Effects of handrail use on healthy treadmill walking

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INTRODUCTION

Upper extremity movements and forces have important implications for rehabilitation of pathological gait. Patients with impaired gait due to stroke often rely on an outside source (such as a cane or handrail) to assist them. When performing treadmill studies with stroke patients, a handrail is often used. Stephenson et al. found that when handrails were present, a small amount of weight was borne through the upper limbs in healthy and stroke subjects which affected the activity of the proximal leg muscles [1]. The amount of force used on the handrail varies between subjects and may influence loads on the lower extremity. Therefore, it is important to consider whether the weight applied to the handrail significantly alters the ground reaction forces.

The objective of this study was to evaluate the effect of handrail use on the kinetics during treadmill walking in healthy subjects. We will (1) compare magnitudes of handrail and ground reaction forces and (2) compare left and right handrail forces when only one handrail is used.

METHODS

Three healthy subjects between 18 to 40 years of age with no history of muscle, bone or nervous system disorders were recruited. Potential subjects were asked to complete a physical activity readiness questionnaire and sign an informed consent prior to participating in this study.

The subjects walked at a self-selected speed in the hallway for 10 meters to assess their comfortable speed. This speed was used during the treadmill trials. All trials were recorded in Cortex (version 1.0.0.198) by eight cameras (Motion Analysis Corp., Santa Rosa, CA) that capture motion of reflective markers attached to the body segments at 60 Hz. Two force plates (embedded in the treadmill) and two force transducers (embedded in the handrails) (Bertec Corp., Columbus, OH) captured the ground reaction forces and handrail forces, respectively, at 1080 Hz.

Table 1. Subject Information (mean ± st dev)

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<table>
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<tbody>
<tr>
<td>Age</td>
<td>23</td>
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<tr>
<td>Gender</td>
<td>2 F, 1 M</td>
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<tr>
<td>Height (m)</td>
<td>1.67 ± .06</td>
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<tr>
<td>Weight (kg)</td>
<td>59.87 ± 15.89</td>
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<tr>
<td>Walking Speed (m*s$^{-1}$)</td>
<td>1.37 ± .2</td>
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<tr>
<td>Hand Dominance</td>
<td>Right</td>
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The subjects were asked to walk under four conditions (no hands on handrail (NHR), both hands on the handrail (BHR), left hand only on the handrail (LHR), and right hand only on the handrail (RHR)). The order of these trials was randomized and each trial was recorded for 30 seconds.

A model was created in Visual 3D including feet, legs, torso, arms and hands with segments scaled to subject height and weight. The handrail data was imported into Visual 3D, converted from volts to newtons and normalized to body weight. A Butterworth lowpass filter with a cutoff frequency of 25 Hz was used on the force plate and handrail data. Gait events were identified and trials were averaged over gait cycles and normalized to 101 points. The maximum ground reaction and handrail forces in the vertical direction were extracted for each trial.
RESULTS AND DISCUSSION

Figure 1: Differences noted in the first peak but not the second peak of the right vertical GRF.

The first peak force ranged from 1.19 ± .06 BW (NHR) to 1.0 ± .07 BW (BHR). The LHR and RHR conditions had a peak ground reaction force of 1.14 ± .1 BW. At the second peak, all four conditions reached a force 1.19 BW (Figure 1). The four conditions had varying peak forces during the first 30 percent of the gait cycle (foot flat to the local minima) and then had approximately the same peak force before right toe off. The left ground reaction force followed in a similar pattern. This suggests that force was applied to the handrail for balance after heel strike and no longer needed once stabilized.

The handrail forces for the BHR condition were approximately twice as great as the handrail forces when only one of the handrails were held. This may be due to the subjects resting on the handrails. When the left handrail forces were plotted from LHS to LHS, they followed a similar trend to the right handrail forces. The right handrail was out of phase with the right ground reaction force, similar to arm swing.

The right arm exerted a higher peak force than the left arm under each comparable condition (Figure 2). The right BHR peak was .1 ± .12 BW while the left BHR peak was .08 ± .09 BW. Similarly the right RHR peak was .06 ± .04 BW and the left LHR peak was .04 ± .03 BW. It is important to note that all three subjects were right handed, which may suggest that hand dominance is a factor in the amount of force exerted on the handrails. To determine if hand dominance does play a role, more subjects with varying hand dominance will be collected.

Handrail forces ranged up to 10% of body weight and type of handrail usage affects the magnitude of the vertical GRF which will have implications for inverse dynamics calculations. It is likely that subjects with a pathological gait pattern who use handrails have altered joint loads which should be considered during rehabilitation and other treadmill studies.

REFERENCES