Variability measures of trunk and pelvis acceleration during walking and quiet stance are related in patients with multiple sclerosis and in healthy controls

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INTRODUCTION
Postural control is essential for any movement task, but postural control strategies during one task in a specific environment may not generalize to another task or situation [1]. Thus, it is difficult to identify common postural control mechanisms across tasks. Control of balance during walking and during quiet standing likely involve both overlapping and independent control systems since walking differs from standing in that the center of mass is constantly moving beyond the base of support [2]. A set of common measures which can be used in gait and in balance tasks to classify postural control across tasks would allow for a better understanding of how postural control is regulated according to task conditions. Thus, the purpose of this study was to apply the same set of variables to measure postural control during steady state walking and during quiet stance. We used body-worn inertial sensors, which could be used in a clinic setting, to identify acceleration measures that reflecting postural control. Both healthy controls and persons with multiple sclerosis (MS) were examined to identify whether the measures are robust enough to identify differences in postural control between controls and very mildly-affected MS subjects. It was hypothesized that variability of the acceleration patterns of the pelvis and the trunk would be related between walking and standing tasks and that there would be differences in variability of acceleration between groups.

METHODS
Six patients with MS (35.8 ± 8.1 yrs; 25 foot walk < 5 sec) and 6 healthy, age-matched controls (35.0 ± 7.9 yrs) performed a walking and a quiet standing task. The walking task consisted of walking up and down a 50-meter hallway at self-selected speed continuously for two minutes. Data was analyzed only for the first 30 seconds of steady-state walking. For the quiet standing task, participants stood quietly, with eyes open for 30 seconds. During both tasks, the subjects wore 6 MTX Xsens sensors (49A33G15, Xsens, Enschede, NL, USA) sampling at 50 Hz. The sensors contained 3D accelerometers (± 1.7 g) and 3D gyroscopes (± 300°/s range) mounted on: (i) sternum, (ii) sacrum (L5 level), (iii) right and left wrist, (iv) right and left lower leg (Figure 1). Only accelerometer data from the sternum and sacrum were analyzed here. For both tasks, the same variables were analyzed: range, standard deviation (SD), root mean square (RMS), Lyapunov exponent (LyE), and approximate entropy (ApEn). A 2x2 ANOVA was performed to compare Group (MS v. control) and Sensor location (sacrum v. sternum) effects. Correlations were performed to identify any relationship between variables across the two tasks.

RESULTS
There were significant correlations between walking and standing M/L acceleration range (p=0.001) and SD (p=0.036). No other variables were correlated between tasks.

A/P direction walking
Acceleration in the A/P direction showed a significant effect (p<0.001) of Sensor location on range, SD, and RMS in which the sacrum sensor values were higher than at the sternum. Also in the A/P direction, there was a significant Group x Sensor interaction for SD (p=0.017) and RMS (p=0.019) in which the sacrum values were lower in the MS group but there was no difference between groups at the sternum. LyE (p=0.000) and ApEn (p=0.001) in the A/P direction showed a significant effect of Sensor location in which values were higher at the sternum compared to the sacrum, with no Group by Sensor interaction.
**M/L direction walking**

Acceleration in the M/L directions showed a significant effect (p<0.01) of Sensor location on range, SD, and RMS in which the sacrum sensor values were higher than the sternum. There was also a significant effect of Sensor location on ApEn in the M/L direction (p=0.001) in which the ApEn value was higher at the sacrum compared to the sternum.

**Vertical direction walking**

Acceleration in the vertical direction also showed a significant effect of Sensor location for LyE (p=0.019) and ApEn (p=0.000) in which the LyE and ApEn values were higher at the sacrum than at the sternum in both groups. There was also a significant Group x Sensor interaction for LyE (p=0.006) and ApEn (p=0.026) in which the difference between sternum and sacrum values was smaller in the MS group.

**A/P direction standing**

There was a significant effect (p<0.01) of Sensor location on A/P range, SD, and RMS in which sacrum values were lower than sternum values. LyE of acceleration in the A/P direction showed a significant effect of Sensor location (p=0.037) and a Group x Sensor interaction (p=0.042) in which the LyE value was the same for both sensors in the control group but LyE at the sacrum was lower compared to the sternum in the MS group. There was a significant (p=0.030) effect of Sensor location on ApEn in the A/P direction where the ApEn value was lower at the sacrum compared to the sternum.

**M/L direction standing**

There was a significant effect (p<0.01) of Sensor location on M/L SD and RMS in which sacrum values were lower than sternum values. There was also a significant effect of Sensor location on LyE (p=0.017) and ApEn (p = 0.041) in the M/L direction in which LyE and ApEn values were higher at the sacrum than the sternum in both group.

**Vertical direction standing**

There was a significant effect (p = 0.027) of Sensor on ApEn in the vertical direction where the ApEn value at the sacrum was higher than the sternum.

**DISCUSSION & CONCLUSIONS**

Lack of differences in variability of trunk accelerations during walking and standing between groups may be due to the very mild gait and balance problems in the MS group. However, the Group x Sensor interaction in the A/P direction during walking for SD and RMS and the interaction in the A/P direction during standing for LyE suggest a difference in trunk control between MS and control subjects.

The Sensor location effects are likely due to the attenuation of accelerations from the pelvis to more proximal segments during gait and stance [3]. This is specifically illustrated by the decrease in the range, SD, and RMS value of the A/P and M/L acceleration components while the vertical acceleration displays negligible variations. Also, differences in LyE and ApEn between the sacrum and sternum during walking and standing could be due to this distal to proximal attenuation of the acceleration signal.

The significant correlations between walking and quiet standing for both acceleration range and SD in the ML direction is consistent with common neural control of M/L body center of mass stability across tasks [4]. Excessive M/L trunk motion during walking has been associated with falls [5]. Larger trunk acceleration range during walking and standing, which can be easily measured with a single accelerometer instead of a complex kinematic laboratory, may be valuable for identifying subjects in a clinical environment who are at risk for falls such as persons with neurological disorders or elderly individuals.

**REFERENCES**


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