Attenuation of Transient Foot-Ground Reaction Forces

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Introduction: Excessive foot-ground reaction forces (GRF) are often cited as the cause of gait related injuries. To gage the effectiveness of an intervention (e.g. insoles, footwear, floor material, prosthetic components), measurements of accelerations and foot GRFs have become widely used methodologies. While studying accelerations measured during walking with footwear of varying hardness, Light *et al.* [1] observed that high frequency components are superimposed on an ill-determined rising baseline due to the progression of the body center of mass in the direction of motion and changes in its vertical accelerations. This observation might suggest the use of a Fourier transform to obtain frequency domain information. However, because the Fourier transform assumes stationary waveforms over the sample period [2], the magnitude of transient components will be under-estimated and subtle features in the foot GRF data, particularly when they only occur for short durations, are likely to be obscured.

We present a wavelet-based analysis of the vertical foot GRF (Fz) data that preserves both the time and frequency content and does not under-estimate transient magnitudes. Our interest is the frequency content and magnitude of the foot GRFs during the first 200 msec following initial contact and how it changes in response to different shock-absorbing interventions. We suspect magnitude, frequency, and dose are all related to the incidence of gait-related injuries and hypothesize that interventions that attenuate higher frequency components will provide the greatest benefit.

Statement of Clinical Significance: By developing novel approaches to understanding impact attenuation by prosthetic components for amputees and prophylactic footwear for diabetic patients, we seek to achieve improved mobility and independence while reducing health care costs associated with ineffective interventions.

Methodology: To estimate the magnitude of foot GRF transients induced during walking, ten intact subjects (body mass: 81 ± 10 kg, mean ± S. D.) were recruited and all provided informed consent. Fz was measured while walking barefoot (5 repeated trials) at their self-selected walking speed (1.5 ± 0.1 m/s) over a force plate (Kistler, Switzerland) filtered with a 100 Hz low pass 2-pole Butterworth analog anti-alias filter and sampled at 1280 Hz. Subjects were presented with two conditions in random order: (1) no shock-absorbing sheet on the force plate and (2) a 9.5 mm thick Sorbothane™ sheet covering the force plate.

Wavelet analysis on the Fz data was calculated using a stationary discrete wavelet packet algorithm created with Matlab software (Mathworks; USA). A Least Asymmetric wavelet of filter width 8 was used as it closely approximates an ideal band-pass filter due to small side-lobes outside the band-pass corner frequencies. The peak foot GRF observed during the first 200 msec of stance was calculated across each of nine frequency pass-bands from 10 to 100

Hz. We compared the mean peak force observed for both conditions within each frequency pass-band using an *a priori* alpha level of $p < 0.05$.

Results: The magnitude of Fz in the first 200 msec of stance across the spectrum (10 to 100 Hz) was on the order of five to 10 percent of the time series loading response peak (Figure 1). Statistically significant differences between the barefoot and shock-absorbing sheet conditions were found for pass-bands 10-20, 50-60, 60-70, 70-80, 80-90, and 90-100 Hz ($p < .05$). The shock-absorbing sheet amplified the peak force between 10 and 20 Hz and it attenuated the peak force from 50 to 100 Hz.

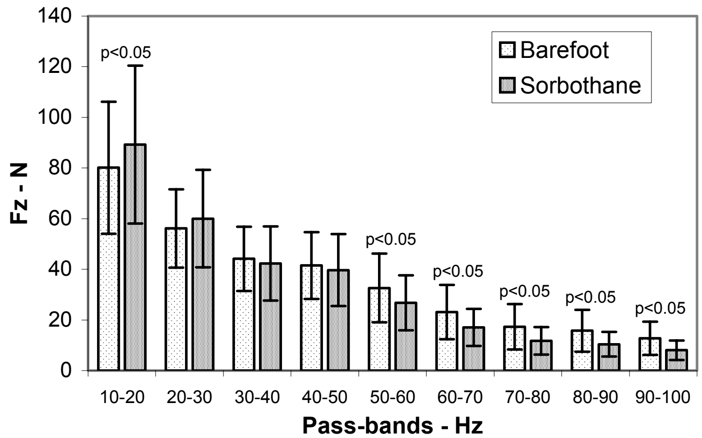

Figure 1: The mean peak vertical foot GRF (Fz) at each pass-band (mean ± s.d.).

Discussion: The results demonstrate that walking on a common shock-absorbing material attenuates forces at higher frequencies (50 to 100 Hz), but not at lower frequencies (10 to 50 Hz). Coupled with reports that shock-absorbing materials were effective in reducing stress fractures, overuse injuries, heel pain, Achilles tendonitis, foot bruises and blisters in four of five prospective studies [3-6] but see also [7], this data lends support to the hypothesis that higher frequencies are a responsible factor in gait-related injuries.

References:

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