muscle Merging With Extensor Hallucis Brevis

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Abstract

The extensor hallucis longus (EHL) muscle/tendon complex has been used in a variety of tendon transfer and tenodesis surgeries to correct iatrogenic hallux varus deformity, equinovarus foot deformity, clawed hallux associated with a cavus foot, and dynamic hyperextension of the hallux and, even, to prevent pedal imbalance after transmetatarsal amputation. Although it is usually considered a unipennate muscle inserting into the dorsum of the base of the distal phalanx of the hallux, a vast majority of EHL muscles possess 1 accessory tendinous slips that insert into other neighboring bones, muscles, or tendons, which can complicate these surgeries. The present report reviewed the reported data on EHL variants and describe a new variant, in which the tendons of the extensor primi internodii hallucis muscle of Wood and extensor hallucis brevis muscle merged together proximal to the tarsometatarsal (Lisfranc) joint, a site of rupture for extensor tendons of the foot. The reported variant might have contributed to the development of the clawed hallux seen in our patient and could complicate its operative management by mimicking the normal extensor digitorum longus tendon. Knowledge of the EHL variants and the particular muscular pattern described in the present review could improve the diagnosis and tendon transfer and tenodesis operative planning and outcomes.

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Keywords

clawed hallux; extensor hallucis brevis variant; extensor hallucis longus variant; foot extensor variant; hallux varus deformity; tendon transfer and tenodesis

The extensor hallucis longus (EHL) muscle/tendon complex has been used in a variety of tendon transfer and tenodesis surgeries to correct iatrogenic hallux varus deformity (1–5), equinovarus foot deformity (6), clawed hallux associated with a cavus foot (7–9), and dynamic hyperextension of the hallux (10) and, even, to prevent pedal imbalance after transmetatarsal amputation (11). Although it is usually considered a unipennate muscle with 1 tendon inserting into the dorsum of the base of the distal phalanx of the hallux, a vast majority of EHL muscles possess 1 accessory tendinous slips that insert into the normal insertion point or into other neighboring bones, muscle, or tendons, which can complicate tendon transfer or tenodesis surgeries (12–24).

EHL variants often possess additional tendinous slips, which are named according to their distal attachment. The extensor primi internodii hallucis muscle of Wood (EPIH) is an accessory tendinous slip that inserts distally into the base of the proximal phalanx of the hallux, distal to, medial to, or directly into the extensor hallucis brevis (EHB) tendon distal attachment (12,13,16,17,21,22,24–28). Rarely, this variant has been found as a separate muscle distinct from the EHL (12,13,17,22,24,25,28). The prevalence of the EPIH has varied from 29.3% (85 of 290 feet) (17), to 54.0% (27 of 54 feet) (14), and 80.6% (58 of 72 feet) (12), with ~90% of these variants originating from the EHL and the remainder originating primarily from the tibialis anterior (12,14,17,22,24). In the recent data, a similar EHL variant has been shown to insert into the capsule of the first metatarsophalangeal joint in 80% to 88% of specimens (29,30), which led to its name of extensor hallucis capsularis (EHC) (22,24,29–33). Although some investigators have reported the EHC was synonymous with the EPIH, Boyd et al (30) reported that the EHC only inserts into the base of the proximal phalanx in 1% of cases; thus, discrepancies between these 2 EHL variants exist (22,24). A rare EHL variant is the musculus extensor primi metatarsal of Gruber, which inserts distally into the dorsal aspect of the distal segment of the first metatarsal (15,17,24,34). In 1930, Hallisy (17) reported this variant in 2 of 290 feet (0.69%), and although rare, its presence has been confirmed by other investigators (14,16,19,24,29). Similarly, a muscular variant arising intermediate to the EHL and extensor digitorum longus, called the accessory extensor digiti secundus muscle, has been reported to have a tendinous bifurcation near the base of the second metatarsal. The medial tendinous slip of the accessory extensor digiti secundus merged with the tendon of the EHL and the lateral tendinous slip merged with a tendon of extensor digitorum longus to insert into the extensor expansion of the second digit (35). A summary of EHL variations is presented in the Table.

Case Report

Cadaveric dissection of an 85-year-old white female led to the observation of a variant combination of the extrinsic and intrinsic musculature of a right-sided cavus foot (Fig.). The variant muscle, which possessed its own muscle belly arising from the EHL, traversed the metatarsophalangeal joint capsule and inserted into the base of the proximal phalanx of the

hallux, inserting deep to the tendinous splay of the EHL at the hallux. It was, therefore, identified as an EPIH. Moreover, the tendon of the EHB inserted into the tendon of the EPIH at the tarsometatarsal (Lisfranc) joint, immediately medially and proximally to the prominence formed by the base of the second metatarsal.

The muscle belly of the EPIH was 4.2 cm long. The tendon arising from the EPIH muscle belly measured 9.0 cm before joining the tendon of EHB and traveling for another 5.2 cm as a composite tendon that inserted into the base of the proximal phalanx of the hallux. The widest portion of the EPIH tendon measured 0.88 cm. The width of the EPIH– EHB tendon measured 0.87 cm. The entire length of the EPIH, from its origin at the distal third of the fibula to its insertion, was 18.4 cm.

Discussion

The example presented in our review documented a unique communication between the tendons of the EPIH and the EHB. The EPIH variant also possessed its own muscle belly, which is exceedingly rare (12,13,17,25,28,36). Moreover, 90% of EHL accessory tendons have been reported to exist medially to the EHL (29). The described EPIH should, therefore, be considered unique because of its presence lateral to the primary tendon of the EHL. Also, because of its position, it can be confused with the extensor digitorum longus tendon during surgery (36). Likewise, the communication between the EPIH and EHB medial to the base of the second metatarsal adds complexity to the unique variant pattern.

Considering a scenario in which the EHB tendon inserted, in a typical manner, at the hallux in this individual, the EHB tendon would be oriented in an oblique plane and might perhaps be situated anterior to the base of the second metatarsal. In such a scenario, the first metatarsophalangeal joint would be subject to minor torsional force and adduction. However, in the actual scenario, the base of the second metatarsal would act as a pulley for the combined EPIH–EHB tendon, thereby aligning the tendon with the longitudinal axis of the phalanx. Thus, the torsion and adduction would be limited, and extension would be the prevailing force at the first metatarsophalangeal joint.

Owing to the location of the union of the EPIH and EHB tendons, which occurred slightly proximally to the prominence formed by the base of the second metatarsal, repetitive flexion and extension of the hallux could cause aberrant stress to the tendons and subsequent extensor tendinopathy (37). Also, individuals with cavus foot deformity, such as the individual described in our case study, often have excessive rubbing stressors to the dorsum of the foot, which can lead to the rupture of the EHL tendon at the level of the tarsometatarsal (Lisfranc) joint (37–39). The location of the EPIH–EHB communication is in an area that can be of particular risk of excessive mechanical stressors and subsequent dorsal foot pain and has also been demonstrated as a region prone to rupture of the EHB tendon (36,37). Albeit speculative in the absence of largescale studies, the forces that have been demonstrated to predispose the EHL and EHB damage along the dorsum of the cavus foot, might also predispose this variation to similar damage.

The EPIH–EHB variation has a number of operative implications owing to its location. The EPIH originated from a supernumerary EHL muscle belly and coursed in close proximity to a main tendon of the EHL, in particular, at the forefoot. Because of their close proximity and similar orientation, the EPIH tendon might be mistaken for the EHL tendon by an inexperienced surgeon, which could be of particular importance with regard to EHL transfer surgeries. The EHL has been transferred for the correction of iatrogenic hallux varus deformity (1–5), correction of equinovarus foot deformity (6), prevention of pedal imbalance after transmetatarsal amputation (11), correction of the clawed hallux associated with a cavus foot (7–9) or after poliomyelitis (40), and correction of dynamic hyperextension of the hallux (10). Therefore, operative knowledge of this variant is important in preventing confusion and potential adverse events.

It has been implied that hallux deformities are associated with accessory EHL tendons (21,29,41). The EPIH described in the present report might have added extension forces to the proximal phalanx that could have contributed to the clawing of the hallux. Hypothetically, if accessory EHL tendons are implicated in hallux deformities, individuals with accessory tendons would, in turn, have an increased likelihood of undergoing tendon transfer surgery to correct a hallux deformity. Thus, the presence of an accessory muscle could have a twofold influence: first, as an etiologic factor for the hallux deformity; and second, as a potential difficulty during surgery to treat the deformity for which the accessory tendon was partly responsible for causing in the first place.

Similar to the EHL, the EHB might be used in tendon transfer or tenodesis surgeries (42). The EHB in the present case study was observed to communicate with the EPIH, which, in the case of EHB transfer surgery, could also lead to operative disorientation. Boyd et al (30) noted that 14% of individuals will have an accessory EHL tendon (e.g., EPIH) suitable for grafting during reconstructive surgery. Regarding this particular study, a tendon transfer of the EPIH would be complicated by union of the EHB and EPIH tendons.

In conclusion, owing to the great variety and incidence of EHL muscular variants, it is particularly important for surgeons to be aware of their different presentations. The present report reviewed these EHL variants and described a unique variation of an EPIH joined with an EHB tendon in a cavus foot with a clawed hallux. The variant might have contributed to the development of the clawed hallux and, like-wise, might also have complicated operative management. Although most variants exist medial to the normal EHL tendon, in certain cases, such as the EPIH described in the present study, an accessory tendon might exist lateral to the normal EHL tendon (29). It is important to note that ultrasonography could be used to identify both the EHL tendon and the dorsomedial cutaneous nerve of the hallux as it crosses the EHL tendon (43). Therefore, preoperative ultrasonography could aid in identifying EHL variants and the anatomic relationships between EHL variants and the nearby nerves to avert iatrogenic injuries. Knowledge of the particular muscular pattern described in the present report could improve diagnosis and preoperative screening and tendon transfer and tenodesis operative planning and outcomes.

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Fig.

Right distal anterior leg and dorsum of a cavus foot with an extensor primi internodii hallucis, arising from the extensor hallucis longus, which communicates with the extensor hallucis brevis. BaseMT2, base of the second metatarsal; EDL, extensor digitorum longus; EHB, extensor hallucis brevis; EHL, extensor hallucis longus; EPIH, extensor primi internodii hallucis; TibAnt, tibialis anterior. *Tendinous intersection between the extensor primi internodii hallucis and the extensor hallucis brevis.

Table

Extensor hallucis longus and its variants, often named based on distal attachment

Name	Distal Attachment
Extensor hallucis longus (typical)	Dorsal base of distal phalanx of first digit
Extensor primi internodii hallucis (of Wood)	Base of proximal phalanx of first toe
Extensor hallucis capsularis	Capsule of first metatarsophalangeal joint
Musculus extensor primi metatarsal (of Gruber)	Dorsal surface of head of first metatarsal
Accessory extensor digiti secundus	Tendon of extensor hallucis longus and second digit tendon of extensor digitorum longus
Extensor hallucis longus tricaudatus *	Not applicable
Extensor hallucis longus minor †	Not applicable

* Not defined by distal attachment but because muscle has 3 bellies or 3 tendons.

† A subtype of extensor hallucis longus tricaudatus, defined when 1 of 3 bellies is a separate independent muscle.