FOOT AND ANKLE KINEMATICS DURING DESCENT FROM VARYING STEP HEIGHTS

1 Emily Gerstle, 1Kristian O’Connor, 1Kevin Keenan, and 1Stephen Cobb

1 The University of Wisconsin-Milwaukee, Milwaukee, WI, USA
email: egerstle@uwm.edu

INTRODUCTION

Ankle injuries account for approximately two million emergency room visits in the US annually. An estimated 26% of those injuries occur due to a fall from steps [1]. A study utilizing random population surveys found the total incidence of ankle injuries to be up to five times greater than the emergency room visit estimates [2].

Previous research has modeled the foot as a single rigid segment and focused on hip, knee and ankle movement during multiple step descent [3-5]. However, a study by Yu, 1997 reported the stepping mechanics of descending a single step differed from multiple step descent. Furthermore, recent studies have shown there is significant motion within the distal articulations of the foot during gait [6, 7].

The purpose of this study was to identify foot and ankle kinematics of uninjured individuals during descent from varying step heights.

It was hypothesized that landing strategy would transition from the rearfoot to the forefoot as step heights increased. These changes were anticipated to be accomplished through significant kinematic differences in the rear-, mid-, and forefoot both at initial contact and during weight acceptance. Regarding initial contact in the sagittal plane, the rearfoot, midfoot and medial forefoot were predicted to become more plantarflexed while the lateral forefoot would become more dorsiflexed. In the frontal plane a more inverted position was expected at both the rear and midfoot. We further hypothesized that the rearfoot and medial forefoot ranges of motion during the weight acceptance phase of the step down would be increased when initial contact was made with the forefoot versus the rearfoot. Finally, we proposed that the midfoot and lateral forefoot range of motion would be decreased during weight acceptance to facilitate foot stability when initial contact was made with the forefoot.

METHODS

Participants:
15 participants (8 female, 7 male; age = 25.6 ± 5.4 years; height = 173 ± 9.7 cm; mass = 70.8 ± 13.4 kg) were recruited for the study. All subjects had weight bearing ankle dorsiflexion ROM ≥ 25°, did not wear bifocals, and had no history of lower extremity surgery or recent injury.

Gait analysis:
A 10 camera motion analysis system was used to capture 3D positions of clusters of retroreflective markers placed on the foot and leg to define five functional articulations [Rearfoot complex (RC), Lateral midfoot (LMF), Medial midfoot (MMF), Medial forefoot (MFF), and Lateral forefoot (LFF)].

At a self-selected pace, participants walked along a level 5 m walkway, stepped down a height of 5, 10, 15, 20 or 25 cm and continued walking. After completing practice trials to establish a consistent self-selected pace 10 trials were recorded for each step height.

The calibrated anatomical systems technique was used to reconstruct 3D segment positions and orientations. Joint angles between adjacent segments were calculated using the joint coordinate system technique.

Data analysis:
Univariate RM ANOVAs were performed with five within subject factors (step height) to investigate sagittal plane RC, MMF, LMF, MFF, and LFF initial contact angles and ranges of motion during weight acceptance. Frontal plane RC, MMF, and LMF initial contact angles and ranges of motion
during weight acceptance were also calculated. Pairwise comparisons with Bonferroni adjustments were performed to investigate significant RM ANOVA results. Significance level for all tests was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Initial contact angles
In the sagittal plane the LMF was significantly more plantarflexed at the 25-cm step compared to the 5-cm (p=0.003) and 10-cm (p=0.026) steps.

In the frontal plane, the RC at the 25-cm step was significantly more inverted than the 20-cm height (p=0.023). While at the 20-cm step the LMF was significantly less everted then at the 10-cm height (p=0.022).

Range of motion
The sagittal plane RC ROM differed significantly between the 5-cm and the 20 and 25-cm heights as well as between the 10-cm and 25-cm steps. During weight acceptance, the RC plantarflexed at the 5 and 10-cm steps but dorsiflexed at the 20-cm and 25-cm steps. The LMF went through significantly greater dorsiflexion ROM at the 25-cm step compared to the 5-cm step (p=0.008). Finally, the LFF went through significantly more dorsiflexion at the 25-cm step compared to the 5-cm (p=0.013) and 15-cm (p=0.038) steps.

The frontal plane RM ANOVA for the RC was also significant (p=0.049), however the pairwise comparisons did not show any significant differences between any of the step heights.

CONCLUSIONS
The kinematics during negotiation of a single step are influenced by step height. At higher step heights, the more inverted RC and less everted LMF initial contact positions may act to stabilize the foot during the forefoot landing. The increased RC dorsiflexion ROM during weight acceptance as height increased, was consistent with the transition from a heel to forefoot landing strategy. The increased LMF and LFF dorsiflexion ROM during weight acceptance may have been due to the ground reaction force location associated with a forefoot landing strategy. The change in landing strategy preference may be clinically relevant due to the fact that the plantarflexed position of the ankle joint during the forefoot landing strategy results in decreased bony joint stability thus placing greater dependency upon ligaments and muscles (dynamic stabilizers) of the ankle and foot. This may be especially important in groups that may have compromised strength and/or ligamentous stability such as older adults or patients with chronic ankle instability.

REFERENCES

ACKNOWLEDGEMENTS
This study was partially funded by a grant from the University of Wisconsin-Milwaukee College of Health Sciences.