The vestibular influence on balance control during stair negotiation vs. locomotion

Introduction

Stair negotiation accounts for 16% of fall related traumatic spinal cord injuries. The vestibular system plays a crucial role in maintaining balance during human locomotion through its influence over muscles in the lower limb, however, its role during stair negotiation is unknown. The aim of this study was to compare the vestibular contribution to a) stair negotiation versus locomotion and b) stair ascent to stair descent in healthy young participants. We hypothesized that, with cadence held constant, vestibular influence would increase during stair negotiation when compared to locomotion. We also expected the timing of muscle responses to change due to differences in gait patterns.

Methods

- 10 healthy college aged participants
- Stochastic electrical stimulation - random bandwidth limited (0-25 Hz, ±5mA)
- Stairs: 9-step staircase over 78 separate trials, at a cadence of 76 steps/min
- Treadmill: 312 steps at a cadence of 76 steps/min and a velocity of 0.4 m/s
- EMG: tibialis ant, soleus, med gastroc, vastus medialis, rectus femoris, semimembranosus, biceps fem, and glute med
- One-way repeated measures ANOVA with SPSS

Results

Observed significant differences in the coherence between the three conditions in muscles such as the soleus ($F_{2,18}=21.627$, $P=.000016$), medial gastroc ($F_{2,18}=6.538$, $P=.007$), and semimembranosus ($F_{2,18}=6.480$, $P=.008$). Vestibular modulation of the soleus was significantly lower during locomotion than stair ascent (.146 ± .080 vs. .259 ± .105, $p = 0.001$), and significantly greater during ascent than descent (.176 ± .076) with $p = 0.001$. Significant differences were also seen in modulation timing.

Conclusions

Our findings support the hypothesis that vestibular influence is more prevalent during stair negotiation than during level walking. These findings also suggest that stair ascent produces a greater challenge to balance than stair descent. This could be due to a range of biomechanical factors associated with stair negotiation. We also found the timing of maximum vestibular modulation varies in some muscles, across the three conditions, while gait pattern changes. This study has provided the first in depth look at how the vestibular system influences muscle activity during stair negotiation.