ACCELERATION DURING WALKING: THE EFFECT OF ANKLE KINETICS ON CENTER OF MASS POSITION AND VELOCITY

Michael S. Orendurff, Ava D. Segal, Jocelyn S. Berge, Kevin C. Flick and Glenn K. Klute

Motion Analysis Laboratory, Rehabilitation Research and Development, Seattle, WA. USA
michael.orendurff@med.va.gov www.seattlerehabresearch.org

INTRODUCTION

Most gait analysis is conducted at constant walking speed. But human gait involves increases in walking speed to navigate obstacles or meet timing deadlines. Hurrying to avoid an approaching car in a crosswalk, catching a closing elevator door, or rushing toward a hissing teapot involves an increase in walking speed. Theoretical experiments using induced acceleration analysis (Lohmann, 2004) and energy transfer modeling (Meinders, 1998) have attempted to explain the contribution of limb segments and individual joints to the body’s center of mass (COM) acceleration during constant speed walking, but to date no work has focused on the joint mechanisms used to increase walking speed. Understanding individual joint contributions used in accelerating gait may improve prosthetic designs for amputees. The purpose of this experiment was to compare the differences in COM position, COM velocity and ankle kinetics during accelerating and constant speed walking.

METHODS

Seven adults who were free from gait abnormalities gave informed consent to participate in this IRB-approved protocol. Gait measurements were made using a 10-camera Vicon 612 system (Lake Forest, CA). Thirty-eight reflective markers were placed on each subject according to Vicon’s full-body Plug-In-Gait model. Subjects completed six trials across an embedded forceplate (Kistler, Wintethur, CH) at their self-selected walking speed (SSWS) and were then instructed to walk at their self-selected speed to the forceplate and then accelerate as quickly as possible until the end of the walk way (Accel). Kinematic data was collected at 120 Hz, smoothed using a quintic spline at 20 MSE, labeled and modeled using Vicon Workstation software. Segmental analysis was used to calculate the COM of each segment and then for the whole body. COM forward (Y) velocity, sagittal ankle moments and sagittal ankle powers were compared across walking speeds using repeated measures ANOVAs and Scheffe’s tests post hoc (p < 0.05).

RESULTS and DISCUSSION

Self-selected walking speed was 1.5 ± 0.2 m/s. Subjects were able to increase their COM speed from 1.4 ± 0.2 to 2.2 ± 0.3 m/s during the acceleration task (p > 0.05). The onset of COM acceleration often coincided with a drop in COM position (see figure 1). The maximum ankle plantarflexor moment at 25% of the gait cycle was significantly lower in the acceleration trials than during constant speed walking (0.1 ± 0.2 VS 0.3 ± 0.1 Nm/kg; p < 0.05; see figure 2), suggesting that reduced support from the ankle was influencing the vertical position of the COM. This may be an indication that a potential-to-kinetic energy exchange was utilized to accelerate the COM forward at a faster rate during midstance. In late stance the peak plantarflexion moment was
greater during acceleration than constant speed walking (1.7 ± 0.2 VS 1.4 ± 0.1 Nm/kg; \( p < 0.05 \)). The peak ankle power in pre-swing was also increased during accelerating gait (5.3 ± 2.7 VS 3.9 ± 1.1 W/kg; \( p = 0.05 \); see figure 3), suggesting that the ankle is an important joint for increasing walking speed.

**Figure 1.** COM forward velocity (a) and vertical position (b) shown as a subject accelerates from 1.3 to 1.8 m/s.

**Figure 2.** Ankle plantarflexor moments were reduced in midstance and increased in pre-swing during acceleration trials.

**Figure 3.** Sagittal Ankle power increased in late stance during acceleration trials.

**SUMMARY**

Increasing walking speed appears to involve both potential-to-kinetic energy exchanges and increased joint power output at the ankle. The function of the ankle may permit acceleration by altering support moments and propulsive moments. Further work is needed to understand the contribution of other joints to increasing walking speed. Amputees who lack a sound ankle joint face unique challenges in gait acceleration which must be overcome by compensation at other joints. Understanding how amputees increase their walking speed may assist in defining design parameters for novel lower extremity prostheses. Improving the ability of amputees to meet the demands of changing walking speed may improve their mobility.

**REFERENCES**


**ACKNOWLEDGEMENT**

Funded by Department. of Veteran Affairs grant #A2661C.