Walking ability and daily functioning in Multiple Sclerosis

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2013


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CHAPTER 5

Dynamic and static balance are not related in patients with Multiple Sclerosis

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ABSTRACT

Background

Abnormalities in balance control are a common finding in multiple sclerosis (MS) patients. Although early recognition of balance impairments in these patients might provide an opportunity for beneficial interventions, current clinical assessment tools appear to lack sufficient sensitivity to detect and quantify balance impairment. The aim of this study is to explore, in patients with MS, the relationship between a quantitative value for dynamic balance during walking, expressed in the margin of stability (MoS), and static balance as measured with posturography, and to evaluate the capacity of the MoS to distinguish levels of disease severity as expressed by the Expanded Disease Severity Scale.

Methods

Eighty-one patients were included and all were able to walk 10 meters without assistance from another person. Static balance was measured with posturography and the MoS was determined from the center of pressure during walking. In addition to the MoS, step width and double support time were measured as dynamic balance variables.

Results

The correlation coefficients between the static and dynamic balance measurements were generally statistically significant, but low (range 0.10 - 0.49). Age-corrected regression analysis demonstrated a significant relationship between the EDSS and the MoS ($\beta = 0.583$, $p = 0.04$), but the explained variance was only 12%.

Conclusion

MoS and other dynamic balance measurements are, at best, only marginally related to posturography measurements. The results of this study question the value of the MoS as a measure of dynamic balance in patients with mild to moderate MS.

INTRODUCTION

Abnormalities in balance control are common in patients with multiple sclerosis (MS).[1-3] The resulting dynamic instability is problematic because it causes difficulties in moving from one position to another, increasing the risk of falling and leading to major restrictions on daily living.[4,5] Balance control is characterized by a complex interaction between musculoskeletal and neuromuscular systems, including sensory, vestibular, and visual components. The neuronal demyelination in MS can occur in one or more locations in the brain or spinal cord and may therefore affect several of these systems, increasing the risk of balance deficits.[1,2,6]

The serious consequences of balance impairments require both suitable interventions and appropriate outcome measures. Although early recognition of balance impairments in patients with MS provides an opportunity for interventions aimed at optimizing functional abilities,[7] current clinical assessment tools do not appear to be sufficiently sensitive to detect and quantify balance impairment in minimally impaired MS patients.[3,6-8]

Balance is often divided in static and dynamic balance. Static balance is when subjects maintain their body position in a relatively unperturbed state,[5] while dynamic balance can be defined as the ability to control the whole body position and momentum during gait or other activities, in which the center of mass must be displaced outside the base of support.[9,10] Posturography is used to measure the static balance.[11,12] There are several posturography techniques available. In this study posturography is measured in a relatively unperturbed state (quiet stance on a fixed surface).[5] Dynamic balance is assessed according to the model of Hof.[13,14]

Posturography is considered to be less dependent on the judgment of the clinician and an objective measure of balance and postural instability,[5] with the potential to be more sensitive to subtle balance impairments.[15,16] Posturography assesses postural control while subjects maintain stance in a relatively unperturbed state. With different test conditions, the relative contributions of the sensory, visual, and vertebral systems involved in balance control can be studied. Yahia et al.[17] showed that patients with MS in quiet stance had a larger sway area and total distance travelled from the center of pressure than healthy subjects. However, Kessler et al.[18] did not find significant differences in sway parameters between mildly (Expanded Disability Status Scale, EDSS 0 - 2.5) and moderately (EDSS 3 - 4) disabled MS patients. Because posturography does not seem to differentiate well between disease severity levels, the clinical importance of posturography is limited.[5]

Balance control is generally more challenged during dynamic activities, such as reaching or walking.[19,20] Where dynamic tasks elicit differences in balance even at low levels of disability, stance can appear unaffected even at severe disability levels. Frzovic et al.[1] found that balance impairments were most apparent in tests that required patients to respond to internally and externally generated perturbations to their center of mass, rather than in tests that required the maintenance of a steady stance without perturbations. This indicates that impaired balance is most prominent during movement or ambulation.

Hof et al.[13,14] developed a model that generates a quantitative value for dynamic balance during walking, i.e. the margin of stability (MoS) (see Figure 5.1). This model takes into account the 'extrapolated center of mass' (XCoM), which is equal to the center of mass (CoM) position plus CoM velocity divided by the eigenfrequency. The MoS is the distance between the border of the base of support and this XCoM. In addition to the MoS, more traditional gait parameters are commonly used as indirect measures of dynamic balance.[7,9] In studies of age-related gait changes[21,22] and vestibular disorders,[23] spatiotemporal parameters such as gait speed, step length, step width and double support time have been used to study dynamic balance. It has been suggested that people with balance problems adopt a more conservative gait pattern, characterised by reduced gait speed and step length and an increased step width and double support time.[21-2]

The purpose of the present study was to explore the relationship between dynamic balance expressed by the MoS and balance during bilateral standing measured with posturography, in patients with MS. Since a gold standard for dynamic balance is lacking, static balance measurements are used in order to investigate the concurrent validity of the MoS. Although static and dynamic balance might be different constructs, it is supposed that poor static balance will be accompanied by a poor dynamic balance. A further aim was to evaluate if the MoS could distinguish between the levels of disease severity measured with the Expanded Disease Severity Scale (EDSS). We hypothesized that: (1) the more challenging conditions during posturography would show a stronger correlation with dynamic balance, (2) patients with larger static sway parameters would also have a larger MoS, and (3) the MoS can distinguish levels of disease severity (EDSS scores) and, in contrast to posturography, can do this even in a minimally impaired patient group.

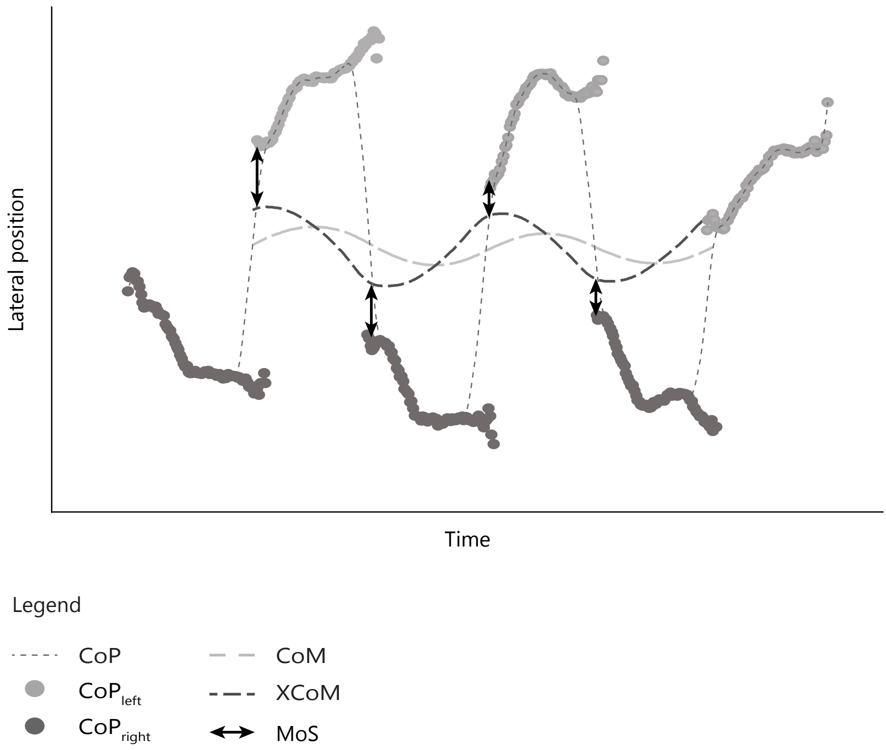

Figure 5.1 The model of Hof
Margin of stability (MoS) is the shortest distance between the 'extrapolated center of mass (XCoM) and the center of pressure (CoP). The XCoM is equal to the center of mass (CoM) position plus CoM velocity divided by the eigenfrequency

METHODS

Participants

Study data were derived from patients participating in a longitudinal study on outcome measurement and functional prognosis in early MS.[24] A subgroup of 81 ambulant patients with MS was assessed in an outpatient clinic. Patients were included if able to walk for ten meters without assistance from another person.

The study was approved by the Ethics Committee of the VU University Medical Center.

Measurements

The margin of stability and spatiotemporal gait parameters

The margin of stability (MoS) and spatiotemporal gait parameters were derived using the GAITRite® System (CIR Systems Inc. Clifton, NJ 07012), which consists of a 4.88 meter-long walkway with integrated pressure sensors (sample frequency of 120 Hz). The GAITRite produces reliable and validated measures of spatiotemporal parameters.[25,26] The GAITRite was integrated in a six-minute walking test and the patient walked across the GAITRite mat with a constant, self-selected, comfortable walking speed. Data from the mechanical pressure-activated sensors were collected and the GAITRite software immediately transformed the raw data into center of pressure (CoP) data and spatiotemporal gait parameters. The spatiotemporal parameters, gait speed and double support time, were extracted from every passage (each containing several footsteps). All passages were used to calculate one mean for each spatiotemporal parameter.

Posturography

The posturography test contained four different conditions of 60 seconds duration, in the same order. In the first two conditions the patients stood on a firm surface, first with eyes open, followed by eyes closed. In the third and fourth condition patients stood on foam (density: 31.2kg·m^{-3}, height: 115mm), with eyes open and closed respectively. Participants were standing barefoot with each foot on a separate force plate (force plate 1 model OR6-5-1000; force plate 2 model OR6-6-1000, AMTI, Watertown, Massachusetts, USA). Three orthogonal ground reaction forces (F_x, F_y and F_z) and three moments (M_x, M_y and M_z) were collected by each force plate, at a sample frequency of 1000 Hz. The positions of the feet were standardized (medial sides of the heels 10cm apart and each foot placed with toes outward at a 10º angle). Participants were instructed to hold their arms alongside their trunk, not to talk and to stand as quietly as possible. A research assistant stood close to the patient during testing to ensure safety.

Berg Balance Scale

The reliable and validated Berg Balance Scale (BBS) consists of 14, mainly static, balance tasks, with performance rated on each task from 0 (cannot perform) to 4 (normal performance) and with a maximum score of 56 points.[4,27,28] The BBS evaluates the ability to sit, stand, transfer, lean, turn and maintain the upright position in tandem stance and stance on one leg and has been validated in MS.[4]

Descriptive variables

The EDSS was assessed to indicate the severity of MS. Scores on the EDSS range from 0-10; lower scores (0-3.5) reflect the scores obtained from the neurological systems (visual/optical, brainstem, pyramidal, cerebellar, sensory, bowel/bladder, mental and other), intermediate scores (4.0-7.0) reflect level of walking disability, and higher scores (7.5-10) are mainly based on the inability to perform self-care activities.[29]

Data analysis

Margin of Stability

Leg length and CoP data were used to determine the margin of stability. The leg length, defined as the distance from the trochanter major to the malleolus lateralis, was determined during physical examination. CoP data, collected with the GAITRite, was exported and then analyzed with a custom Matlab® program (The Mathworks, Natick, MA, USA). The CoM was determined through low pass filtering of the CoP data.[9,30] The cut-off frequency of this low-pass filter depends on the pendulum eigenfrequency.[13] The XCoM was calculated as the first derivative of the CoM position. The MoS was calculated with formula 1.[13] A positive MoS indicates that the XCoM projection is within the CoP.

$$MoS = CoP - XCoM \qquad (1)$$

The first and the last step were excluded from every GAITRite measurement when calculating the MoS. The mean MoS was calculated for the steps in between (an average of four steps). Finally, one mean MoS was calculated from all the GAITRite passages for each patient.

Step width

The CoP data collected with the GAITRite was also used to calculate the step width. The perpendicular distance between initial contact of one foot and the same point on the other foot at the subsequent contact was calculated with a Matlab® program.

Posturography

Signals of both force plates were combined and the CoP_x (medio-lateral direction) and CoP_y (anterior-posterior direction) were calculated using the following equations[31]:

$$CoP_x = -M_y/F_z \qquad (2)$$

and

$$CoP_y = -M_x/F_z \qquad (3)$$

where M is the moment, F the ground reaction force and *x*, *y* and *z* are the mediolateral, anterio-posterior and vertical direction, respectively. Signals were down sampled to 100 Hz. To quantify postural control, two different parameters were calculated in Matlab®: mean velocity of the CoP (V_{CoP}) and 95%-ellipse area (A_{CoP}).[32,33] The time-interval between 10 - 60 seconds was used for analysis. The first 10 seconds were left out to avoid initial transients in the signal.

Statistical analyses

Statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS, version 18.0 for windows). The demographics of the study population and the static and dynamic variables were summarized with descriptive statistics. For the posturographic measurements, a possible significant difference between the four conditions was determined using one-way ANOVA and Bonferroni post hoc tests.

The first hypothesis, that the more challenging conditions during posturography would show a stronger correlation with dynamic balance, was estimated using Pearson product-moment correlation coefficients (r) or Spearman rank correlation coefficient. Correlations were calculated between the posturography parameters and the MoS, step width and double support time. The dynamic balance variables were first normalized for gait speed by dividing by gait speed. Correlations were interpreted according to Munro's correlation descriptors (very low = 0.15 - 0.24, low = 0.24 - 0.49, moderate = 0.50 - 0.69, high = 0.70 - 0.89, and very high = 0.90 - 1.00).[34] The Steiger's Z test was used to determine if the correlation coefficients significantly differed from each other.[35]

Table 5.1 Patient characteristics (n=81)

Sex		Age		EDSS		BBS		Gait speed[$m \cdot s^{-1}$]*	
Women	Men	Mean ± SD	Range	Median	Range	Median	Range	Mean ± SD	Range
51 (63%)	30 (37%)	47.1 (9.9)	28 - 69	3.0	1.0 - 7.0	56	11 - 56	1.22	0.25 - 1.56

Abbreviation: EDSS: Expanded Disability Status Scale; BBS: Berg Balance Scale; SARA: Scale for the Assessment and Rating of Ataxia
* six missing values

The second hypothesis, that patients with larger static sway parameters would also have a larger MoS, was visualized using scatter plots between the MoS and V_{CoP} and the MoS and A_{CoP}.

With respect to the third hypothesis, that the MoS can distinguish levels of disease severity and can do this even in a minimally impaired patient group, linear regression analysis, with the EDSS as independent variable, was used to investigate whether a significant relationship existed between the MoS and disease severity. Since age is known to affect balance, it was included in the regression analysis as covariate. When the regression coefficient of the EDSS changed more than 10% when age was added, confounding is confirmed.

The significance level was set at 0.05.

Table 5.2 Posturography measurements

	V_{CoP} [$mm \cdot s^{-1}$]	A_{CoP} [mm^2]
Condition 1 (n=73/74) (firm surface/EO)		
mean ± SD	20.5 ± 8.0	684.8 ± 801.4
range	10.5 - 57.2	83.3 - 5938.2
Condition 2 (n=73) (firm surface/EC)		
mean ± SD	28.0 ± 16.1	1037.2 ± 1162.2
range	11.5 - 100.5	93.8 - 4566.6
Condition 3 (n=69) (foam surface/EO)		
mean ± SD	33.2 ± 11.0	1456.9 ± 1025.7
range	14.6 - 56.8	310.3 - 7671.53
Condition 4 (n=54/60) (foam surface/EC)		
mean ± SD	58.1 ± 29.6	3196.0 ± 2734.9
range	20.5 - 169.4	488.2 - 12398.3

Abbreviation: D_{CoP}: total distance of the center of pressure (in 50 seconds); V_{CoP}: mean velocity of the center of pressure; A_{CoP}: 95%-ellips area of the center of pressure; EO: eyes open; EC: eyes closed

Results

Participants

The characteristics of the 81 participants (51 women and 30 men) are presented in Table 5.1. The age range was between 28 and 69 years and the median EDSS was 3.0 (range 1.0-7.0). The BBS showed a ceiling effect with a median of 56 (range 11 - 56).

Posturography

Total posturography measurements could not be obtained for six participants: three were unable to stand without support and three measurements failed due to technical problems.

Overall, an increase in difficulty in each particular condition, from firm surface eyes open and closed to foam surface eyes open and closed, resulted in an increased value of the parameters V_{CoP} and A_{CoP} ($p < 0.001$). The means (±SD) and scoring ranges for all conditions and parameters are presented in Table 5.2. Bonferroni post hoc test showed that the parameter V_{CoP} was significantly smaller in the basic condition 1 compared to the other conditions. There was no significant difference in V_{CoP} between condition 2 (firm surface, eyes closed) and condition 3 (foam surface, eyes open). In condition 4 (foam surface and eyes closed) both parameters are significantly larger compared to the other conditions. Furthermore, there were no significant differences in A_{CoP} between condition 2 (firm surface, eyes closed) and condition 1 and 3 (foam surface, eyes open).

Dynamic balance

The MoS was available for a total of 65 participants. Six participants were not able to perform the GAITRite measurement and the MoS could not be calculated for 8 participants, as they needed a walking aid to perform the test, preventing proper identification of the base of support (BoS). Two participants had missing anthropometric data. The means (±SD) and scoring ranges for the dynamic balance variables are presented in Table 5.3.

Associations between static and dynamic balance

The correlation coefficients between the four conditions of the posturography and the dynamic balance measurements are presented in Table 5.4. Although most correlation coefficients are statistically significant, they are all very low or low (from 0.10 - 0.49).[34] The correlation coefficients with dynamic balance measurements did not increase for the more challenging posturography conditions.

The scatterplots in Figure 5.2 showed the association between the MoS and the static sway parameters V_{CoP} or A_{CoP}. The positive correlation coefficients between the MoS and the V_{CoP} were small, and not significantly different when the more challenging posturography conditions were compared with the easiest condition (firm surface, eyes open), tested with the Steiger's Z test. The same applies to the correlation coefficients between the MoS and the A_{CoP}. None of the correlation coefficients between MoS and A_{CoP} were significant. The scatterplots displayed a widely spread pattern and every condition contains some outliers (minimal ±2 SD from the mean). Excluding these outliers did not alter the results (data not shown). All data were therefore used in the analyses.

Table 5.3 Dynamic balance measurements

Double support time [%]		Step width [cm]		Margin of Stability [cm]	
Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
25.4 ± 5.1	17.3 - 50.1	15.7 ± 4.5	6.7 - 31.7	5.0 ± 1.7	2.2 - 10.6

Table 5.4 Correlation coefficients between the four posturography conditions and the dynamic balance measurements

	Condition 1 (firm surface/EO)		Condition 2 (firm surface/EC)		Condition 3 (foam surface/EO)		Condition 4 (foam surface/EC)	
	V_{CoP}	A_{CoP}	V_{CoP}	A_{CoP}	V_{CoP}	A_{CoP}	V_{CoP}	A_{CoP}
Normalized MoS	0.33**	0.13	0.33**	0.20	0.21	0.10	0.13	0.11
Normalized Step	0.42**	0.15	0.40**	0.27*	0.33**	0.16	0.36**	0.29*
Normalized DSP	0.30*	0.37**	0.48**	0.48**	0.37**	0.33**	0.37**	0.45**

Abbreviation: MoS: margin of stability, DSP: double support percentage; EO: eyes open; EC: eyes closed
* significance $P<0.05$
** significance $P<0.01$

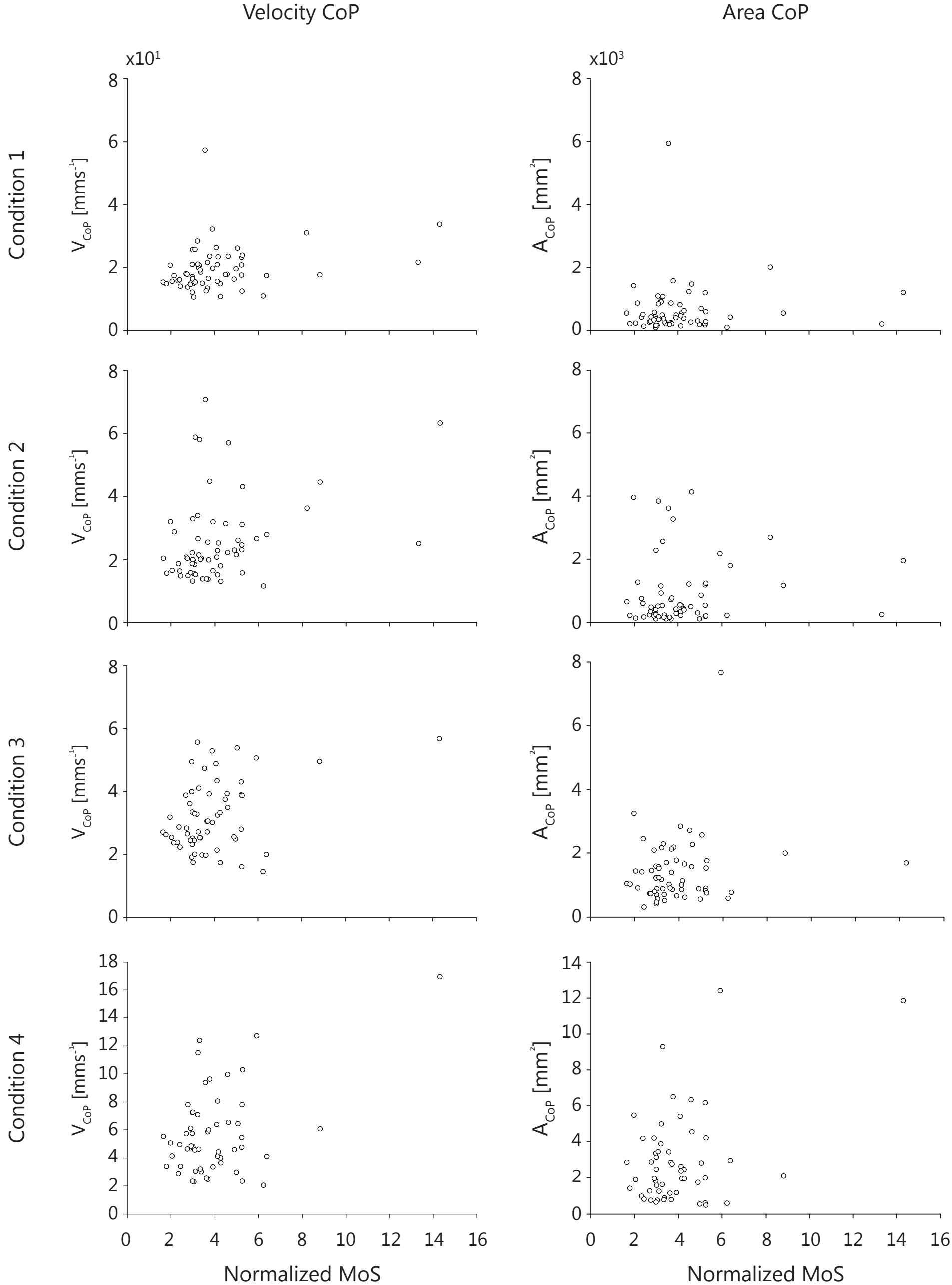

Figure 5.2 The variables V_{CoP} and A_{CoP} related to the MoS in all four conditions.
Abbreviation: V_{CoP}: mean velocity of the center of pressure; A_{CoP}: 95%-ellips area of the center of pressure; MoS: margin of stability

All correlation coefficients of double support time and step width with V_{CoP} and A_{CoP} were low, but significant, except for the correlation coefficient between step width and A_{CoP} of conditions 1 and 3. Again, there were no significant differences between the correlation coefficients for the different postural conditions.

Margin of stability and disease severity

A significant bivariate unstandardized regression coefficient was found between the EDSS (β = 0.685, p = 0.012) and the MoS, with an explained variance in MoS of 10%. The relation between EDSS and age was tested for colinearity. The regression coefficient of the EDSS changed more than 10% when age was added to the regression equation, which confirmed that age was a confounder. The age-adjusted regression coefficient for the EDSS was β = 0.583, with an explained variance in MoS of 12% (see Table 5.5).

To investigate whether there was a significant relationship between the MoS and the EDSS within minimally impaired patients, a subgroup analysis was performed for the patient group with EDSS 0 to 3.5. No meaningful regression model could be developed (results not shown).

Table 5.5 Regression analyses Margin of Stability

	unstandardized			
	β	standard	Standardized β	p
Constant	0.812	1.334		0.55
EDSS	0.583	0.272	0.265	0.04
age	0.037	0.028	0.164	0.19
R^2	0.12			

Abbreviation: β: beta; EDSS: expanded disability status scale

DISCUSSION

To the best of our knowledge, this is the first study to apply the margin of stability (MoS) as a dynamic balance variable in patients with MS. Our results show that the correlation coefficients between the posturography balance parameters for each of the four conditions and the dynamic balance measurements MoS, step width and double support time are (very) low and not significantly different from each other. Therefore, our first hypothesis, that a more challenging condition during the posturography measurement shows a stronger correlation with the dynamic balance variables, is not confirmed. Our second hypothesis, that patients with larger static sway parameters would also have a larger MoS, was not confirmed. Although the regression analysis shows a significant regression coefficient between MoS and the EDSS, the explained variance of 12% indicates that other (unknown) factors perhaps better explain the variance. Therefore, the third hypothesis, that the MoS can distinguish levels of MS severity, could also not be validated. Despite the theoretically validated construct of the MoS, the results of this study question the value of the MoS as a useful measure for dynamic balance in patients with MS.

In comparison with other studies, our study had a sufficient number of patients to allow robust conclusions to be drawn. Although severely impaired patients were not able to participate in all measurements, the MoS could be calculated for 65 patients (median EDSS 2.5, range 1.0 - 5.5). However, one should be cautious when generalizing results to patients using a walking aid.

The low correlation coefficients do suggest that posturography and the MoS may measure different constructs. Comparing the MoS with other studies might substantiate our results. The MoS found in patients with MS during comfortable walking ranged between 2.2 and 10.6cm. Hof et al.[14] measured the MoS in both healthy subjects and above-knee amputees. Participants walked with different gait speeds (slow, normal and fast) on a treadmill, and both groups showed increased MoS with increasing gait speed. For all three gait speeds used, a significant difference in MoS was seen between the amputees and the controls and between the prosthetic and unaffected leg of the amputees. The average MoS in above knee amputees measured at normal gait speed was 2.74cm (SD = 0.54) for the prosthetic leg and 1.90cm (SD = 0.62) for the normal leg. In the healthy controls, the MoS for the left and right leg were respectively 1.61cm (SD = 0.71) and 1.67cm (SD = 0.70). Hof et al.[14] concluded that a wider MoS is safer for patients with balance problems. Also the results of Hak et al.[36] showed an increase in the MoS when perturbations increased the risk of falling. The participants seemed to create a sufficiently wide margin to compensate for a decrease in dynamic stability.

The MoS values we found in patients with MS were much larger, suggesting that they employ larger safety margins during walking due to dynamic instability. An alternative explanation for this large difference may lie in the fact that in our study the patients walked overground. In the study by Hof et al.[14] the amputee patients were allowed to use the side bars of the treadmill when necessary and were secured against falling. This safer environment may have contributed to less compensation for balance deficits. However, when Rosenblatt et al.[37] investigated a possible difference in MoS between overground walking and treadmill walking in 10 healthy young subjects, no difference was found. These authors calculated the MoS with the CoM constructed in a 10 segment rigid body model, instead of using a force plate. Interestingly, a mean MoS of 6.63 cm was found during overground walking, which was even larger than the MoS found in our study. Furthermore, they determined the MoS by calculating the distance between XCoM and BoS, instead of the CoP.[37] They proposed that this could have led to the difference of 4 - 5 cm between their results and the results of Hof et al..[14] The differences in MoS values could also be a result of using the GAITRite. A major advantage of the GAITRite is its ecological validity, as the measurement can be performed during normal overground walking, outside a movement laboratory. The treadmill with a built-in force plate[14] and the 10 segment rigid body model[37] to calculate the MoS, could be more precise than the CoP calculation from the GAITRite. Furthermore, the limited length of the GAITRite results in fewer steps with which to measure the MoS, which can be a disadvantage when the variability in steps is large. Further research should reveal which method of MoS measurement is preferable.

Our first hypothesis could not be confirmed, which may be related to the choice of the static balance measurement. In a narrative review on the clinical utility of posturography, Visser et al.[5] described three studies which indicated that postural instability can be better identified using velocity-related sway measures than displacement-related sway measures. As our results showed that the correlation coefficients between the MoS and V_{CoP}, and the MoS and the $A_{CoP,}$ did not differ significantly from each other, we are not able to confirm these findings. There is currently no agreement on which parameters should be considered as standard, or which are superior in describing balance control.[5,38] The lack of agreement in choice of outcome measure in posturography was ascribed to the absence of a widely accepted gold standard for balance, providing the rationale for our exploration of the more dynamically oriented MoS.

We also investigated the relationship between disease severity and the MoS. A higher EDSS score signifies more serious problems in walking, which was expected to be reflected in the MoS. The regression analysis showed that with an increase of 1 point on the EDSS, the MoS increased with 0.58 cm. As the range of the EDSS in this study was six points, the maximum possible difference of the MoS based on the EDSS was 3.48 cm. This is a relatively small contribution given that the MoS in our study ranges from 2.2 to 10.6 cm. Thus, while the MoS does seem to covary with disease severity, the clinical significance of this relationship remains to be determined.

In the elderly, stride length, step width or double support time are often used as dynamic balance parameters.[22,39,40] Increased double support time and shorter stride length are suggested to indicate the adoption of a more conservative and stable gait pattern to compensate for reduced balance control. In our study the correlation coefficients between posturography and double support time and step width were significant but low. Other studies,[41,42] with an MS population comparable to our study, have found similar values of 24.6% for double support time and 15.3 cm for step width. Gianfrancesco et al.[43] reported a larger double support time (32.9%) in patients with a median EDSS of 4.5. On the other hand, Martin et al.[7] and Benedetti et al.[44] found a larger double support time (respectively 29.3% and 27.6%) in patients with lower EDSS scores (range 0.0 - 2.5) than our study population. Although all studies found larger double support time values than in healthy subjects,[45,46] the association with disease severity remains unclear. Different compensation strategies to maintain balance during walking could be an important reason for the diversity in results. People with increased fall risk choose a variety of adaptation strategies to maintain balance,[47] some walk with shorter or wider steps, others with longer or narrower steps. The value in discriminating between patients with MS and healthy controls, the ease of measurement and the simple clinical interpretation are important advantages of using double support time or step width as dynamic balance measures.

For the dynamic balance measurement participants were asked to walk with a comfortable walking speed. This self-chosen speed enabled them to apply compensation strategies. From a clinical point of view these adaptations are beneficial, because within certain limits, the patients have the ability to solve their own balance problems. However, these compensation strategies can confound the results of research. Further research should aim to determine the effect of compensation on the dynamic balance variables, for example by imposing gait speed and/or step width.

Recommendations for further research

The clinical utility of the MoS needs further investigation and a longitudinal study could provide greater insight into the changes in the MoS over time or resulting from deterioration due to disease.

CONCLUSION

In patients with MS, who walk without a walking aid, the MoS and other dynamic balance measurements are, at best, only marginally related to posturography measurements. The results of this study question the usefulness of the MoS as a measure for dynamic balance in patients with mild to moderate MS. Step width and double support time showed the same results as the MoS. The MoS might therefore be reflective of a strategy to keep balance, rather than a direct balance stability measurement.

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