Swing Phase Adaptations Upon Stair Approach

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INTRODUCTION
Stair ascent and descent have been researched extensively in a variety of populations [1, 2]. Examining the transition from normal walking to stair ascent has not received as much attention yet it is important as the swing phase adaptations prior to ascent influence the trajectory of the entire body and this has been shown to be a key event with respect to fall risk [3]. It has been established in normal walking that the swing phase is completed with very little muscle activity [4]. The body uses intersegmental dynamics to achieve appropriate limb elevation for obstacle clearance hence minimizing energy costs [5]. Vision plays a very important role in guiding a limb over an obstacle where it allows for appropriate planning of joint trajectories to achieve the overall goal of overcoming an obstacle in one’s path [6]. By occluding vision and observing swing phase adaptations the role of vision of the lower visual field and the nature of transitioning from walking to stair ascent can be revealed. The purpose of this experiment was to measure kinematic and kinetic changes that occur in swing phase while walking up stairs normally, with the use of the handrail and with occluded vision. These three tasks were completed twice. On some occasions initial stair contact was made upon the first step, on other occasions initial stair contact was made upon the second step hence skipping over the first.

METHODS
18 participants were included in this study (9 males; 9 females) and asked to walk toward a staircase consisting of 5 stairs with a force plate embedded in the floor in front of the first step. All participants completed a total of six different tasks. The tasks included, normal stair walking, normal stair walking with forced handrail use and stair climbing with partially occluded vision. These three tasks were done while stepping onto the first step and were repeated with the second step being the initial target. Five trials for each of the six tasks were collected. Data were collected with an OPTOTRAK motion capture system (NDI, Waterloo, ON) and an AMTI (AMTI, Watertown, MA) force platform. 24 IRED markers were placed on the lower extremity to form a bilateral marker set. Motion data were sampled at 60 Hz while analogue data from the force platform were sampled at 1024 Hz. Raw marker trajectories were filtered by using a 4th order Butterworth filter with a low-pass cutoff of 7 Hz and were then interpolated to a maximum of 20 missing data points. Kinetic and kinematic data were imported into Visual 3D (C-Motion, Rockville, USA) where a link segment model was developed using an inverse dynamics approach to calculate joint reaction forces, joint moments and powers. Joint kinematics and kinetics for the swing phase were normalized to 40 data points. Discrete outcome measures obtained from analysis include toe velocity, hip velocity, and hip position all at heel contact. Toe clearance was also calculated at the point in time where the toe crossed over the corresponding step.

RESULTS AND DISCUSSION
Kinematic results indicated that joint angles changed between the first step task and second step task to accommodate for the greater distance and height travelled. When comparing normal stair climbing to handrail use, joint angles did not differ. Occluded vision caused greater ankle plantarflexion upon the second step condition.

Knee moment data showed a typical knee flexor action at the beginning of swing phase for all conditions with the second stair tasks having a prolonged flexor moment (Figure 1). The occluded vision task upon the second step had an earlier knee flexor moment during late swing paired with a lower peak compared to normal stair climbing onto the second step. The shaded grey area on Figure 1 depicts one standard deviation from the normal stair condition. It can be seen that variability increases in late swing as the limb prepares for stair contact.

Figure 1: Knee moment data for swing phase (60 – 100 % of stride). Single step tasks are denoted by thin black lines while second step tasks are denoted by thick black lines. Dashed lines represent the occluded vision task onto the first step (thin) and second step (thick). The shaded area represents one standard deviation of the mean normal first step condition.
Knee power showed prolonged concentric activity subsequent to the original flexor moment for the second stair tasks. Grading between the occluded, handrail and normal tasks can be seen and may be a function of joint angular velocity. Toe clearance was significantly larger for the second step tasks with respect to the corresponding stair (Figure 2). Toe clearance did not differ between normal stair climbing and handrail climbing tasks for the first step condition (Normal = 5.73 ±1.43 Handrail = 5.59 ±1.63) and second stair condition (Normal = 7.52 ±2.02 Handrail = 7.56 ± 2.05). Toe clearance during the occluded task was significantly greater than the normal stair climbing condition for both the first stepping condition (t(16) = -6.18, p < .05) and the second stepping condition (t(16) = -5.89, p < .05).

Figure 2: Toe clearance data presented for the six tasks. Data is relative to the corresponding stair. Significant differences between 1st stair task and 2nd stair task denoted by *. Significant differences between occluded vision and corresponding normal walking denoted by †.

Toe velocity upon heel contact was similar for all first step tasks and second step tasks at .5 m/s and .75 m/s respectively.

**CONCLUSIONS**

When approaching stairs, increased knee and hip flexion occur to meet the demands of the increased height of the support surface. Uncertainty of limb position leads to increased toe clearance and the second step condition requires a more forward position of the whole body centre of mass which both influence an increased safety margin. Occluded vision while stepping onto the second step showed the greatest swing phase alterations. Previous research on transitioning from level ground to ramp walking has shown increased hip and knee flexion along with increased toe clearance with larger ramp angles [7]. These findings are relevant as there is increased vertical demand within the task. Handrail use did not greatly alter swing phase adaptations when compared to normal stair ascent. This may be due to the young and healthy population included in the study. Transitioning from normal walking to stair ascent is completed on a daily basis. In pathological populations preparation for stair ascent may be a risk factor for falling and or tripping. Determining which joints adapt during swing phase will allow insight into what the specific risks may be and how they can be minimized.

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**REFERENCES**