GAIT ADAPTATIONS WHEN WALKING ON A DESTABILIZING ROCK SURFACE

1Deanna H. Gates, 1Jason M. Wilken, 2Shawn J. Scott, 1Emily H. Sinitski, and 3Jonathan B. Dingwell

1Brooke Army Medical Center, Ft. Sam Houston, TX, USA
2Moncrief Army Community Hospital, Fort Jackson, SC, USA
3University of Texas at Austin, Austin, TX, USA
email: deanna.h.gates@gmail.com

INTRODUCTION

People frequently encounter a variety of different walking surfaces in their daily lives. The ability to compensate for the destabilizing effects of some of these surfaces is essential to maintain balance and prevent falls. Previous work on challenging walking surfaces primarily focused on changes in temporal-spatial parameters. Depending on the challenge of the walking surface, young adults may [1] or may not [2,3] adapt by decreasing their walking speed. In contrast, when negotiating uneven terrain, older adults typically adopt a more conservative walking pattern characterized by a slower walking speed [4], greater double support time [1] and wider steps [3]. Each of these studies instructed individuals to walk at a self-selected pace [3], which has generally been slower for uneven terrain [1,4]. As such, changes in step parameters may reflect changes in speed more than any differences in movement strategies. To date, no studies have examined what kinematic adaptations healthy adults make to successfully negotiate uneven terrain at controlled walking speeds. The purpose of this study was to quantify lower limb joint kinematics while subjects walked across a level walkway and a destabilizing surface (loose rocks) at four controlled speeds.

METHODS

Fifteen healthy young adults (22 ± 5 years) participated. Subjects walked over two ground surfaces: level, over ground (‘OG’) and rocks (‘RO’; Fig. 1) at each of 4 controlled speeds. Five strides for both the right and left foot were collected for each speed. Walking speeds were normalized to scale speed to each subject’s leg length.

The motion of 55 reflective markers were tracked at 120 Hz using Motion Analysis (Santa Rosa, CA) and used to construct a 15 segment rigid body model. Angular motions of the ankle, knee, and hip were calculated using Euler angles. Peak angles were assessed at multiple points in the gait cycle (Fig. 2). Step length (SL), time (ST), and width (SW) were calculated from the positions of the heel markers at heel contact. Foot angle was the sagittal plane angle between the heel and toe markers and horizontal at heel-strike [1]. A series of 2-factor (Surface x Speed) within-subjects ANOVAs were used to identify differences across speeds (1-4) and walking surfaces (OG v RO) for each dependent measure.

RESULTS

Temporal-Spatial
When walking at faster speeds, subjects increased their SL (p < 0.001) and decreased their ST (p < 0.001), but maintained constant SW (p = 0.634). There were no differences in SL, ST, or SW between walking surfaces (p > 0.230).

Kinematics – Stance
Compared to level ground, subjects struck the ground with a relatively flatter foot when walking over the rock surface (p < 0.001). Foot angles increased with walking speed (p < 0.001). There was an absence of ankle plantarflexion during early stance when walking over the rock surface (Fig. 2).
The knee was more flexed during initial stance when subjects walked over the rock surface compared to level ground (p < 0.001). Similarly, the hip was also more flexed during early stance over the rock surface (p < 0.001). Peak ankle plantarflexion and peak knee and hip flexion all increased with walking speed (p < 0.001).

Subjects dorsiflexed their ankles quickly during midstance, when walking over the rocks, such that they reached similar final positions prior to toe off as during level walking. They also reached similar peak extension at the hip and knee in late stance over both surfaces. While the differences at the ankle and hip were statistically significant, they were <1° on average.

Kinematics – Swing
When walking over the rock surface, subjects exhibited increased hip, knee and ankle flexion during swing (p < 0.001). Peak knee and hip flexion increased with walking speed (p < 0.001), while ankle dorsiflexion decreased (p < 0.001). There were significant speed x surface interactions for all comparisons (p < 0.03). Changes in peak hip and knee angle with speed were greater when subjects walked on the rocks than on level ground. At the ankle, dorsiflexion decreased with speed over level ground, but did not change in the rocks.

CONCLUSIONS
The subjects in this study successfully negotiated the rock surface without changing their speed, SL, ST, or SW. These results suggest that subjects adapted to the rock surface by making preparatory adjustments to their posture prior to contact with the walking surface.

REFERENCES

ACKNOWLEDGEMENTS
Supported by Military Amputee Research Program (JWM), US Army Medical Specialty Corps Long-Term Health Education Training Fellowship (SJS) and NIH Grant 1-R01-HD059844 (JBD & JWM). The views expressed herein are those of the authors and do not reflect the official policy or position of Brooke Army Medical Center, the U.S. Army Medical Department, the U.S. Army Office of the Surgeon General, the Department of the Army, Department of Defense or the U.S. Government.

Figure. 1. A) Bands represent the mean ± standard deviation of the average joint angle across subjects. Peaks during early stance (B) were identified between 0 and 25% of the gait cycle. Swing phase peaks (C) were the maximum joint angle between 65 and 100% of the gait cycle. Errorbars represent the 95% confidence intervals about the mean. There were statistically significant main effects for walking speed (p ≤ 0.001) and walking surface (p < 0.001) for all peaks presented in B and C.