Early embryonic development of long tendons in the human foot

By

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Summary: To examine a common plantar tendinous plate for long flexors of the toe and fingers in human embryos, we observed sections of 10 embryos at 5–6 weeks (crown-rump length or CRL 15–21 mm). The heel or tuber of the calcaneus was underdeveloped in 3 embryos with CRL 15 mm and the talus appeared not to be piled up on the calcaneus but these two bones were arranged along the lateromedial axis. As reported in the hand, we demonstrated, in the deep side of tarsal bones, a common tendinous plate formed by a joining of the flexor halluces longus and flexor digitorum longus tendons. In the tendinous plate, much or less, some connections between tendons seemed to remain even after birth to provide much greater types of tendon anomalies than in the hand. In addition, we postulated a hypothetical change in course of the peroneus longus tendon. In the initial phase, because of the underdeveloped calcaneus, the peroneus tendon might take an almost straight course similar to long flexor tendons. However, at 6 weeks and later, the inferomedially expanding calcaneus beneath the talus was likely to push the tendon to the cuboid bone.

Materials and Methods

The study was performed in accordance with the provisions of the Declaration of Helsinki 1995 (as revised in Edinburgh 2000). We observed paraffin sections of the ear region in 10 human embryos at 5–6 weeks (crown-rump length or CRL 15–21 mm; 3 specimens, CRL 15 mm; 3 specimens, CRL 16 or 18 mm; 4 specimens, CRL 20 or 21 mm). The sectional planes were longitudinal to the tibia, fibula and foot (5 specimens) or tangential to the foot planta (5 specimens). All specimens were part of...
the large collection kept at the Institute of Embryology, Universidad Complutense Madrid, and were products of miscarriages and ectopic pregnancies managed at the Department of Obstetrics at the university. The sections had already prepared and stained with hematoxylin and eosin (HE) or azan. The study protocol was approved by the university ethics committee in Madrid (No. B08/374).

Results

In contrast to the upper extremity, sections of the foot at the early stage were obtained from a limited number of specimens (10 specimens) since major targets of the collection might be the head, neck and thorax. The heel or tuber of the calcaneus was underdeveloped in 3 embryos with CRL 15 mm (Figs. 1 and 2) and the talus appeared not to be piled up on the calcaneus but these two bones were arranged along the lateromedial axis. However, in the other 7 embryos, the calcaneus expanded medially and superficially (inferiorly) beneath the plantar side of the talus (Figs. 3 and 4). The early development of the calcaneus is summarized in Fig. 5.

Long flexor tendons to the toe and fingers were thick and extended distally in the medial side of the tibia, calcaneus, talus and the other tarsal bones (Figs. 1 and 4). Since nerves were as thick as muscle belly, the topographical anatomy of between nerve and muscle was helpful for identification of muscles (Fig. 1DH). A common tendinous plate of flexor tendons was thick and evident in both of the longitudinal and tangential sections of the foot planta (Figs. 2–4). From the deep side of the navicular bone, the flexor hallucis longus tendon merged with the flexor digitorum longus tendon to provide the

Fig. 1. Longitudinal sections of the lower extremity in a specimen with CRL 15 mm. HE staining. Panels A–D (or F–H) display the right (left) lower extremity. The flexor digitorum longus tendon (FDLT) extends distally in the immediately superficial and medial sides of the flexor hallucis longus tendon (FHLT). Both tendons are located in the medial side of the tibia (TI), fibula (FI), talus (TA), navicular (NA) and metatarsal bones (MT). The peroneus longus muscle (PL) also appears to extend to the medial side of the foot bones (panel H). The heel or tuber of the calcaneus is not evident. All panels are prepared at the same magnification (scale bar in panel A, 1 mm). Other abbreviations, see the common abbreviation.
common plate. The extensor tendons also appeared to join to provide a plate-like structure but it was thin (figure, not shown). An identification of the peroneus longus tendon was difficult in the longitudinal sections because the oblique or transverse course was overlapped the tarsal bones in sections (Fig. 1). Both of the peroneus longus muscle belly and its tendon in the planta were seen only in a single specimen with CRL 20 mm (Fig. 3). In contrast to the flexor digitorum brevis muscle and tendons in the superficial side of the common tendinous plate, we did not find the quadratus plantae muscle.

Discussion

In the present study, we demonstrated a common
Fig. 3. Tangential sections of the foot in a specimen with CRL 20 mm. Azan staining (panels A and B) and HE staining (panels C-G). Panel A (or G) displays the most deep (or superficial) site in the figure. The peroneus longus tendon (PLT; arrows in panels A-C) crosses the foot planta between the calcaneus and cuboid bones (CU, CA) to reach the first metatarsal bone (MT1). The heel or tuber of the calcaneus is evident in the superficial sections (panels D-F). Tendons of the flexor digitorum longus and flexor hallucis longus muscles (FDLT, FHLT) join to provide a thick tendinous plate (arrowhead in panels E and F). All panels are prepared at the same magnification (scale bar in panel A, 1 mm). Other abbreviations, see the common abbreviation.
Fig. 4. Longitudinal sections of the lower extremity in a specimen with CRL 21 mm. HE staining. Panels A (or G) displays the most lateral (medial) site in the figure. The heel or tuber of the calcaneus is evident and receives the calcaneal tendon (CAT) in panel A. The flexor digitorum longus tendon (FDLT) and flexor hallucis longus tendon (FHLT) join to provide a thick tendinous plate (arrowhead in panels C and D). The peroneus longus tendon is not clearly identified in the sections. All panels are prepared at the same magnification (scale bar in panel A, 1 mm). Other abbreviations, see the common abbreviation.
tendinous plate for flexors in the foot planta of human embryos. The hand also carried the common tendinous plate for superficial and deep flexors, but well developed lubricales muscles seem to later separate each of deep tendons (Cho et al., 2012). The destruction of tendinous connections seems to induce macrophage accumulation in the flexor aspect (Kim et al., 2012). In adult human cadavers, the foot planta contains much frequently and greater types of flexor tendon anomalies than in the hand palmar aspect (Bergman et al., 1988). Moreover, in contrast to the hand, lumbrical muscles are poorly developed in the adult foot (Oukouchi et al., 1992). Therefore, in the common plate in human embryos and fetuses, much or less, some connections between tendons seemed to remain even after birth. As Beckham et al. (1977) experimentally demonstrated using chick, finger excises would play a great role to separate foot flexor tendons each other.

Uchiyama et al. (2014) demonstrated that the initial quadratus plantae muscle was located in a level or depth same as the flexor digitorum tendon. In contrast to the flexor digitorum brevis muscle developing in the superficial side of the common tendinous plate, the quadratus plantae muscle might develop later in the common tendinous plate itself. This seemed to connect with a fact that the adult quadratus plantae shows variations in almost 20% (Onari, 1960). Although the identification of the tendon was often difficult near and along the developing calcaneus, we postulated a hypothetical change in course of the peroneus longus tendon (Fig. 5). In the initial phase, because of the underdeveloped calcaneus, the peroneus longus tendon might take an almost straight course similar to long flexor tendons. However, the inferomedially expanding calcaneus beneath the talus was likely to push the tendon to the cuboid bone. A famous bony groove on the cuboid might be sculptured by this expanding process of the calcaneus. Horiguchi et al. (1986) reported that the so-called “tendon groove of the cuboid bone” does not contain the peroneus longus tendon. The tendon pulley or a facet on the cuboid seen in adults seemed to develop outside of or distant from the initial bony groove after establishment of plantar ligaments: the latter event occurs very late because of likely contribution of muscle contractions (Uchiyama et al., 2014).

Fig. 5. A hypothetical change in a plantar course of the peroneus longus tendon. Plantar or superficial view of the right foot. Panel A displays the initial phase in which, because of the underdeveloped calcaneus (CA), the peroneus longus tendon (PLT) takes an almost straight course similar to long flexor tendons. In panel B (at 6 weeks), the inferomedially expanding calcaneus pushes the peroneus tendon to the cuboid bone.

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Figure legend

Common abbreviation for figures:

CA, calcaneus bone;
CAT, calcaneus tendon;
CFN, common fibular nerve;
CU, cuboid bone;
DFN, deep fibular nerve;
EDB, extensor digitorum brevis muscle;
EDL, extensor digitorum longus muscle;
EHLT, extensor hallucis longus tendon;
FE, femur;
FI, fibula;
FN, femoral nerve;
FDB, flexor digitorum brevis muscle;
FDL, flexor digitorum longus muscle;
FDLT, flexor digitorum longus tendon;
FHL, flexor hallucis longus muscle;
FHLT, flexor hallucis longus tendon;
GA, gastrocnemius muscle;
IC, intermediate cuneiform bone;
LC, lateral cuneiform bone;
MC, medial cuneiform bone;
MT, metatarsal bones;
NA, navicular bone;
ON, obturator nerve;
PL, peroneus longus muscle;
PLT, peroneus longus tendon;
SFN, superficial fibular nerve;
SN, sciatic nerve;
SO, soleus muscle;
TA talus bone;
TI, tibia;
TN, tibial nerve;
TPT, tibialis posterior tendon.