THE INFLUENCE OF FOOTWEAR AND SHOE HARDNESS ON LOWER EXTREMITY INTRALIMB COORDINATION STRATEGIES

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INTRODUCTION
The influence of footwear and shoe hardness on lower extremity intralimb coordination strategies was examined in this study. Evaluation of curve correlations and mean absolute differences of segmental relative phasing curves revealed that the phasing relationships between segments were different while running barefoot and with shoes. The results suggested that adaptations due to footwear are probably located at the ankle (shank-foot relationships).

REVIEW AND THEORY
The inability of the body to dissipate the forces experienced during impact has been speculated to be the cause of running injuries (Nigg & Segesser, 1992). Previous research has not provided convincing evidence that shoe hardness is related to a decrease in impact forces (Clarke et al., 1983; Nigg et al., 1987). The lack of evidence has been speculated to be due to individual adaptive strategies (Clarke et al., 1983; Nigg et al., 1987). However, limited research efforts have been made to investigate these adaptive strategies and how they relate to shoe hardness. Insight into the strategies elicited by shoe hardness may be gained through evaluation of coordination via relative phasing relationships between segments. Relative phasing (RP) is a tool from the Dynamical Systems Theory of movement coordination that can describe the coordinative behavior of two segments while completing a task (Scholtz, 1990). Thus, the purpose of this study was to describe the influence of shoe hardness and footwear on intralimb coordination patterns during running.

PROCEDURES
Eight male heel-to-toe runners ran on a treadmill at a self-selected pace under the following randomly selected conditions: hard shoe, soft shoe, and barefoot. The two shoes were tested using an Impact Testing System (Exeter Research Inc.) in accordance with ASTM recommended procedures. The two shoes were classified as hard (15g) and soft (10g) based upon the impact test results. Ten consecutive footfalls were analyzed for each condition. Right side, sagittal and frontal (rear) plane 2D kinematic data were collected with two synchronized 180 Hz cameras (Peak Performance Technologies, Inc.). Phase portraits from normalized segmental angular positions and velocities were used to calculate phase angles (Scholtz, 1990). RP curves were calculated for three segmental relationships (sagittal thigh-shank, sagittal shank-foot, and rear shank-foot) by subtracting the phase angle of the proximal segment from the distal segment (Scholtz, 1990). Mean ensemble RP curves were calculated for all conditions. The RP curves were compared between conditions via (a) curve correlations (Derrick et al., 1994) and (b) by computing a mean absolute difference (MAD) between the curves. A high correlation indicates that the RP curves are similar or in other words the coordinative relationships between segments remain the same between conditions. A low correlation indicates the opposite. The MAD technique produces similar results with the curve correlations. However, it is
more sensitive to differences between curves and overcomes the limitations of the curve correlations (Derrick et al., 1994).

### RESULTS AND DISCUSSION

The results revealed lower correlations between the RP curves when barefoot was compared with either shoe condition for both the rear and sagittal shank-foot. When the two shoes were compared differences were minimal. For the sagittal shank-thigh relationship, correlations were similar for all comparisons. The MAD results were similar with the curve correlations. However, the curve differences were augmented and further clarified via this technique. Clark et al. (1983) has suggested that inter-subject changes in knee geometry is possibly the cause of the inconclusive results in shoe studies. However, this study suggested that adaptations due to footwear are probably located at the ankle (shank-foot relationships). The lack of differences between the shoes in this study might be due to lack of statistical power. Bates and Stergiou (1996) have suggested that 25 trials per condition are needed to avoid masking differences due to within-subject variability. In this study only ten trials were analyzed.

### REFERENCES


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