UPHILL AND DOWNHILL WALKING: THE BEFORE AND AFTER

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INTRODUCTION

It is nearly impossible to avoid uphill and downhill terrain when walking in the natural environment. Yet, walking on a hill increases the potential for instability due to modifications in both shear and propulsive force [1]. For this reason, the United States National Safety Council recommends carefully traversing hills as an effort to decrease the likelihood of falling.

Kawamura et al [2] and Lay et al [3] quantified the modifications to step width and muscle activity *during* hill walking. Their results illustrate how we maintain stability on uphill and downhill surfaces. It is possible that walking individuals also alter their kinematic and neuromuscular patterns in both anticipation of a change in terrain and as an aftereffect. Therefore, the purpose of our current study is to determine if step width and muscle activity are modified *before* and *after* hill walking. We hypothesized that, in comparison to controlled level walking, step width and muscle activity would be higher during the anticipation stride and aftereffect stride during hill walking in order to maintain stability.

METHODS

Nine men and nine women completed the protocol. All of the walking trials were completed at a self-selected velocity on a 25 m walkway. We utilized a custom-built portable apparatus composed of a 2.4 m ramp inclined at 15 degrees continuous with a 4.8 m plateau.

We collected 5 walking trials for each of the following 6 conditions; level (L), anticipation of uphill ramp (anUP), uphill ramp only (UP), aftereffect of uphill ramp (UPaf), anticipation of downhill ramp (anDN), downhill ramp only (DN), aftereffect of downhill ramp (DNaf).

We measured kinematic data with a six-camera, passive marker 3D photogrametry system and electromyography signals using a wired amplifier system. Prior to data collection, we placed retroreflective markers on the first metatarsal (TOE) and posterior calcaneus (HEEL) of both shoes for each participant to evaluate step width. In addition, we placed surface electrodes on the tibialis anterior (TA), lateral gastrocnemius (LG), tensor fascia latae (TFL), and adductor longus (ADL) muscles.

Step width and muscle activity were analyzed across all conditions using a repeated measures design (ANOVA). We performed Newman-Keuls post hoc tests to analyze the differences between conditions and reported all values as mean $\pm$ standard deviation. Significance was defined as $p \leq 0.05$.

RESULTS

Our kinematic results illustrate that step width did not change in anticipation of a hill. But step width did increase at the toe as an aftereffect from walking up a hill and decreased at both the toe and heel after walking down a hill. In addition, our neuromuscular results show that the TA, LG, and ADL muscle activity increased in anticipation of both an uphill and downhill ramp while the TFL only increased prior to a downhill ramp. The LG and ADL muscle activity also increased as an aftereffect from walking down a hill and decreased after walking up a hill.

	TOE	HEEL	TA	LG	ADL	TFL
anUP	101	102	**111**	**112**	**150**	102
UP	**74**	109	**151**	**189**	**193**	**166**
UPaf	**116**	99	101	**89**	97	92
anDN	101	103	107	101	**121**	104
DN	**184**	108	**128**	**143**	**159**	**134**
DNaf	**60**	**85**	105	**117**	**126**	97

Table 1. Mean toe and heel step width during the first double support phase and mean rectified muscle activity during the stance phase as a percentage of level walking. The bold values indicate a statistically significant difference from level walking ($p \leq 0.5$).

DISCUSSION

Toe step width decreased during uphill walking and increased during downhill walking possibly in an effort to enhance propulsion [4] and stability [5], respectively. Following these significant modifications, toe step width significantly changed in the opposite direction during the step after the hill. Thus, it appears that the ability to return to the optimal, level walking pattern cannot be achieved immediately.

Muscle activity in each muscle increased during both uphill and downhill walking. In anticipation of uphill walking the LG and ADL activity increased in preparation for the hill. In contrast, as an aftereffect to downhill walking these muscles maintained the increased activity from the hill.

Together, our kinematic and neuromuscular data demonstrate that toe step width, ankle extensor activity, and hip adductor activity are potential variables that aid in the maintenance of stability before and after hill walking.

REFERENCES

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