RECOVERY GAIT FOLLOWING AN UNEXPECTED SLIP

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INTRODUCTION

Falls due to slipping are a major cause of injury. The incidence of falls results in high economic and societal costs including medical care and lost productivity. In 2000, approximately 11.6 million fatal and nonfatal incidences of falls were reported and total lifetime costs of injury due to falls were estimated at $81 billion.[1] Falls often result from a loss of balance that can be attributed to slipping.[2] Thus it is important to study response to slips and quantify biomechanics in order to improve workplace environments and decrease the number of slips and falls.

One variable commonly evaluated when studying the biomechanics of slips is the required coefficient of friction (RCOF), defined as the ratio of shear force to normal force.[2] Most slips occur due to a high ratio of shear force to normal force applied on a floor surface immediately following heel contact.[2,3] Previous studies have shown that subjects adjust their gait on potentially slippery surfaces, which often results in a reduction in their peak RCOF as subjects reduce the relative shear force applied at heel contact.[2] However, it has not been determined how quickly a subject's gait returns to normal patterns following a slip.

The purpose of this study is to determine whether gait returns to normal baseline conditions after an unexpected slip by analyzing peak RCOF values before and after a slip.

METHODS

Ten young subjects (20-35 yrs,) screened for neurological and orthopedic abnormalities, were instructed to walk at a self-selected pace across a vinyl tile walkway, while ground reaction forces and whole body motion were sampled at 1080 and 120 Hz, respectively. Subjects were informed the first few trials would be dry, 'baseline dry' (BD). Without the subjects' knowledge, a glycerol solution (glycerol-water ratio of 75:25) was applied at the left/leading foot-floor interface, generating an 'unexpected slip'. Subjects were then told that the next few trials would be dry, 'recovery dry' (RD). Fifteen trials were collected on a dry floor.

Table 1: Subject characteristics, mean (SD).

	Male (n=5)	Female (n=5)	Total (n=10)
Age (years)	23.6 (1.34)	24.8 (4.49)	24.2 (3.19)
Height (cm)	178.0 (8.28)	165.9 (5.42)	172.0 (9.18)
Weight (kg)	80.8 (11.77)	65.4 (15.92)	73.1 (15.50)

Ground reaction force data was time normalized with respect to stance time for each foot with 0% = heel contact (HC) and 100% = toe off (TO). RCOF was calculated using the ratio of force in the anterior-posterior direction to the normal force.[2] The maximum RCOF value during 10-30% of the stance was selected for analysis.[2] Within subject repeated measures ANOVAs were conducted on the peak RCOF using condition (BD/RD) and trial number nested with condition as independent variables. Significance level was set at 0.05. A post-hoc analysis was performed when necessary.

RESULTS AND DISCUSSION

Mean peak RCOF values for all subjects during the RD trials for right foot and left foot are displayed (Figures 1 and 2). Subjects had a mean BD peak RCOF of 0.193 ± 0.029 and 0.199 ± 0.030 for the right foot and left foot, respectively.

The results for the right foot showed no statistically significant difference in peak RCOF values between BD and RD conditions (p=0.4918). As such, RD trial was not significantly different either (p=0.1709). However, the peak RCOF values for the left (previously slipped) foot displayed a significant difference in condition (p=0.0278). In addition, RD trial number was also significant for the left foot (p=0.0003). The post-hoc analysis revealed that mean peak RCOF values for RD trials 1, 2, 3, 4 and 6 were different than the mean BD peak RCOF values. Therefore it took approximately

5-6 RD trials for the left (previously slipped) foot to return to mean BD conditions.

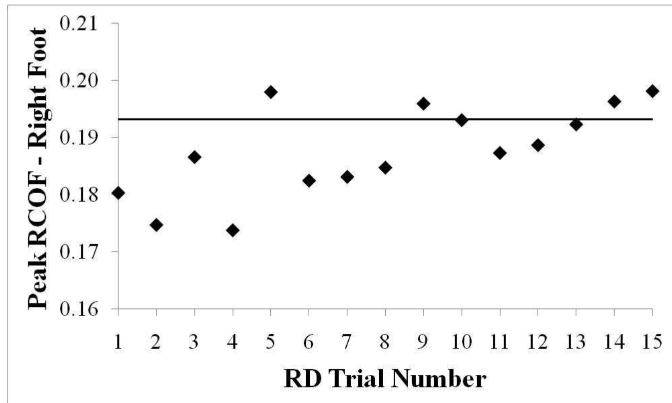

Figure 1: Mean peak RCOF during RD trials on right foot. Black horizontal line represents mean peak RCOF at BD. No individual RD trials were significantly different from mean BD peak RCOF values.

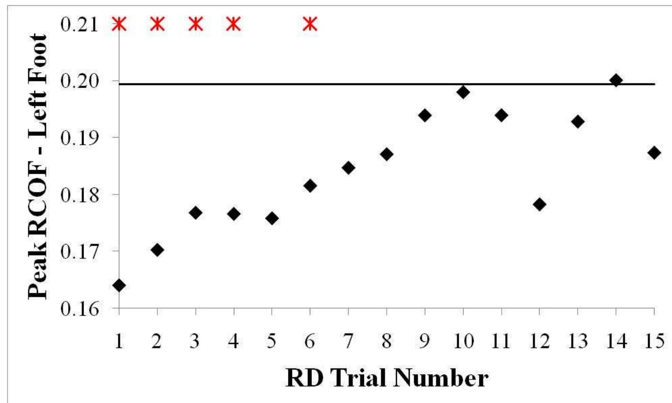

Figure 2: Mean peak RCOF during RD trials on left (previously slipped) foot. Black horizontal line represents mean peak RCOF at BD. Red asterisks denote RD trial number is significantly different from mean BD peak RCOF values.

After experiencing a slip, subjects significantly reduced their peak RCOF even though they were informed that the remaining trials would be dry. A reduction in peak RCOF has been shown to decrease slip risk and was present when subjects were warned that there was potential for a slip.[2,3] Reduced peak RCOF was present in the first few trials following the slip for both feet, suggesting that subjects were walking with more caution. However, the peak RCOF values for the right foot showed no significant difference between BD and RD conditions or trial effect. The peak RCOF values for the left (previously slipped) foot were significantly different from BD immediately following a slip and then gradually increased to the mean BD peak RCOF value. This suggests that subjects eventually 'relax' and return to their baseline gait in which they are no longer anticipating a slip. According to the data presented here this occurs after the sixth RD trial immediately following a slip. It is possible that with a larger subject pool this trial number would be later based on Figure 2. Additionally, the directions or warning conditions provided by the researcher could impact this 'relaxation' effect. If subjects do in fact return to baseline values, it may be possible to generate an additional 'unexpected slip'.

Previous research has shown that young adults only adjust their gait on the foot that would be slipping.[3] This could explain the differences found between the right foot and left foot. It was also found that older adults required an additional step before a potentially slippery surface to adjust their gait.[3] Therefore, it is possible that older adults would exhibit similar behavior on their right foot as on their left foot.

CONCLUSIONS

The left (previously slipped) foot displayed significant differences between peak RCOF values in BD and RD trials, while the right foot did not show any significant difference. In addition, it appears that after 6 RD trials, young adults 'relax' and peak RCOF values return to BD values for the left (previously slipped) foot. These results show that subjects are initially anticipating a slippery floor regardless of verbal instruction. Also, this implies that it may be possible to generate more than one 'unexpected slip' in young adults.

REFERENCES

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