Feet and Footwear

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NORM DATA FOR BENDING AND TORSIONAL LOADS OF THE FOOT IN SHOES INCLUDING THE EFFECT OF GENDER

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Introduction and Objectives: The measurement and estimation of foot loading is of great interest, especially in case of diabetes mellitus. The weight bearing of the foot has been widely measured in several studies with the help of pressure distribution systems [1]. One problem of pressure measurement is that it only measures the vertical component of the force acting on the foot. In daily life, the foot is protected and supported by shoes. Insole-Systems are used to receive information about the interaction between foot and shoe. A new system: betois (bending torsional insole system) which measures three dimensional deformations was developed. It measures bending and torsional moments between foot and shoe proximal to the Metatarsophalangeal Joint (MTP) I and V and distal to the processus calcaneus (H) with a coefficient of determination of $R^2 > 0.99$ and a linearity near 1. These moments seem to be important variables in the detection of stresses acting on the foot. Before pathological moments can be determined, data from healthy subjects must be available and the effect of gender has to be investigated.

Methods: Betois measures bending (Mb) and torsional (Mt) moments using strain gauges proximal to the caput metatarsal I and V and distal to the processus calcaneus. 53 healthy subjects (38,7y ± 11,7y) participated in this study walking at self-selected speed with the same shoe (Saucony Hattori LC) on a treadmill. After a familiarization period, data were collected with a sampling frequency of 125 Hz over one minute of walk. For data analysis, data were low-pass filtered (Butterworth, 10Hz, 2. order). Heel strike was determined using the sensor beneath the heel. Afterwards, gait cycle curves were normalized to 100 % of gait cycle (gc) (101 data points) and the mean of 30 steps computed. Mean curves and 95 % confidence bands were calculated using the bootstrap-method. Positive values represent dorsalextension and negative plantarflexion moments. In case of torsional moments positive values describe eversion and negative inversion moments. To examine the difference between the gender groups the confidence bands for the difference of the mean (CBDM) were established [2].

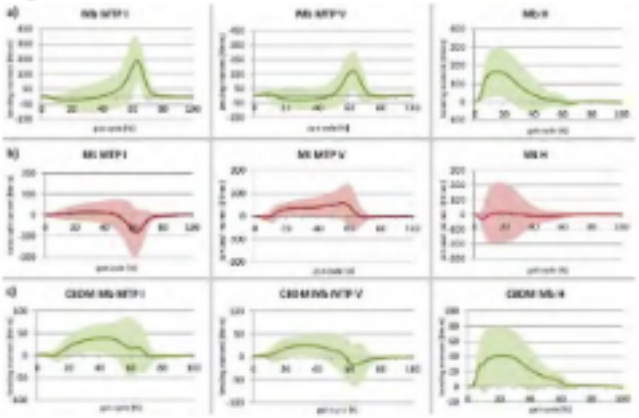
Results: For MTP I and V alternating bending moments were measured. At the beginning of gc a slight plantarflexion moment occurs with its maximum of -21Nmm at 21 % of gc for MTP I and –27Nmm at 28% of gc at MTP V. At terminal stance the moments act in direction of dorsalextension. MTP I reaches its maximum at 63% gc with 243Nmm. Simultaneously, MTP V reaches its maximum with 174Nmm (figure a).

The torsional moments are smaller than bending moments. At loading response a slight eversion moment occurs until 50% of gc at MTP I. Afterwards an inversion moment occurs with its maximum of 82Nmm at 62% gc. At MTP V an inversion moment is measured with its maximum of 58Nmm at 56% gc (figure b).

For the heel a sharp rising dorsalextension moment occurs with its maximum of 166Nmm at 14% gc. Then it flattens slowly until zero crossing at 61 % gc (figure a). The mean of the torsional moment is near zero with a wide confidence band (figure b).

Comparing gender groups, bending moments at MTP I and V were significantly different at mid stance with a maximum difference of 38Nmm (43% gc) at MTP I and 48Nmm (38% gc) at MTP V (figure c). There is also a slight difference for torsional moments at MTP V during loading response. Looking at the gender difference for the bending moment at the heel, significant differences occur from 17 % until 32 % gc, with men tend to have higher bending moments (max. 80Nmm, figure c). For the torsional moments significant differences can be measured from 8 % until 39 % gc (max. 83Nmm). Men tend to have higher eversion moments.

Figure:



Conclusion: In this study norm data for bending and torsional loads were collected. Due to the large number of subjects and the large age range, the norm data created are representative of the loads on healthy feet. An alternating bending moment could be measured at MTP I and V. This alternating moment can be related to the deceleration before the mid-stance and push-off after mid-stance. The data show clearly a higher variability for torsional stresses compared to bending, and further investigation is needed to detect the reason for this variability. The norm curves can be used for comparing different groups of subjects, such as Diabetics with neuropathy. The examination of gender has shown that it has to be considered when comparing data. This result confirms the findings of other studies [3]. The significantly different bending moments in the middle and late stance phase indicate a gender-specific performance of the stance phase. Furthermore, the influence of other factors like age, walking speed, bodyweight or step length has to be determined.

References: [1] Owings et al.,Diabet.Med.,26:1141–1146,2009.

[2] Duhamel et al.,Gait & Posture,20:204-212,2004.

[3] Roislien et al.,Gait & Posture,30:441-445,2009.

Disclosure of Interest: None Declared