Three-Month Test-Retest Reliability of Center of Pressure Motion During Standing Balance in Individuals with Multiple Sclerosis

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Background: *Balance impairment and an increased rate of falls are commonly reported in individuals with multiple sclerosis (MS). Force platform–generated center of pressure (COP) metrics have previously been recommended as an outcome measure to quantify balance deficits and distinguish between fallers and nonfallers in MS. Information is limited regarding the preservation of postural control in individuals with MS over extended time frames in the absence of an intervention. This report examines the test-retest reliability and magnitude of change of COP motion during standing balance over 3 months.*

Methods: *Twenty individuals with MS and a history of falling underwent testing on two occasions 3 months apart in the absence of an intervention. On both occasions, participants completed two 30-second trials of three conditions: eyes open, eyes closed, and eyes open with concurrent cognitive challenge (dual task). Measures of COP area, velocity, and temporal structure were calculated and included in the reliability analysis.*

Results: *The COP metrics displayed fair-to-excellent reliability over 3 months without an intervention. Reliability was maintained across the three commonly used balance conditions.*

Conclusions: *These results offer insight into the reliability of COP measures over a 3-month period in MS and can inform the use of COP metrics for future study design (eg, sample size estimates) and balance outcome assessment during randomized controlled trials and fall-prevention studies in individuals with MS.*
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Multiple sclerosis (MS) frequently results in balance impairment and increased risk of falls.[1,2] One common research technique for quantifying balance impairment and fall risk is the use of force platforms.[3] Such devices quantify center of pressure (COP) movement during standing tasks.[4] The metrics of COP, such as sway area, sway velocity, and sway range, distinguish fallers from nonfallers in MS.[5,6] Measures that quantify the time-dependent structure of posture sway (eg, approximate entropy) provide novel information concerning postural control in people with MS.[7]

There are minimal data on test-retest reliability and observed changes of postural control based on COP measures over extended durations (eg, 3 months) in MS. To date, one study has investigated COP movement reliability over a single day in MS.[5] Such estimates of reliability would not be suitable for informing the design of randomized controlled trials (RCTs) or postural control research observations that take measurements over longer time frames.

This study estimated the reliability and preservation of postural control using COP measures for three commonly used testing conditions (eyes open, eyes closed, and dual task) across a 3-month period without an intervention in individuals with MS who had a history of falling. Three months represents a commonly accepted

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interval for measuring fall-related outcomes in MS.[8] Reliability measures and quantification of changes to these COP values for this duration can inform the use of COP measures as an outcome in future RCTs and fall-prevention studies with intraclass correlation coefficients (ICCs) benefiting power analyses and difference measures quantifying the naturally occurring changes to postural control over time in the absence of an intervention.

Methods

Participants

This study included 20 individuals with MS enrolled in the observational period of a fall-prevention study.[9] The inclusion criteria for the study were a neurologist-confirmed diagnosis of MS, being relapse free for the 30 days before testing, age of 50 to 75 years, the ability to walk with or without an assistive device for at least 6 minutes continuously, and a self-reported fall in the previous 12 months.

Procedures

All the procedures were approved by the University of Illinois at Urbana-Champaign institutional review board. On arrival, participants received verbal and written explanations of the study, were permitted to ask questions, and then provided written informed consent. Participants completed demographic questionnaires and underwent a static balance assessment on a force platform. They repeated the static balance assessments after a 3-month observational period without an intervention. Participants received $20 per visit.

Outcomes

Demographic information included age, sex, MS subtype, years since MS diagnosis, and self-reported Expanded Disability Status Scale score.[10] Six 30-second trials were completed during the balance assessment. Participants were asked to stand on a force platform (Bertec model FP4060-05-PT-1000, Bertec Inc, Columbus, OH) with feet shoulder width apart and arms at their sides for two trials each of three conditions: 1) eyes open, 2) eyes closed, and 3) eyes open with concurrent cognitive challenge (dual task). Participants did not use assistive devices or braces during the trials. During dual-task conditions, participants simultaneously completed a word-list generation task listing animals (eg, dog, lemur) during the first trial and words beginning with "H" (eg, help, hyperbola) during the second trial. Word-list generation has previously been used as a cognitive challenge in individuals with MS during standing balance assessments.[11]

The COP data from each trial were exported and processed using a custom MATLAB script (The MathWorks Inc, Natick, MA). Parameters included in the reliability analysis were total sway area (SA), 95% confidence ellipse (CE), and the mean velocities in the anteroposterior (MVAP) and mediolateral (MVML) directions. In addition, the nonlinear measure of approximate entropy (ApEn) of the COP motion in the anteroposterior and mediolateral directions was examined. The ApEn quantifies the time-dependent structure of a signal and was calculated based on established procedures.[12] These particular COP parameters were selected because they have previously distinguished between fallers and nonfallers in MS[5,13] and distinguished slight changes in COP motion between testing conditions.[7,12] For an individual participant, computed values of COP measures were averaged within each condition.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 22 (IBM Corp, Armonk, NY). Paired-samples *t* tests were used to determine whether COP values were different over time. The ICCs (2,1 mixed model)[14] and 95% confidence intervals were computed to examine the test-retest reliability of the COP parameters. The significance level for all the tests was set at $P \leq .05$.

Results

The sample consisted of 18 women and 2 men. The mean (SD) age of the participants was 61.1 (6.0) years, and the mean (SD) time since MS diagnosis was 15.7 (9.2) years. The median self-reported Expanded Disability Status Scale score was 5.0 (interquartile range = 2.5). Sixteen participants reported having relapsing-remitting MS, one had secondary progressive MS, and three had primary progressive MS.

Descriptive statistics for the COP measures are presented in Table 1. Paired *t* tests showed a decrease in MVAP and SA during the dual-task condition over time. In addition, an increase in MVML was observed in the eyes-closed condition over time. There were no other significant changes over time.

The ICCs and 95% confidence intervals for all the COP metrics across the three testing conditions are given in Table 2. All the measures displayed fair (ICCs of 0.4–0.59) to excellent (ICCs >0.75) test-retest reli-

Table 1. Descriptive statistics of the COP measures

Variable	Eyes open		Eyes closed		Dual task	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
MVAP, mm/s	15.8 (8.8)	15.0 (8.0)	25.5 (15.2)	26.1 (17.3)	19.3 (9.9)	17.1 (8.5)[a]
MVML, mm/s	9.1 (6.4)	10.0 (7.3)	13.9 (9.9)	15.6 (12.0)[a]	11.3 (7.1)	10.8 (6.4)
SA, mm^2	1836 (2258)	1496 (1718)	3294 (4034)	3223 (3119)	2158 (1921)	1755 (1668)[a]
CE, mm^2	938 (1126)	751 (801)	1234 (1731)	1217 (979)	877 (652)	836 (742)
ApEn AP	0.68 (0.16)	0.72 (0.19)	0.83 (0.21)	0.84 (0.21)	0.74 (0.16)	0.73 (0.22)
ApEn ML	0.64 (0.16)	0.69 (0.15)	0.71 (0.19)	0.71 (0.17)	0.67 (0.16)	0.69 (0.23)

Abbreviations: ApEn AP, approximate entropy anteroposterior; ApEn ML, approximate entropy mediolateral; CE, 95% confidence ellipse; COP, center of pressure; MVAP, mean velocity anteroposterior; MVML, mean velocity mediolateral; SA, sway area.
Note: Values are given as mean (SD).
[a]Significantly different ($P \leq .05$) from time 1.

ability based on established interpretation guidelines.[14] The largest ICCs for standard COP parameters were observed during eyes-open trials for MVAP (ICC = 0.93), eyes-closed trials for MVML (ICC = 0.95), and dual-task trials for SA (ICC = 0.93) and CE (ICC = 0.84). The smallest ICC was observed in CE during eyes-closed trials (ICC = 0.62). The ApEn anteroposterior and mediolateral ICCs were largest during the eyes-closed condition (ICCs = 0.83 and 0.79, respectively) and smallest during eyes-open trials (ICCs = 0.74 and 0.59, respectively).

Discussion

The present analysis provides estimates of the test-retest reliability of postural control based on COP in individuals with MS who had a history of falls. Overall, the examined COP parameters exhibited fair-to-excellent reliability across all task conditions over the 3-month period in the absence of an intervention. Whereas previous research assessed the reliability of balance based on COP metrics over short time frames (30 minutes) in MS,[5] the present analysis is the first to provide estimates over a recommended duration for outcomes in studies of falls in MS and include nonlinear measures (ie, ApEn).[8]

Table 2. Intraclass correlation coefficients and 95% confidence intervals for COP measures

Variable	Eyes open	Eyes closed	Dual task
MVAP	0.93 (0.83-0.97)	0.85 (0.66-0.94)	0.89 (0.75-0.96)
MVML	0.89 (0.74-0.95)	0.95 (0.88-0.98)	0.94 (0.86-0.98)
SA	0.88 (0.73-0.95)	0.74 (0.45-0.89)	0.93 (0.84-0.97)
CE	0.74 (0.46-0.89)	0.62 (0.26-0.83)	0.84 (0.65-0.94)
ApEn AP	0.74 (0.45-0.89)	0.83 (0.62-0.93)	0.83 (0.63-0.93)
ApEn ML	0.59 (0.21-0.81)	0.79 (0.55-0.91)	0.60 (0.23-0.82)

Abbreviations: ApEn AP, approximate entropy anteroposterior; ApEn ML, approximate entropy mediolateral; CE, 95% confidence ellipse; COP, center of pressure; MVAP, mean velocity anteroposterior; MVML, mean velocity mediolateral; SA, sway area.

The results of this study provide useful data for the inclusion of COP metrics in future fall-prevention trials and RCTs. Reliability estimates can be implemented in power estimations for such trials, permitting accurate sample size estimations.[15] For example, using a default ICC of 0.5 in the power analysis for an RCT based on a small effect size ($F = 0.1$) and an assumed power of 0.8 would provide a sample size estimate of 200 individuals. However, if the experimentally determined ICC of approximately 0.90 for COP velocity parameters averaged across the three balance conditions was used, the estimated sample would be reduced to 42 participants. This is important because the smaller sample size would optimize both monetary and time costs for completing research.

Previously, test-retest reliability of balance based on COP metrics in MS and other populations has primarily been observed between same-day testing sessions.[5,16]

PracticePoints

- The examined center of pressure parameters displayed fair-to-excellent test-retest reliability over 3 months.
- Intraclass correlation coefficients can be used to inform the design and outcome measure selection of future randomized controlled trials or fall-prevention programs.

Similar to the present results, good-to-excellent reliability was noted in COP parameters (MVAP, MVML, and SA) during eyes-open and eyes-closed trials. Note that the previous examination computed reliability estimates based on concordant correlation coefficients, whereas the current investigation used ICCs.

There was a reduction in MVAP and SA during dual-task trials and in MVML during eyes-closed trials over the 3-month period. Despite these changes, reliability in those parameters remained excellent (ICCs = 0.89, 0.93, and 0.95, respectively), suggesting a common difference over time throughout the sample. Regarding the observed changes during the dual task, it is possible that they occurred because of a practice effect, with participants having been familiarized with the eyes-closed and cognitive task during the initial assessment. Overall, these naturally occurring changes in COP parameters suggest caution when interpreting fluctuations of these measures over the course of a long-duration RCT.

The present study is not without limitations. Primarily, there is a concern regarding generalizability of the results because the present sample consisted of older fallers with MS. However, the present sample may possess the largest degree of instability, thus offering worst-case scenario estimates of reliability. Overall, the inclusion criteria resulted in a sample with a high degree of imbalance and prime candidates for fall-prevention interventions and balance rehabilitation.[17] It could be expected to observe even better estimates of reliability and lesser magnitudes of differences over time for MS samples with minimal balance deficit.

The present study provides important data regarding the test-retest reliability and naturally occurring changes of postural control assessed using COP metrics in MS. All the measures demonstrated fair-to-excellent reliability over the 3-month period. Moreover, reliability was maintained across the three commonly used balance conditions of eyes open, eyes closed, and dual task. It is expected that these results in the absence of an intervention will inform the understanding of balance preservation in MS and aid future study design. □

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