

KINEMATICS OF THE SLIPPING FOOT

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INTRODUCTION

Accidental injuries and deaths are often a consequence of slip and fall incidents (Courtney 2001). The participant's a-priori knowledge of the floor's contaminant condition impacts his/her risk of slipping (Cham 2002). Thus, the goal of this study was to investigate the impact of a-priori knowledge of the floor's contaminant condition on (1) the kinematics of the leading foot at heel contact just prior to slipping and (2) on the severity of the slip.

METHODS

Equipment: Subjects were equipped with a safety harness to prevent injuries in case of a fall. Full body motion (Vicon 612 / M2-cameras system) was recorded at 120 Hz, while ground reaction forces (Bertec Force plates) were recorded at 120 Hz.

Subjects and protocol: Two healthy male and three healthy female subjects, aged 20 to 35 years (mean 24.8 years, SD 5.2 years), were screened for neurological, vestibular and orthopedic abnormalities prior to participation. Subjects were instructed to walk naturally across a vinyl tile walkway such that each foot hit one force plate. After collecting 2 dry trials, a diluted glycerol solution (75% glycerol by volume) was applied to the force plate without the subject's knowledge ("unexpected" slip), so that the left foot (leading) came into contact with the slippery area. Next, the subject was informed that he/she might encounter slippery conditions. Five additional dry trials were collected under this "alert" condition

followed by an "alert" glycerol-contaminated trial. Finally, in the "no-doubt" condition, the subject was informed that the floor was contaminated.

Data processing and analysis: Position data of various markers on the foot and ankle were used to derive kinematic variables such as heel velocity and foot floor angle. In addition, slipping distance at the heel was calculated as a measure of slip severity. Finally, the outcome of the slip (no-slip, slip-recovery, slip-fall) was reported based on the heel's trajectory and visual video data. Within-subject repeated measures ANOVAs were conducted on the heel velocity and foot floor angle evaluated at heel contact as well as the sliding distance to investigate the impact of slippery surfaces anticipation.

RESULTS

At heel contact, the heel was moving in the forward direction as it was brought down onto the floor. There were no statistical significant differences in the horizontal heel velocity among anticipation conditions; however vertical heel velocity decreased significantly by 29% in the no-doubt condition compared to the unexpected slip (Figure 1).

Foot floor angle evaluated at heel contact was affected significantly by the anticipation condition (Figure 2). More specifically, the mean (SD) values of the foot-floor angles were 28.6° (5.9), 27.3° (4.72), and 21.1° (3.58) during the unexpected, alert, and no-doubt slippery condition, respectively.

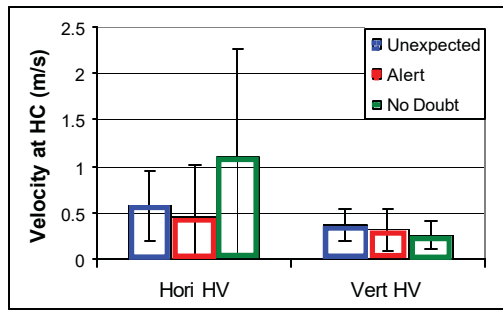


Figure 1: Heel velocity at heel contact (HC) (Error bars represent standard deviations). Hori HV is the heel velocity in the direction of travel and Vert HV is the negative vertical heel velocity.

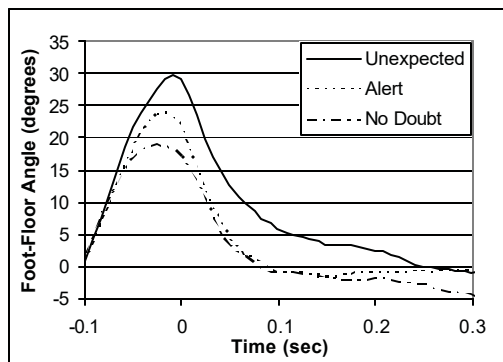


Figure 2: Left foot-floor angle for Subject 1(HC=0 s)

The slipping generated pronounced gait disturbances in the unexpected conditions. Three out of the 5 subjects lost their balance and were caught by the harness during the unexpected slippery condition, whereas only one fell during the alert-condition and all subjects were able to recover when informed of the slippery condition. Furthermore, 2 out of 5 subjects did not slip at all (slip distance < 1 cm) during the no-doubt condition. Another measure of slip severity is the slip distance of the left heel derived from the heel's horizontal trajectory (Figure 3). On average, unexpected slips resulted in slip distances greater than 15 cm (12) [distances during falls were calculated from heel contact to the recovery attempt] compared to average distances of 8 (6) and 3 (4) cm during the alert and no-doubt conditions, respectively.

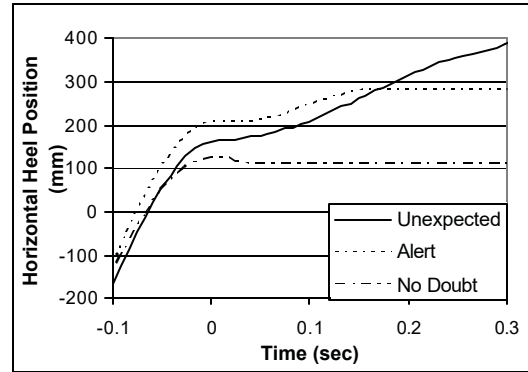


Figure 3: Typical profile of the left heel's horizontal trajectory (HC = 0 s)

DISCUSSION AND CONCLUSIONS

The a-priori knowledge of the floor contamination condition caused participants to adapt their gait when they suspected or knew the floor was contaminated. Those postural adaptations decreased not only slipping risk as reported in Cham and Redfern (2002), but also gait disturbances during slipping. Finally, it is important to acknowledge other gait adaptations, e.g. changes in knee and hip angles, which are beyond the scope of this paper and reported in another ASB submission (Chambers 2003).

REFERENCES

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