Correlation between calcaneal eversion, navicular drop, and displacement of the center of pressure during walking

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INTRODUCTION

Plantar pressure plates are widely used in both fundamental and applied gait research. Linking the output of these plates (e.g. sites of peak pressure, displacement of the center of pressure; CoP) to foot kinematics is not trivial. Yet, having an insight in such relationships (or lack thereof) is of interest to scientists and clinical practicioners.

In this paper we address the question whether calcaneal eversion and navicular drop (ND) can be reliably predicted from the medio-lateral displacement of the CoP. We calculate the latter displacement in two ways: (1) based on the pressures measured under the whole foot and (2) based on the pressures measured under the heel only. The rationale of the latter approach is based on a model of the heel as a rolling ball[1], to a large extent uncoupled from the midfoot.

METHODS

Data from left feet of 36 healthy subjects (5 good trials per subject) were collected on a 22-m long instrumented (Kistler force plate, RSScan pressure plate) walkway. Kinematics were recorded using an infrared 7-camera (Vicon M1) system, tracking the motions of three calcaneal markers and one navicular marker (reconstruction error 0.4 mm). All measurements were synchronized electronically and collected at 250 Hz.
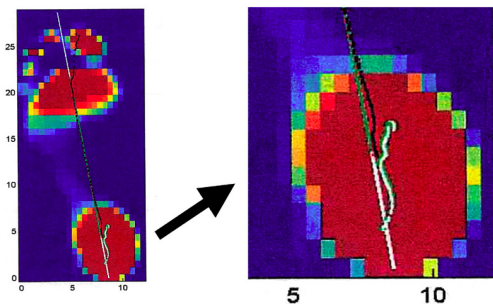

Figure 1: Figure 1: calculation of the CoP based on the entire foot (black line) or on the heel area (white line)

We defined five instants at which inversion/eversion angles, CoP positions, inversion/eversion velocity and CoP verlocity were determined: heel impact, maximal heel pressure, maximal eversion, maximal navicular drop and heel lift. Additionally, the ranges of total eversion and total CoP displacement were calculated.

We defined three instants at which navicular drop and its velocity were determined: initial contact of the first metatarsal, maximal navicular drop, and heel off. Additionally, the range of total navicular drop was calculated.

Where appropriate, we also used angle and displacements values with the initial values (at heel touchdown) subtracted. Pearson Correlation coefficients were calculated between all these variables. This analysis was performed twice; either using CoP data calculated from the entire foot or from the heel zone only.

RESULTS AND DISCUSSION

The *ranges* of CoP displacement, eversion and ND are significantly correlated when using the CoP based on foot data (see Figure 2 for Pearson Correlation Coefficients and P values), much less so when using the CoP of the entire foot.
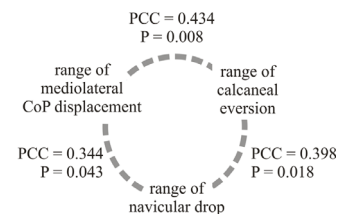

Figure 2

Significant correlations were found between the angular and positional *values* of eversion and CoP respectively, at the instant of maximal heel pressure (PCC = 0.478, P = 0.024) and at the instant of maximal eversion (PCC = 0.449, P = 0.036). Correlations correspond well to those found in related studies [2,3].

Highly significant correlations were found between the angular and linear *velocities* of eversion and CoP respectively, at the instant of heel impact (PCC = 0.540, P = 0.001) and at the instant of maximal heel pressure (PCC = 0.515, P = 0.001).

CONCLUSIONS

Eversion of the heel is correlated highly significantly with mediolateral CoP movement and significantly with ND, confirming clinical observations. Correlations are best with heel-based CoP calculations, thus confirming the validity of the "rolling ball" model of the heel[1]. Despite these (and other) significant correlations, predictive power is rather small with R² values typically ranging from 0.15-0.25. CoP measurements are no perfect predictors of eversion; this should be kept in mind in clinical studies. In scientific studies, direct measurements of eversion should be preferred.

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