NON-SAGITTAL MOVEMENTS IN LOWER LEG AND FOOT, AND SOME OF THEIR UNDERLYING ANATOMICAL AND KINEMATICAL PRINCIPLES

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Introduction

In human gait, at the end of the stance phase, the lower leg normally performs a slight temporary lateral rotation, while the foot simultaneously shows inversion through mid-stance until toe-off. The subsequent swing phase mostly shows the foot swaying more or less in inversion, in order to be repositioned, as the lower leg does, during late swing and after touchdown. While these non-sagittal events in lower leg, ankle and foot have been hitherto insufficiently analyzed in quadrupeds [1], more profound analyses in terms of arthrology and myology of lower leg and foot in primates and their predecessors remained quite scarce as well [2, 3, 4]. Therefore, in our laboratory of anatomy, a series of measurements in anatomical specimens of human lower leg and foot was performed, in order to quantify with regard to gross anatomy some of the underlying functional-morphological mechanisms of such non-sagittal movements. As the majority of the abovementioned studies has been published else already [5, 6], this review emphasizes their *methods* and *results*, with possible applications to well-known phenomena of foot inversion and foot eversion, that occur during the normal walking and running cycles, e.g. in children.

Measurements

The slight lateral rotation of the lower leg at the end of the stance phase, coupled to inversion of hind foot and mid foot (while the forefoot is still on the ground), inevitably implies unwinding of anatomical structures in shank and foot. Both *chiasma cruris* (i.e. crossing of tibialis posterior tendon over flexor digitorum longus tendon, in lower leg) and *chiasma pedis* (i.e. crossing of flexor digitorum longus tendon over flexor hallucis longus tendon in sole of the foot) are involved in this unwinding during foot inversion in late stance, and in winding-up during foot eversion in late swing and after touch-down [2].

A **first** series of measurements quantified by goniometry, the changing angles of crossing of this *chiasma cruris*, in five lower leg anatomical specimens, of which these tendons *in situ* were brought into view. Goniometry was applied on prints of photographs, performed of each anatomical specimen under standard conditions, starting from a neutral foot position. Foot inversion and foot eversion were manually applied, and the *chiasma cruris* was measured anew, performing goniometry on HR prints of photographs.

A **second** series of measurements concerned rotations, of the foot's first metatarsal bone around its axis, in push-off positions, in ten lower-leg-and-foot anatomical specimens. At standardized positions, stainless screws ("intracortical pins") were inserted perpendicularly into the dorsal shaft of each first metatarsal. Lateromedial radiographs, of each anatomical specimen being immobilized in a special device at standard conditions, displayed changing lengths of these screws, as projected in each roentgenogram. Neutral foot position ("midstance") was compared to inversion and extreme inversion position mimicking "push-off" and "push-off prior to swing" respectively. Roentgenphotogrammetry allowed calculating by trigonometry, rotation degrees of each first metatarsal as a measure of foot inversion during push-off [6].

A **third** series of measurements applied basic roentgenstereophotogrammetry, to theoretically calculate the possible capabilities of intrinsic foot muscles in particular during sway (when the foot-in-inversion is "in the air") to successfully reposition it into a foot-in-eversion, right before or during touch-down. In ten lower-leg-and-foot anatomical specimens, stainless metal wire markings were wound around extrinsic invertor and evertor muscle tendons, and around intrinsic dorsal and plantar muscle tendons, to clearly identify these tendons on AP and LM radiographs. Tracing the X-ray pictures allowed quantifying directions and moment arms of tendons relative to *Chopart's* joint longitudinal inversion-eversion axis [5].

Results and Conclusions

1. Average acute angles of lower leg *chiasma cruris* tendons in anatomical specimens increase about 1º from foot eversion to inversion. This supports winding - unwinding hypotheses, from stance to sway.
2. From mid-stance to push-off, prior to swing, average foot specimens show inversion of about 9º.
3. Of all *intrinsic* foot muscles playing additional roles repositioning a freely swaying foot from inversion to eversion, before touchdown, *caput transversum* of *m. adductor hallucis* is the most likely candidate.

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