POSTURAL CONTROL RELATED TO FLEXIBILITY OF THE HINDFOOT WHEN BEARING HEAVY LOADS

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INTRODUCTION

Flexibility of the hindfoot is often used to help prescribe in-shoe orthotics for intervention or treatment of overuse injuries to the lower extremity. The high incidence of stress fractures in military recruits during basic training is of particular concern because high frequency of loading is exacerbated by carrying a heavy backpack. Properly designed in-shoe orthotics could potentially reduce the incidence of stress fractures and shorten recovery time, but clinical assessment of hindfoot flexibility is generally qualitative, and prescription of orthoses is often subjective and occasionally contentious. Concomitantly, this study investigated a quantitative measure of hindfoot flexibility versus postural control with a heavy load, as a prelude for future gait studies.

Karlsson et al. [1] suggest a load-unload strategy for medial-lateral (ML) postural control by shifting weight from one foot to the other, and a more active strategy for anterior-posterior (AP) stability using the muscles crossing the ankle joint. ML load-unload is typically actuated by lateral sway of the torso with feet and ankles in a more passive role.

Random walk analysis has been applied to center of pressure (COP) measurements under the feet during quiet standing to investigate control characteristics of postural stability [2]. It employs the mean-square-difference (MSD) in digitized signal x_i over different latency intervals τ as shown in Equation 1. Correlating MSD with τ as shown in Equation 2 permits estimation of scaling exponent H.

$$MSD(\tau) = \Sigma\,[(x_{i+k} - x_i)^2]\,/\,(n\text{-}k) \qquad \text{for } \tau = k\,\Delta t \qquad (1)$$

$$MSD \sim \tau^{2H} \qquad (2)$$

Scaling exponent H equals 0.5 for classical Brownian motion, is above 0.5 for more active control, is below 0.5 for less active control, and equals 0 for a purely random signal. Typical plots of *log*(MSD) versus *log*(τ) for COP during quiet standing with shoes exhibit characteristic H_1 between 0.4 to 0.7 for τ below a critical time interval (CTI) of approximately 1 second, and H_2 between 0.1 to 0.2 for τ above the CTI.

METHODS

A vernier caliper was used to measure navicular drop [3] for each foot of 22 female volunteers. At least two measurements per foot by different investigators were averaged. The sum of right and left navicular drop was used to quantify hindfoot flexibility. The subjects then donned cross-training shoes and stood on a force platform under two conditions: two feet quiet standing, and wearing a military backpack (18.1 kg). COP data were collected at 1000 Hz over 30 seconds per trial. One trial per condition was used. Correlation coefficients for scaling exponent H_1 in ML and AP directions for each trial were computed as linear functions of navicular drop.

RESULTS AND DISCUSSION

AP scaling exponent H_1 for two feet was effectively constant across all values of navicular drop with mean 0.60 ($r^2 = 0.01$). AP scaling exponent H_1 while wearing the backpack was effectively constant with mean 0.68 ($r^2 = 0.03$). These values indicate moderately active control in the AP direction with slightly more active control effort when wearing a backpack.

ML scaling exponent H_1 for two feet was effectively constant across all values of navicular drop with mean 0.38 ($r^2 = 0.04$) indicating less active control than AP. However ML scaling exponent H_1 while wearing the backpack was moderately correlated to navicular drop ($r^2 = 0.32$) as shown in Figure 1. More flexible feet exhibited less ML active control while stiffer feet exhibited more active control.

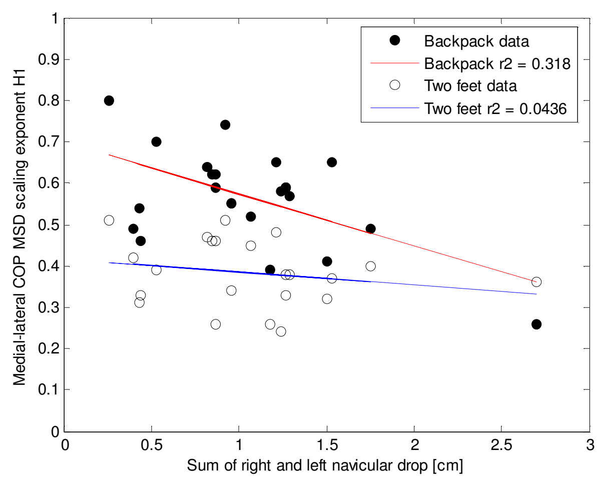

Figure 1: ML postural control versus hindfoot flexibility

CONCLUSIONS

These data support active AP ankle strategy with higher H_1 in the AP direction compared to ML for two feet, and even higher H_1 when a heavy load is carried on the back. In regard to the ML load-unload model, a flexible foot would provide a better damping mechanism and require less ML control than a more rigid foot.

A correlation with $r^2 = 0.32$ is not definitive. However the relationship between ML postural control when wearing a backpack and hindfoot flexibility quantified by navicular drop warrants further investigation, particularly in regard to prescribing in-shoe orthotics to reduce lateral ankle forces.

REFERENCES

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