

# SLIP POTENTIALS DURING LOAD CARRYING

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## INTRODUCTION

The ratio of shear to normal foot forces described by Strandberg and Lanshammar (1981) as the instantaneous “friction used,” may also be thought of, on dry surfaces, as the “required” coefficient of friction (RCOF) (McVay and Redfern, 1994). The peak RCOF has been used to assess the frictional requirements of walking and related to slip potential (Hanson and Redfern, 1999). Although carrying loads is a common industrial task, few studies have investigated the effect of external loads on gait biomechanics (Myung and Smith, 1997). Holbein and Redfern (1997) suggested that carrying symmetrically might increase postural stability. However, if a slip occurs during load carrying, the chance of recovery might decrease compared to walking with no load. The first aim of this study was to investigate the effect of load carrying on the RCOF during walking. Second, for a given carrying task, the relationship between RCOF and body height was examined, along with a comparison of the results between men and women.

## METHODS

Ten healthy young adults divided equally by gender participated. A previously built ramp instrumented with a force platform (FP) was used (Redfern and Dipasquale, 1997). An Optotrak-3020 motion measurement system was used to record body and foot movements. Both motion and foot forces were recorded at 350 Hz. The data describing ground reaction forces are reported here. The independent variables

included 2 ramp angles (0° and 10°) and 3 load conditions (0, 2.3 and 6.8 kg). A total of 235 dry trials were recorded on a dry vinyl-flooring surface. The same polyvinyl chloride (PVC) hard-soled shoes were used for all trials. After informed consent was given, subjects were equipped with a safety harness, handed the appropriate load to carry and instructed to walk down the ramp at a comfortable pace while looking straight ahead on the wall.

## RESULTS

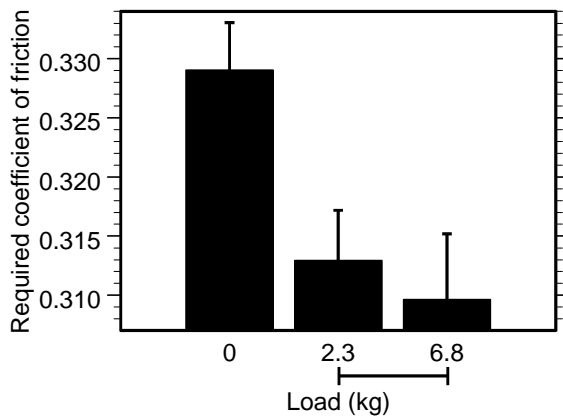
Peak values of the RCOF time series were found for each trial. A repeated measures ANOVA on the RCOF values was performed with the independent variables being subject, ramp angle, load level and all first and second order interaction terms. All of the independent variables except load had a statistically significant effect ( $p < 0.001$ ) on the RCOF ( $r^2=0.96$ ). For the no load carrying condition, the RCOF increased from  $0.183 \pm 0.040$  for level walking to  $0.329 \pm 0.027$  when descending a 10° ramp.

The specific relationship among ramp angle, load and RCOF was further investigated with an analysis of within-subject differences from the no load condition (Table 1). For level walking (0°), there was no significant effect of load on the peak RCOF. However, for the 10° ramp, significant differences were noted in the peak RCOF among the load carrying levels. More specifically, post-hoc Tukey comparisons showed a significant decrease in the peak RCOF when carrying a load

compared to the control condition (0 kg) (Figure 1). There were no significant differences between the 2.3 and 6.8 kg load conditions.

**Table 1:** p-values for peak RCOF

Angle →	0°		10°	
Variable ↓	p	r <sup>2</sup>	p	r <sup>2</sup>
Subject	<0.001		<0.001	
Load	0.537	0.83	<0.001	0.76
Subject x Load	<0.001		<0.001	

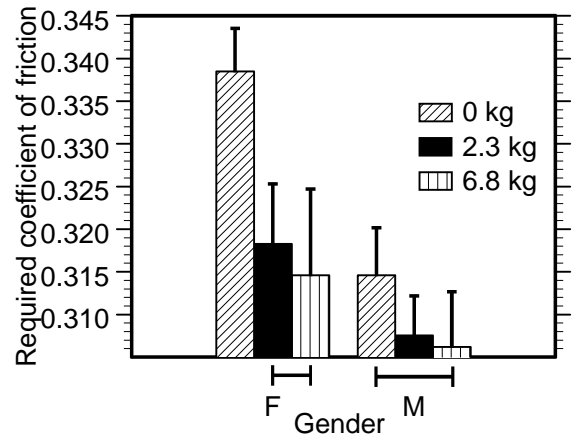


**Figure 1:** Peak RCOF for the 10° ramp condition during load carrying averaged across all subjects (mean ± S.E.M.)

Gender and height effects on RCOF values were investigated using a linear regression model with the independent variables being load, gender, height and second order interaction terms of these variables. For level walking, only gender was a significant factor. However, for a 10° degree ramp, all effects were statistically significant. Women had generally higher peak RCOFs compared to men (Figure 2). Load carrying effects found in Figure 1 still apply for both genders. For the 10° ramp, body height and RCOF were inversely related with peak RCOF decreasing with increased subject stature.

In summary, carrying a load affected the ratio of shear to normal foot force when

descending a 10° ramp, but not for level walking. This finding was more evident for women than men. This study suggests that people adapt their gait for sloped surfaces when carrying to reduce slip potentials. These findings are part of a larger study that investigated gait kinematics and kinetics on different surfaces of varying inclination and slipperiness to fully understand the biomechanics of slips and falls toward their prevention.



**Figure 2:** Load carrying effect on the RCOF compared between men and women (10°)

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