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Comparison of Ankle Strategies for Balance in Persons After Mild Head Injury

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Background:

Balance deficits are common in persons after mild head injury (MHI) however standard clinical tests are sometimes not sensitive enough to assess changes in balance skills. This limitation becomes especially evident when testing younger adults such as highly trained athletes. Recent evidence suggests that there are more sensitive clinical assessments which may provide a better representation of balance skills using models of specific joint torques during challenges to postural control.[1,2]

Purpose:

The purpose of the project was to characterize and compare standing balance strategies in persons with MHI using ankle torques or stiffness during sensorimotor challenges to the postural control system.

Subjects:

Using an observational cohort study design, twenty-seven healthy, active males (n= 10) and female participants (n= 17) aged 28.72 ± 8.24 years of age participated in this study after providing written consent according to university guidelines. Participants were grouped as being without (Group A, n = 14) or with (Group B, n = 13) a history of MHI over the past 12 months according to stated medical history. MHI was defined as a GCS grade of 13 – 15 with or without a loss of consciousness. Exclusion criteria included musculoskeletal impairments affecting standing balance.

Methods:

Computerized protocols of the NeuroCom EquiTest® system (NeuroCom International, Inc) were used to assess static and dynamic standing balance as influenced by alterations in sensory feedback while standing on a fixed or sway-referenced force platform. The standardized clinical assessment includes six sensory conditions called the Sensory Organization Test (SOT). (Figures 1 & 2) A summary composite score documented the amount of sway during testing all conditions. (Equation 1, Figure 3) In addition, a method proposed by Zhiming et al. (2004) called the "Postural Stability Index" (PSI) was used to process force plate data to document balance using ankle torque ratios or stiffness during each sensory condition. The composite PSI score was calculated using Equation 2. (Figure 4)

MHI0014 with MHI

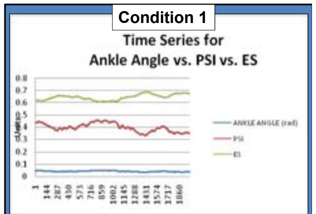
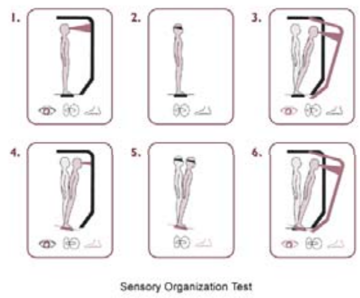


Figure 1a: Quiet standing for 20 seconds during Condition 1. (sampling freq 100Hz). Notice high ES values with low PSI to maintain balance. Ankle angle = radians, Postural Stability Index (PSI) = meters, Equilibrium Score (ES) = %



Standardized clinical assessment of balance during six sensory conditions with altered visual or surface feedback. Computerized visual surround or force platform are sway –referenced.

MHI0017 without MHI

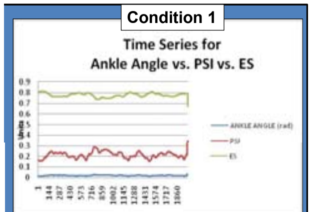


Figure 2a: Quiet standing for 20 seconds during Condition 1. (sampling freq 100Hz). Notice high ES values with low PSI to maintain balance. Ankle angle = radians, Postural Stability Index (PSI) = meters, Equilibrium Score (ES) = %

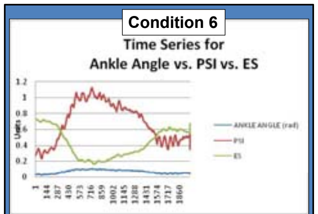


Figure 1b: Standing balance over 20 seconds during Condition 6. (sampling freq 100Hz). Notice the prolonged period of large ankle torques necessary for data points 400 – 1400. Ankle angle = radians, Postural Stability Index (PSI) = meters, Equilibrium Score (ES) = %

Subject Standing on Dual Force Platform

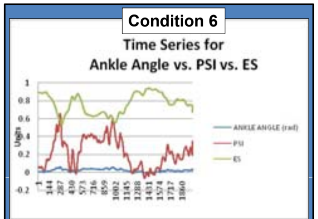


Figure 2b. Standing balance over 20 seconds during Condition 6. (sampling freq 100Hz). Notice brief periods of increased ankle torque for postural correction. Ankle angle = radians, Postural Stability Index (PSI) = meters, Equilibrium Score (ES) = %

Balance = Postural Sway

Equation 1: Equilibrium Score

$$ES = 100 \times \{(12.5 - (Ant\ \theta_{max} - Pos\ \theta_{max}))/ 12.5\}$$

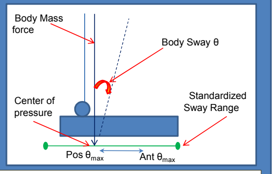
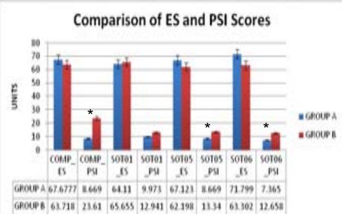


Figure 3
Ant θ_{max}= maximum anterior sway angle within 12.5°
Pos θ_{max}= maximum posterior sway angle within 12.5°

Graph 1



	COMP_ES	COMP_PSI	SOT01_ES	SOT01_PSI	SOT05_ES	SOT05_PSI	SOT06_ES	SOT06_PSI
GROUP A	67.6777	8.669	64.11	9.973	67.123	8.669	71.799	7.365
GROUP B	63.718	23.61	65.655	12.941	62.198	13.34	63.302	12.658

*Significant at $p \leq 0.05$ level.

Balance = Ankle Stiffness

Equation 2: Postural Stability Index

$$PSI = 100 \times (\sum |Mgh\ \theta| / \sum |\tau|)$$

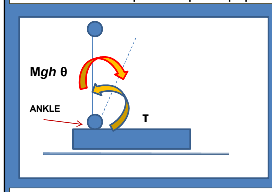


Figure 4
M*gh* θ = Destabilizing torque, **τ = stabilizing torque**
M = mass above the ankles, g = gravity (9.8 m/s^2)
h= height of COM above ankle(.55 total height)
θ = ankle joint angle

Data Analysis:

Data analysis for group mean scores (Groups A vs. B) included standardized Student's T-Test statistics (SPSS v.16). In addition, a Pearson's Correlation Coefficient was calculated to identify significant relationships within the data pool. Alpha level = 0.05

Results:

Preliminary findings indicate that there were no significant group differences in standard calculated EquiTest® SOT scores (calculated from postural sway). However, there were significant group differences for PSI scores (calculated from ankle torques or stiffness) during sensory test conditions which challenged visual and vestibular feedback systems. (Graph 1) Composite ES = 67.677±10.48 vs. 63.68 ± 8.382 while Composite PSI = 8.97 ± 3.875 vs. 23.61 ± 6.097. This was especially evident during sensory conditions 5 (no vision with sway-reference surface) and 6 (sway-reference visual surround and surface) Condition 5, ES = 64.10 ±10.71 vs. 65.65 ± 8.80 while PSI = 9.97 ± 4.25 vs. 12.36 ± 5.14. During condition 6, ES = 71.80 ± 12.96 vs. 63.30 ± 12.93 while PSI = 7.37 ± 4.56 vs. 12.653 ± 4.18.

There was also a significant inverse relationship between PSI and ES values ($r_{(27)}$ = - 0.814) suggesting that increased ankle stiffness (PSI scores) were highly correlated to decreased balance scores (ES). See Figures 1 & 2

Conclusions:

There were significant group differences for PSI scores compared to traditional calculations of balance using postural sway for persons with and without MHI. In addition, there was a significant inverse relationship between higher ankle torque values and decreased postural control during challenging sensory conditions.

Clinical Relevance:

Preliminary results indicate that assessment of ankle strategies used during challenging sensory conditions may be a more sensitive indicator of balance skills in patients after MHI especially in active, younger populations. Incorporating the assessment of ankle strategies for balance is proposed as a more targeted approach to balance rehabilitation for persons during recovery from MHI.

References:

1. Zhiming et al. Computational method to evaluate ankle postural stiffness using ground reaction forces. JRRD. 2004; 41:207 - 214.
2. Chaudry et al *Postural Stability Index more reliable than Equilibrium Score, JRRD*. 2005;42:547 - 556.
3. Chaudry et al *Measures of Postural Stability, JRRD*. 2004;41:713 – 720..