SLIP ANTICIPATION EFFECTS ON HIP/KNEE KINEMATICS
PART I: GAIT ON DRY FLOORS

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INTRODUCTION

Slips and falls are among the leading generators of non-fatal injuries and deaths at work and among the elderly (Courtney T.K., 2001). Slips are often the cause of multidimensional environmental and human factors. Biomechanical gait studies are an important component of slips/falls prevention research (Redfern M.S., 2001). The goal of this study is to investigate the strategies of maintaining balance when anticipating slippery surfaces. More specifically, this study will examine hip and knee kinematics.

METHODS

Equipment: Subjects were instructed to walk naturally across a vinyl tile walkway instrumented with two Bertec force plates (FP) so that each foot touched one plate. The left foot was the leading or stance leg. Ground reaction forces and whole body motion (8 VICON 612 motion cameras) were collected at 600 and 120 Hz., respectively.

Protocol: Five healthy subjects aged 35 or less (mean 24.8, SD 5.2), previously screened for neurological, vestibular, and orthopedic abnormalities, were informed that the first few trials would be dry to ensure natural walking (baseline condition). Next, one unexpected slippery trial, using glycerol, was collected. The subject was then alerted that the floor may be contaminated in the rest of the session (alert). Five dry, one slippery, and five additional dry trials were collected under the alert condition. Finally, one last known slippery trial was conducted (no-doubt condition). This study compared the dry baseline trials and the first five alert dry trials.

Data processing and analysis: To derive 3D kinematics of the knee and hip, a biomechanical rigid body model (left/right shank, left/right thigh and pelvis), Figure 1, was used. The flexion angle of the knee was found from rotation of the shank local frame with respect to the z-axis of the thigh's local system. The hip angle was found by using the rotation of the thigh's local frame with respect to the pelvis' local sagittal axis. The angles from a static anatomical position trial were subtracted from the measurements during gait trials. Within-subject repeated measures ANOVAs were performed on each gait variable of interest, evaluated at left heel contact time, determined by F.P. data, with the independent variable being the anticipation condition (baseline dry versus alert dry).

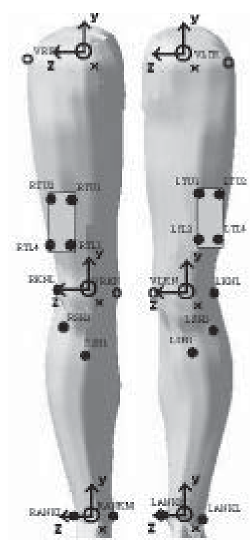
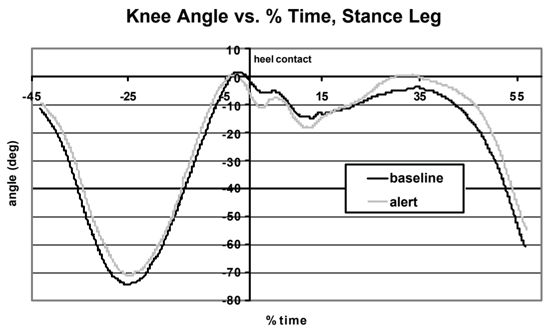


Figure 1: Biomechanical model, lower body used to derive kinematics of hip and knee. Local coordinate systems shown.

RESULTS



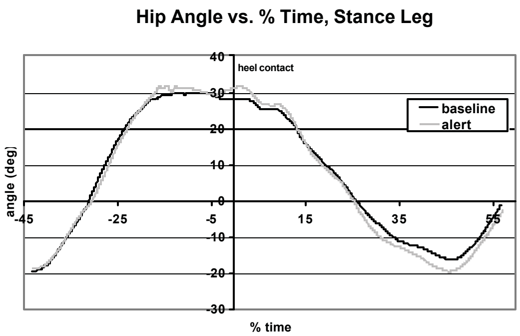


Figure 2: Angles for knee and hip, left leg, for one subject, one trial typical of all others. (+) indicates extension and (-), flexion. Time 0% corresponds to heel contact of stance leg.

Significant differences ($p < 0.001$) in the left knee and hip angles were found between the baseline dry and alert dry conditions. More specifically, increases in left hip angle (greater hip extension) and decreases in left knee angle (greater knee flexion) recorded during the alert dry conditions were compared to baseline trials. Figure 3 shows an average increase of 12.8% in left hip knee angle during alert compared to baseline

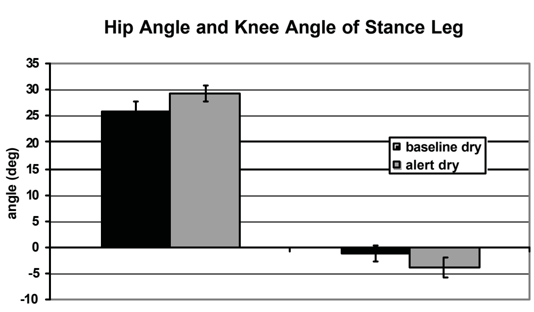


Figure 3: Average angle for knee and hip for left and leg [Error bars represent standard errors]

conditions. Knee angle increases from nearly fully extended in alert to 3.96° flexion. The differences in right hip and knee angles were not statistically significant ($p > 0.1$). The average difference in right hip and knee angles compared to baseline decreased by 2.24% and 9.28% respectively.

DISCUSSION AND CONCLUSIONS

The main finding of this study was that human adapt their gate to “potential” slippery surfaces (increased knee flexion and hip extension) for the stance leg. It is believed that subjects adopt proactive strategies to improve balance in case of a slip. Other gait adaptations include those observed at the feet (Margerum S., 2003). Overall, the gait adaptations adopted when the floor is suspected to be slippery proved effective at minimizing gait disturbances during slipping (Chambers A., 2003).

REFERENCES

Chambers A. et al. (2003) *submitted to American Society of Biomechanics.*

Courtney T.K. et al. (2001) *Ergonomics*, **44**, 1118-37.

Margerum S. et al. (2003) *submitted to American Society of Biomechanics.*

Redfern M.S. et al. (2001) *Ergonomics*, **44**,1138-66.

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