Head and Trunk Kinematics During Stair Descent

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Introduction

Falls on stairs result in a significant number of accidental deaths each year, with falls during descent outnumbering those during ascent three to one [1]. It has been hypothesized that visual input is required during several phases of stair negotiation, and that interruption of this input can lead to an increased risk of falling [1]. The kinematics of the head have been used as surrogate measures of gaze location in other activities, but head kinematics during stair descent have not yet been studied.

Methods

Twelve subjects (4 young (Y), 4 elderly without glasses (E), and 4 elderly with bifocals (BF)) completed 3 stair descent trials on a 7-step staircase. Each trial started 2 m from the first stair edge with the subject looking straight ahead. The 3D kinematics of the head and trunk with respect to the global stair coordinate system were calculated using the MARey package [2]. The magnitude and location of maximum forward head pitch (MFP) angle, head pitch angle on the last stair, and average angular displacement of head and trunk pitch oscillation in the mid-stair region were calculated for each trial. Cross correlation analyses of head and trunk pitch angles in the mid-stair region were also performed.

![Figure 1: Seven step instrumented staircase at the Center for Locomotion Studies.](image)

Results & Discussion

In the majority of trials, the head rotated forward immediately on gait initiation, reaching maximum forward pitch at least ~250 ms before touchdown on the second step (Figure 1), then rotated backwards slowly (presumably during visual scanning of the stairs) until touchdown on the lower landing without (on average) returning to the original, neutral position (30 of 36 trials). A less frequent pattern included a period of quick head up pitch between stair 2 and stair 5, with a reversal to head down pitch from stair 5
to stair 7 (6 of 36 trials) (see Figure 2). The average MFP for all subjects was $-39.4^\circ \pm 7.8^\circ$. The BF subjects tended to have a greater MFP than the Y and E (BF = $-44.1^\circ$, E = $-37.8^\circ$, Y = $-35.9^\circ$), while both BF and E had a tendency to exhibit greater forward pitch on the bottom stair than the Y (BF = $-16.1^\circ$, E = $-13.1^\circ$, Y = $-6.0^\circ$). Cross correlation analyses of the 2-5° higher frequency oscillations of the head and trunk, revealed that this motion was primarily in phase, or that in some trials the head lagged slightly behind the trunk.

While the relationship between head movement and gaze location needs confirmation using eye-tracking technology, the patterns of head pitch described above suggest a feed forward process occurring at least one step prior to a transition from landing to stair, or stair to landing. The trials that included an extra reversal of head pitch where the subject presumably looked upward away from the stairs, demonstrate that visual input during mid-stair descent may not be mandatory for safe stair negotiation.

Figure 2: A comparison of head pitch vs. time for three women (1 young no glasses, one elderly no glasses, one elderly with bifocals) who had similar rates of descent. The dotted vertical lines indicate the approximate time of touchdown on each stair. The subject with bifocals reached a maximum pitch angle of the head almost three full gait steps before the first stair edge during descent, while the young and elderly no glasses subjects did not reach their peak angle until just before touchdown on step 2. The trial for the young subject demonstrates a period of quick head up pitch followed by head down pitch.
Figure 3: Head and trunk pitch for a single trial of one elderly subject who did not wear glasses. Notice the approximately in-phase higher frequency oscillations of the head and trunk in the mid stair region.

References:

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