

INVESTIGATION OF FRICTION FOLLOWING OBSTACLE CLEARANCE DURING WALKING

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INTRODUCTION

Obstacles and low friction conditions are two types of perturbations that could potentially cause instability during walking. Numerous studies (Begg et al, 1998; Chen et al, 1994; Chou & Draganich, 1997; Patla et al, 1991; Patla & Rietdyk, 1993) have investigated the effect of obstacle perturbation during walking. This research has focused on the approach to an obstacle by collecting gait data of the trailing limb while negotiating the obstacle. These studies have attempted to elucidate factors associated with tripping while navigating the obstacle. Several studies (Begg et al, 1998; Patla et al, 1991) have used GRF parameters associated with the landing of the leading limb following obstacle clearance. Slipping after obstacle clearance has received limited attention (Patla & Rietdyk, 1993) but may be an important factor in the loss of dynamic postural stability while traversing a cluttered environment. The purpose of this study was to investigate the effects of shoe traction and obstacle height on friction during walking to better understand the process of slippage avoidance following obstacle clearance.

PROCEDURES

Ten male subjects walked at a self-selected pace during eight different conditions: four obstacle height conditions (0%, 10%, 20%, & 40% of limb length) and two friction conditions. The obstacle was a one meter

wide hurdle formed by two graduated supports and a thin wooden dowel. Friction was manipulated by wearing two different pairs of shoes (high and low traction). The high traction shoes had a dynamic COF of 0.7 and a static COF of 0.8. The low traction shoes had a dynamic COF of 0.3 and a static COF of 0.35. Frictional forces of the leading leg after it cleared the obstacle were calculated from the ground reaction forces (GRF), obtained using a Kistler force plate at 960 Hz. The force ratio (F_y/F_z) trace illustrates friction in-vivo (Figure 1).

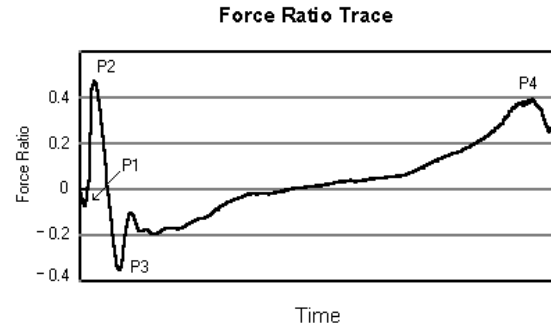


Figure 1: Force ratio trace.

Parameters analyzed were peak 2 (P2), peak 3 (P3), and peak 4 (P4) from the force ratio trace, and time of the braking phase (TB), time of the propulsive phase (TP), and time of stance (TS). Peak 1 (P1) was discarded from the analysis due to its inconsistencies. P1 was difficult to discern and was irregular in its occurrence. Perkins (1978) also stated that P1 was very inconsistent in its appearance. P1 is the first maximum negative peak on the force ratio trace, indicative of a high possibility of a forward

slip. P2 is the first maximum positive peak indicative of a slight possibility of a backward slip. P3 is the second maximum negative peak indicative of a high possibility of forward slip. P4 is the second maximum positive peak indicative of a high possibility of relatively safe backward slip. Slippage may occur when the absolute peak force ratio exceeds the COF of a particular shoe. TB and TP were calculated from the F_y curve. Two-way repeated measures ANOVAs (obstacle x shoe traction) were performed on the subject means for all parameters. Tukey's *post-hoc* comparisons were performed when there was a significant main effect ($p < 0.05$).

RESULTS AND DISCUSSION

P2, P3, P4, and TS revealed statistical significance for both factors (height and traction) and their interaction. The values of all the peaks were similar as in Perkins (1978). All peaks showed significant increases from the low to the high traction shoe. In addition, all peaks significantly increased with increases in obstacle height. P2 and P3 significantly increased from the no obstacle to the obstacle conditions for both shoes. For P4 the obstacle height had no effect regarding the low traction shoe. Inconsequential slippage repeatedly occurred during push off (P4). However, for the high traction shoe P4 showed similar results as in the other two peaks. TS values were significantly shorter for the low traction shoe. Due to the decreased stability of the situation, subjects may have reduced TS in order to increase their dynamic stability. TB differences were significant only regarding obstacle height. The time required to overcome the obstacle allowed the center of gravity (COG) to travel further forward with respect to the foot, thus shortening TB. Placement of the COG over the foot at heel strike decreases the

probability of a dangerous anterior slip. Presence of an obstacle may decrease the chance of slippage, due to the change in vector direction prior to heel strike.

SUMMARY

Peaks 2, 3, and 4 increased with increases in obstacle height. However, slippage did not occur because peak values never exceeded the COF of the corresponding shoes. The low traction shoes yielded smaller peaks than the high traction shoes. Increases in the obstacle height allowed for the subjects to position the center of gravity more anteriorly over the leading leg at foot contact. This led to shorter TB with increased obstacle height, and the shift from braking to propulsion occurred sooner. These compensations appear to reduce the risk to the subject when confronted with an environment characterized by low traction and high obstacles.

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