A new method of interpreting the centre of gravity location using the modified Clinical Test of Sensory Interaction on Balance: A reliability study

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Abstract This study tests the inter- and intra-rater reliability of a new method of interpreting centre of gravity (COG) location results of the modified Clinical Test of Sensory Interaction on Balance (mCTSIB) tested on the NeuroCOM Balance Master™ (BM). Sixty-three women (40–80 years) were randomly selected from a cohort of 500 women from the Longitudinal Assessment of Women (LAW) study. Start location of COG, as provided diagrammatically in the BM test results, for each of the four tests (firm surface, eyes open and closed; foam surface, eyes open and closed) was subjectively allocated by two raters (blinded to one another) to one of nine location categories on two occasions separated by at least 2 weeks. Kappa (κ) analysis of the data showed a substantial level of both inter-rater [κ = 0.84 (95% CI = 0.82–0.86)] and intra-rater [rater 1 κ = 0.78 (95% CI = 0.74–0.79), rater 2 κ = 0.88 (95% CI = 0.86–0.90)] reliability. The strong inter- and intra-rater reliability of this new interpretation of COG location in the mCTSIB test on the BM suggests that this may be an additional reliable method for clinicians to interpret results from steady state balance tests on the BM.

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Introduction
Preservation of standing balance depends on the ability of an individual to control movement of the body’s centre of mass (COM) within the base of support (BOS) [1]. There are several factors that influence the COM movement. These include the location or position of the centre of gravity (COG) (the vertical projection of the COM) within the BOS, the velocity of
The aim of this study is to examine the inter- and intrarater reliability of a new method to monitor the location of the COG which has been developed by the authors. It is based on an analysis of the results produced by the NeuroCom Balance Master 6.0 (BM) (Clackamas, Oregon, USA) for the modified Clinical Test of Sensory Interaction on Balance (mCTSIB) test battery. The BM software provides an average composite location of COG across all tests for the mCTSIB. In addition, the location of the COG is recorded diagrammatically at the commencement of each trial (Fig. 1). An average composite COG location is not useful clinically because it does not provide specific information for each of the surface and visual conditions. A reliable method of categorising the COG location under the different test conditions of vision and surface conditions is necessary so that comparisons can be made for different age groups and different pathologies to inform focused treatments for balance deficits. An analysis of the separate diagrammatic COG recordings from the BM for each of the mCTSIB tests forms the basis for this original method of interpretation of COG location under different test conditions.

Methods

Participants

Balance Master results printouts from 63 participants were selected from a larger sample of 500 independent, community-dwelling women (age range: 40–80 years) who participated in the Longitudinal Assessment of Women (LAW) study [4]. Paper copies of results from participants were stored in seven, four-drawer filing cabinets. The first drawer in each cabinet housed data from the age group of 40–49 years, while the second, third, and fourth drawers held data for the age groups of 50, 60, and 70 years, respectively. Modified systematic sampling was used such that every second file from a single drawer in each of the seven four-drawer filing cabinets was selected: (1) drawer 1 in cabinet 1, (2) drawer 2 in cabinet 2, (3) drawer 3 in cabinet 3, and so on, returning to drawer 1 for cabinet 5. This method enabled an unbiased sample to be extracted and ensured that all age groups were represented in the sample (19 in their 40 s, 19 in their 50 s, 12 in their 60 s, and 13 in their 70 s). Ethical approval for the LAW study was obtained from the ethics committees of the Royal Brisbane and Women’s Hospital and The University of Queensland. All participants provided written consent prior to the start of the study [4].

Measurements

The mCTSIB carried out on the BM consists of four test conditions to explore balance on different surface types with and without vision: (1) firm surface, eyes open (FiEO), (2) firm surface, eyes closed (FiEC), (3) foam surface, eyes open (FoEO), and (4) foam surface, eyes closed (FoEC). It is an abridged version of the Clinical Test of Sensory Interaction on Balance [5], which allows clinicians to bias the three sensory (somatosensory, visual, and vestibular) inputs involved in postural stability during a steady state balance assessment. The summary results provided by the BM software package gave three measurements of COG: (1) the sway velocity (degrees/s) mean for each test condition as well as an average of the mean sway velocity across all four tests (twelve trials in total), (2) the composite Limits of Stability across all four test conditions, and (3) the COG alignment, also calculated as a composite score across all four test conditions, which reflects an average of the subject’s start positions relative to the centre of the BOS. A diagram (Fig. 1) is also presented using symbols (o = FiEO, E = FiEC, * = FoEO, X = FoEC) to represent the location of the COG at the start of each trial. This reliability study was based on an interpretation of the location of the test symbols (described in the Categorisation section) for each 10-second trial as depicted in the diagram.

Procedures

The test protocol for the mCTSIB on the BM required that the subject stood on the force plate with their two feet apart. The stance width was determined by the BM software
based on the height of the subject. The three possible widths [small (S), medium (M), and tall (T)] were marked on the force plate for the FiEO and FiEC tests. For the FoEO and FoEC tests, they were marked on the square of foam. Three trials of each of the four conditions of the mCTSIB (FiEO/C2, FiEC/C2, FoEO/C2, and FoEC/C2) were conducted. Each trial lasted 10 seconds [6]. This procedure was repeated on three occasions over the 5-year time phase of the study. There was a minimum of 1 year between assessments. Altogether four tests on three occasions gave a total of 12 test conditions, which were rated for each participant. A total of 756 test condition results for the sample were obtained from the 63 participants’ files and were used in the reliability testing. Two raters scored the 756 test condition results on two separate occasions in order to calculate intra-rater as well as inter-rater reliability. There were at least 2 weeks separating the first and second rating allocation, and the raters were blinded to one another.

Categorisation

A new method of analysing the output generated by the BM software was developed for the purposes of this study. No previous studies that have used this method of analysing the BM software data were found. The BM software displays COG locations for the three trials of each test via the symbols o, +, *, and X (Fig. 1). This display was used to determine the location of the COG for each condition and formed the basis for category allocation. Nine sectors were identified, and these are shown in Fig. 2. In order to be allocated to a particular sector at least two of the three symbols must occur in the same sector (Fig. 1). In some cases, the symbols could have been allocated to more than one sector and hence the sector numbers indicate the order of prioritisation. In other words, quadrants take precedence over hemispheres and forward/backward hemispheres take precedence over left/right hemispheres. For example, "X" in Fig. 1 could be allocated to Sector 2 (right/forward quadrant) or to Sectors 5 or 8 (forward or right hemisphere respectively) but since quadrants take precedence over hemispheres, the allocation is made to Sector 2. Where two symbols fall in different sectors (e.g., "+" in Fig. 1) and the third is not visible, no allocation is made. Allocation to Sector 9 occurs only when the symbols fall directly in the centre and cannot be allocated to any other sector. The terms "forward/backward" are...
used instead of "anterior/posterior" to conform with the terminology used in the BM output.

Statistical analysis

A reliability analysis using the unweighted kappa statistic was performed to determine the degree of consistency for both intra- and inter-rater reliability. Kappa was chosen for its ability to take into account agreement by chance and its applicability to the nominal, categorical data for just two raters. Scores for kappa range between 0 (consistent with agreement by chance) and 1 (perfect agreement). A kappa value of 0.61–0.80 represents substantial reliability, while a value range of 0.81–0.99 represents almost perfect agreement [7]. A 95% confidence interval (CI) was also calculated for each kappa statistic to give further information regarding the strength of the reliability analysis. Inter- and intra-rater reliability was assessed for each test condition as well as for the reliability across the four test conditions. Statistical analysis was performed using Stata version 11.0 (StataCorp LP, College Station, TX, USA).

Results

The results of the kappa analyses with a 95% CI are presented in Table 1. An overall inter-rater reliability of 0.84 (95% CI = 0.82–0.86) would be described as the almost perfect agreement. The intra-rater reliability for Rater 1 was substantial at 0.78 (95% CI = 0.74–0.79) and for Rater 2 was almost perfect agreement at 0.88 (95% CI = 0.86–0.90) [7]. Analysis of each individual test showed that inter-rater agreement ranged from substantial to almost perfect agreement and intra-rater agreement was substantial for Rater 1 and almost perfect for Rater 2. In addition to the strong kappa values, the CI range was small, emphasising the precision of the reliability coefficients.

Discussion

The usefulness of any outcome measure in the clinical assessment of patients relies on the capacity of the measure to be consistently applied by different clinicians. This study has assessed the reliability of a new method of monitoring the COG start location adapted from data produced in the mCTSIB test conditions on the BM. We have demonstrated levels of agreement ranging from substantial (κ = 0.61–0.80) to perfect (κ = 0.81–0.99) for both inter- and intra-rater reliability. The results from two raters for this method of categorisation are in good agreement. This is the first time, to the best of our knowledge, that the start location of COG has been assessed in a defined, categorical way for each of the four test conditions of the mCTSIB on the BM.

The objective of devising this novel method of categorising the COG location was, principally, to provide clinicians with a simple way to assess the COG location in the clinical setting. The mean COG position is a summary measure that is reported less often in research papers. In a study to assess sampling duration effects on the reliability of summary measures in a group of young adults, Carpenter et al [8] found that the mean COG position for the antero-posterior and medio-lateral planes showed high reliability. Participants in this study were assessed standing on a firm surface with their eyes open. However, a measure of the mean COG position across a number of tests to assess balance under different surface and vision conditions, as provided by the BM results, does not help clinicians to differentiate between the responses for each test.

Further research is needed in order to show whether or not the COG location changes with ageing under different surface or visual conditions in healthy adults. Studies that identify the COG location within the BOS mostly test individuals on a firm surface only when standing with their feet apart [8,9]. Low Choy et al [10], who reported on the same data set used in the current study, found no changes to stability across ages when individuals stood with their feet apart on a firm surface with eyes open using sway velocity data. However, they were able to demonstrate changes for stance stability on a compliant surface as well as for stance with eyes closed. Merlo et al [3] found that the COG location in firm surface tests also showed no difference between groups of fallers and non-fallers. However, they found an association between COG location on a compliant surface with eyes open and the incidence of falls in older adults. These research findings support the need for a clinically reliable measure of COG location in tests that manipulate sensory inputs to be available to clinicians.

There is increasing information available on the behaviour of COG location in the presence of pathology. For example, teenage girls with scoliosis had a more posterior location of COG than controls when standing on a firm surface with their eyes open [11]. This was also the case for participants with chronic low back pain [12], although in this study the same posterior location of COG was also noted when these subjects were standing on foam with their eyes open. As knowledge of differences in COG location increases for participants with different pathologies, there is a need for normative data against which to make comparisons. It would be useful for clinicians to be able to monitor COG location in the treatment setting and to be able to compare the results in the presence of pathology against the results for healthy adults. It may also be possible in the future for the location of COG to be used to evaluate treatment effectiveness.

In this preliminary reliability study, we have investigated a new method by which the Centre of Gravity location can be monitored using the mCTSIB. Further work, including the use of more raters, is needed in order to assess the use of this categorising method as a valid measure of the location of COG in different patient groups. It should be noted that since, in this study, the COG location was measured only at the commencement of each test trial, the method does not purport to offer a true average of the COG location over the complete trial. In spite of these recognised limitations, it is hoped that these results will help to further research in this important field.
Conclusion

The location of the COG in stance warrants further investigation. This study has established the reliability for a novel method of categorising the location of COG, developed by the authors, under a range of test conditions using existing data from the mCTSIB on the BM. Its use will facilitate further exploration by clinicians of COG-within-BOS characteristics across different test conditions for different age groups and in the presence of pathologies.

References


