EFFECTS OF WALKING SPEED AND VISUAL-TARGET DISTANCE ON TOE TRAJECTORY DURING SWING PHASE

Chris Miller [1], Brian Peters [1], Rachel Brady [1], Liz Warren [2], Jason Richards [1], Ajitkumar Mulavara [3], Hsi-Guang Sung [2] and Jacob Bloomberg [4]

[1] Neurosciences Laboratory, Wyle Laboratories, Houston, TX, USA
[2] Universities Space Research Association, Houston, TX, USA
[3] Department of Otorhinolaryngology, Baylor College of Medicine, Houston, TX, USA
[4] Neurosciences Laboratory, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
E-mail: chris.miller-1@nasa.gov

INTRODUCTION

After spaceflight, astronauts experience disturbances in their ability to walk and maintain postural stability (Bloomberg, et al., 1997). One of the post-flight neuro-vestibular assessments requires that the astronaut walk on a treadmill at 1.8 m/sec (4.0 mph), while performing a visual acuity test, set at two different distances ("far" and "near"). For the first few days after landing, some crewmembers can not maintain the required pace, so a lower speed may be used. The slower velocity must be considered in the kinematic analysis, because Andriacchi, et al. (1977) showed that in clinical populations, changes in gait parameters may be attributable more to slower gait speed than pathology.

Studying toe trajectory gives a global view of control of the leg, since it involves coordination of muscles and joints in both the swing and stance legs (Karst, et al., 1999). Winter (1992) and Murray, et al. (1984) reported that toe clearance during overground walking increased slightly as speed increased, but not significantly. Also, toe vertical peaks in both early and late swing phase did increase significantly with increasing speed.

During conventional testing of overground locomotion, subjects are usually asked to fix their gaze on the end of the walkway – a "far" target. But target (i.e., visual fixation) distance has been shown to affect head and trunk motion during treadmill walking (Bloomberg, et al., 1992; Peters, et al., in review). Since the head and trunk can not maintain stable gaze without proper coordination with the lower body (Mulavara & Bloomberg, 2003), it would stand to reason that lower body kinematics may be altered as well when target distance is modified. The purpose of this study was to determine changes in toe vertical trajectory during treadmill walking due to changes in walking speed and target distance.

METHODS

Six males and six females gave informed consent and participated in this study, and the NASA-JSC Committee for the Protection of Human Subjects approved the protocol. Subjects wore lab-supplied shoes (Converse, North Andover, MA) with footswitches (Motion Lab Systems, Baton Rouge, LA) affixed to the soles for the determination of heel contact and toe-off events. Retro-reflective markers (25 mm diameter) were taped over anatomical landmarks on the shoe of the subject's right foot. Three-dimensional marker positions were recorded using a video-based motion

capture system (Motion Analysis, Santa Rosa, CA). The toe was defined by a virtual marker computed at the location of the distal end of the shoe at the 2nd toe.
Subjects walked on a motorized treadmill at five different speeds (0.9, 1.1, 1.3, 1.6, 1.8 m/sec) while performing a visual acuity task (Peters & Bloomberg, 2005) with the optotypes shown on a visual display at two target distances from the eyes: 4 meters ("far") and 50 centimeters ("near"). Subjects performed ten 60-second trials – one for each speed-target combination. The order of speed-target combinations was determined by a balanced-block design, and each subject was randomly assigned to one of the twelve orders.

The marker positions and footswitch data were exported and analyzed using in-house Matlab scripts (Mathworks, Inc., Natick, MA) to determine gait cycle events and kinematics of the foot. The toe's vertical position was reported relative to that during the quiet stance (static) trial for reference. The analysis concentrated on three features of the swing toe's vertical trajectory: minimum toe clearance (TCl), the first toe peak in early swing just after push-off (toemax1) and the second toe peak just before heel contact (toemax2). A linear random-effects model was utilized to determine changes in the parameters due to speed and target distance ($p<0.05$).

RESULTS AND DISCUSSION

In this study, toe clearance significantly *decreased* with increasing speed (Figure 1; slope = -4.3 mm/(m/sec); $p < 0.01$) – a result opposite to that found by Winter (1992) and Murray, et al. (1984). However, like those studies, the toe peak just before heel contact significantly increased with speed (slope = 59.1 mm/(m/sec); $p < 0.01$). Target-fixation distance only had an effect on the toe peak just after toe-off, where the near-target values were lower than far-target values ($p = 0.01$). No significant interactions of speed and target distance were observed.

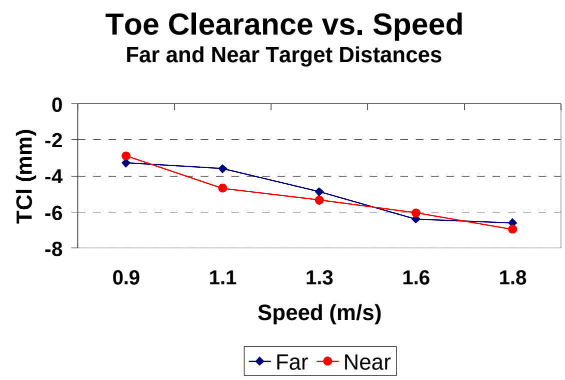

Figure 1: Vertical toe clearance (relative to standing) versus speed for two target distances.

SUMMARY

As speed increased, toe clearance decreased, and vertical toe peak in late swing increased. The vertical toe peak just after push-off was lower during near-target fixation, than far. Therefore speed and visual fixation distance should be considered when analyzing toe trajectory during treadmill walking. These results will be used to enhance the assessment of lower limb control following space flight.

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