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Title
USING BODY WORN SENSORS TO ASSESS POSTURAL CONTROL OF LOWER LIMB AMPUTEES DURING THE MODIFIED TEST OF SENSORY INTERACTION AND BALANCE

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Summary
The use of body worn sensors during balance testing designed to evaluate postural control in four distinct sensory conditions that manipulate the accuracy of visual and somatosensory input can provide information to help guide rehabilitation to improve postural control with lower limb amputees.

Introduction
Postural control has been defined as the act of maintaining, achieving, or restoring a state of balance during any posture or activity. Postural control relies on a complex interaction of sensory information from visual, somatosensory and vestibular systems. The modified test of sensory interaction and balance (mCTSIB) allows clinicians to evaluate postural control during four distinct sensory conditions that manipulate the accuracy of visual and somatosensory input. To remain upright the human body makes constant corrections by oscillating forward, backward, and/or side to side over the fixed base of support. These oscillatory movements, known as postural sway, can be quantified by body worn sensors, such as inertial measurement units (IMUs). The IMU sensors provide raw data (linear acceleration and angular velocity) that is processed to provide meaningful parameters.

Methods
The aim of this study is to describe postural control of lower limb amputees (LLA) during the mCTSIB using IMU-derived measures. A convenience sample of 71 unilateral LLA (TTA n=38, TFA n=33; female n=36, male n=35; mean age 47.5 ± 14) were recruited. Subjects were included if they were 18-80 yoa, more than 12 months post-amputation surgery, and a current prosthetic user with > 3 months in current prosthesis. Subjects wore an IMU sensor attached

at the sacrum. Subjects were asked to balance for 30 seconds in each of the four mCTSIB conditions: 1) on the floor with eyes open, 2) floor, eyes closed, 3) foam, eyes open, and 4) foam, eyes closed. Movement strategies were observed and categorized as: single segment (ankle) or double segment (hip). Parameters of postural control were derived from the IMU data which include: maximal excursion (AP and ML), and sway area. Comparisons the IMU-parameters between subjects using a single segment (ankle) strategy to a double segment (hip) strategy.

Results

Movement strategies and IMU-derived spatial parameters varied across mCTSIB conditions (Table 1). While sway area progressively increased from condition 1-4, the AP and ML increases were dependant on standing surface. When standing on the floor the vast majority LLA relied on a single-segment (ankle) strategy, and demonstrated greater AP excursion to control balance when visual input was inaccurate (eyes closed). However, when standing on foam, LLA relied on a double-segment (hip) strategy and greater ML excursion.

Conclusion

The IMU-derived measures included in this study were able to quantify the magnitude and direction of postural sway movements utilized by LLA to maintain postural control during the mCTSIB. These spatial parameters were able to describe how LLA responded to increasing postural control challenges. The results are similar to research in non-amputee populations, suggesting the mCTSIB is an appropriate tool for assessing postural control in LLA. The utilization of body worn sensors during the mCTSIB can provide information to help guide rehabilitation approaches to improve postural control in different surfaces and environments in LLA. Future work should focus on determining which IMU-derived parameters and sensor locations could be utilized to identify movement strategies utilized by LLA for postural control.

References

1. Pollock; 2000 Clin Rehabil

2. Shumway-Cook; 1986 Phys Ther

Image: Table 1 mCTSIB_2152.png

	mCTSIB Condition			
	1.Floor, EO	2.Floor, EC	3.Foam, EO	4.Foam, EC
Sway Spatial Parameter				
AP (cm)	1.2 ± 0.6	1.7 ± 0.8	1.3 ± 0.5	1.9 ± 1.0
ML (cm)	0.9 ± 0.4	1.0 ± 0.6	1.7 ± 1.0	2.4 ± 1.7
Area (cm^2)	0.8 ± 0.8	1.2 ± 1.1	1.6 ± 1.5	3.6 ± 6.1
Observed Strategy				
Single Segment n (%)	65 (92%)	55 (78%)	9 (13%)	3 (4%)
Double Segment n (%)	3 (4%)	13 (18%)	58 (82%)	47 (66%)
Other n (%)	3 (4%)	3 (4%)	4 (5%)	21 (30%)

Table 1. Mean values for IMU-derived measures of sway spatial parameters and frequencies of observed strategies during mCTSIB.