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published in
Multiple Sclerosis and Related Disorders
2017

DOI (link to publisher)
10.1016/j.msard.2017.06.014

document version
Publisher's PDF, also known as Version of record

Multiple Sclerosis and Related Disorders 17 (2017) 69–74

Contents lists available at ScienceDirect

Multiple Sclerosis and Related Disorders

journal homepage: www.elsevier.com/locate/msard

Predicting falls among patients with multiple sclerosis: Comparison of patient-reported outcomes and performance-based measures of lower extremity functions

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A R T I C L E I N F O

Keywords:
Multiple sclerosis
Falling
Risk factor
Patient-reported outcomes
Performance-based measures

A B S T R A C T

Background: Accurate fall screening tools are needed to identify those multiple sclerosis (MS) patients at high risk of falling. The present study aimed at determining the validity of a series of performance-based measures (PBMs) of lower extremity functions and patient-reported outcomes (PROs) in predicting falls in a sample of MS patients (n = 84), who were ambulatory independent.

Methods: Patients were assessed using the following PBMs: timed up and go (TUG), timed 25-foot walk (T25FW), cognitive T25FW, 2-min walk (2MW), and cognitive 2MW. Moreover, a series of valid and reliable PROs were filled in by participants including the activities-specific balance confidence (ABC), 12-item multiple sclerosis walking scale (MSWS-12), fall efficacy scale international (FES-I), and modified fatigue impact scale (MFIS). The dual task cost (DTC) of 2MW and T25FW tests were calculated as a percentage of change in parameters from single to dual task conditions. Participants were classified as none-fallers and fallers (⩾1) based on their prospective fall occurrence.

Results: In the present study, 41(49%) participants recorded ≥ 1 fall and were classified as fallers. The results of logistic regression analysis revealed that each individual test, except DTC of 2MW and T25FW, significantly predicted future falls. However, considering the area under the curves (AUCs), PROs were more accurate compared to PBMs. In addition, the results of multiple logistic regression with the first two factors extracted from principal component analysis revealed that both factor 1 (PROs) and factor 2 (PBMs) significantly predicted falls with a greater odds ratio (OR) for factor 1 (factor 1: P = < 0.0001, OR = 63.41 (6.72–597.90)) than factor 2 (P < 0.05, OR = 5.03 (1.33–18.99)).

Conclusions: The results of this study can be used by clinicians to identify and monitor potential fallers in MS patients.

1. Introduction

Difficulty in walking is a major feature of multiple sclerosis (MS) (Bethoux and Bennett, 2011). Up to 85% of patients report mobility impairments, while gait is perceived as the most important bodily function by MS patients across the disability spectrum (Bethoux and Bennett, 2011; Heesen et al., 2008). Equally important, the majority of falls (> 60%) occur during dynamic everyday activities such as walking and transfers (Sosnoff et al., 2011). Hence, comprehensive assessment of walking impairments is required to identify those MS patients at high risk of falls and future comorbidities.

Falling is a significant concern for this group, with studies demonstrating that more than 50% of patients with MS have a history of at least 1 fall over a 6-month period (Gianni et al., 2014; Gunn et al., 2013b). The physical impacts of falls can cause activity limitations and may have significant effects on patient's participation in the society (Coote et al., 2014; Gunn et al., 2013b). The number of studies focusing on falls in patients with MS is low compared to studies on falls in older

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http://dx.doi.org/10.1016/j.msard.2017.06.014
Received 23 April 2017; Received in revised form 9 June 2017; Accepted 25 June 2017
2211-0348/

adults (Coote et al., 2014). The results of 2 meta-analyses that focused on risk factors for falls in patients with MS revealed that cognitive impairments, balance deficits, progressive type of MS, and use of mobility aids are associated with future falls (Gianni et al., 2014; Gunn et al., 2013b). Although previous investigations have provided important information regarding fall predictors in patients with MS, there is still limited information regarding any associations between walking impairments and future falls (Gianni et al., 2014; Gunn et al., 2013a, 2013b; Kasser et al., 2011; Nilsagard et al., 2009). To date, the limited prospective studies have not reached consistent conclusions about the predictive values of clinical gait measures for future falls (Gunn et al., 2013a; Nilsagard et al., 2009). For instance, in one prospective study, the timed up and go (TUG) test combined with a cognitive dual task was able to identify MS fallers, while in another study the 10-meter walk test with a cognitive dual task was not predictive of future falls (Gunn et al., 2013a; Nilsagard et al., 2009). Thus, further prospective studies are required for developing more accurate tools to screen fall risk levels among ambulatory MS patients.

Many instruments have been used to evaluate walking impairments in patients with MS, and they are generally classified as follow: laboratory-based measures (spatiotemporal gait characteristics); performance-based measures (PBMs) (eg, timed 25-foot walk (T25FW); 2-min walk (2MW)) and patient-reported outcomes (PROs) (eg, activities-specific balance confidence (ABC); and 12-item multiple sclerosis walking scale (MSWS-12))(Bethoux and Bennett, 2011; Cohen et al., 2015; Potter et al., 2014). Laboratory-based gait analysis, using markers placed on the body as well as force plates, is the gold standard in quantitative gait analysis (Bethoux and Bennett, 2011). However, in clinical settings, several constraints including costs (eg, equipments), space requirements (eg, room for a gait course), and time should be considered when selecting the preferred tests as fall screening tools (Bethoux and Bennett, 2011; Heesen et al., 2008). The results of a multi-center study in patients with MS revealed that walking speed obtained from a short test (i.e. T25FW), and walking distance obtained from a longer test (i.e. 2MW test) are important PBMs for describing an MS patient's general walking capacity (Gijbels et al., 2012). In addition, PROs such as MSWS-12 and ABC, measure self-perceived functional status while attempting various daily activities (Cohen et al., 2015; Nilsagard et al., 2012). Moreover, different aspects such as fear of falling and fatigue experienced during walking can be quantified by PROs such as the fall efficacy scale international (FES-I) and the modified fatigue impact scale (MFIS) (Cohen et al., 2015; van Vliet et al., 2013). These PROs may have added values because fatigue and fear of falling can have adverse effects on patients' performance, while they cannot easily be quantified by simple functional tests.

The relative advantages of each approach have been debated in the literatures (Bean et al., 2011; Beauchamp et al., 2015; Deshpande et al., 2011). PBMs have been proposed to have better objectivity and are less influenced by external factors while PROs offer low cost and convenience, and may represent a broader assessment of functions across daily life (Beauchamp et al., 2015). A study by Cattaneo et al. showed good discriminant validity of 2 PROs (ABC, dizziness handicap inventory) to differentiate MS fallers from non-fallers, whereas the BBS, TUG and hauser ambulation index tests were not able to differentiate between the two groups (Cattaneo et al., 2006). In their study, retrospective falls during the month before the assessment procedure were used to classify fallers and non-fallers (Cattaneo et al., 2006). However, studies comparing the predictive validity of the two approaches with respect to fall identification are scarce in patients with MS. Therefore, the aim of this study was to prospectively analyze the predictive validity of some important PROs and PBMs to identify fall risk in a sample of MS patients, who were ambulatory independent. For this purpose, most commonly used PBMs including TUG, T25FW, cognitive T25FW, 2MW and cognitive 2MW were utilized in this study. In addition, a series of valid and reliable PROs including MSWS-12, ABC, FES-I and MFIS were administered. It was hypothesized that each individual test could predict future falls in patients with MS and among the studied variables, PROs would have greater ability to detect future falls than PBMs. From a clinical point of view, identification of accurate fall screening tools can assist therapists to determine the level of fall risk of MS patients and this may help to promote future fall prevention interventions.

2. Methods and materials

2.1. Participants

For this prospective cohort study, 90 patients with MS were recruited from Khuzestan MS Patients' Society. Inclusion criteria were as follow: (1) a definite diagnosis of MS (of any subtype) diagnosed by a neurologist; (2) an expanded disability status scale (EDSS, physician version) of 0–5.5; and (3) no MS relapses 30 days prior to testing. Patients were excluded under the following conditions: (1) self-reported conditions other than MS known to affect balance and gait; (2) sever cognitive impairments which impeded understanding instructions or filling in the questionnaires; and (3) uncorrected visual impairments.

2.2. Procedures

Data were prospectively collected from August 2015 to February 2016. Each participant signed an inform consent form that had been approved by the Internal Review Board of the University. Prior to data collection, patients' demographic information including disability status, MS subtype, disease duration, age, gender, and body mass index (BMI) were collected. The self-administered EDSS ($EDSS_S$) questionnaire was used to record the disability status of the patients; and it has been shown to be strongly correlated with the physician-administered version (Bowen et al., 2001). For the main part of the data collection process, patients were assessed by a physiotherapist with 5 years of experience in clinical practice on the following PBMs: TUG, T25FW, cognitive T25FW, 2MW, and cognitive 2 MW. In addition, patients were asked to fill in the following PROs including ABC, MSWS-12, FES-I, and MFIS. The order of administering PBMs and PROs was randomized. The assessment was conducted in 1 session. A 2-min rest break was given to the participants between each measure, with additional rest time provided if needed.

2.2.1. Predictor variables

2.2.1.1. PBMs. For the TUG test, which is a composite measure of dynamic balance and mobility, participants were asked to stand up as fast as possible from a seated position, walk out 3 m, turn around, and return to the seated position. The score was the time taken to perform the task. Each participant performed 3 trials of the TUG; then, the mean of the 3 trials was calculated. The TUG has been shown to have a high test-retest reliability in MS patients (intraclass correlation coefficient [ICC] = 0.91) (Nilsagard et al., 2007).

For the T25FW test, which measures total mobility and leg performance, participants were instructed to walk 25 feet as quickly as possible. The average duration of the 2 trials was calculated as the final score. The T25FW has been shown to be a valid and reliable measure in MS patients (Bethoux and Bennett, 2011; Cohen et al., 2015). The cognitive T25FW test was used in this study to investigate whether dual task interference, which is commonly seen in these patients, can contribute to future falls (Hamilton et al., 2009). Thus, participants were asked to perform aloud backward counting (serial 3 subtraction task), while walking as fast as possible, then, the mean time required for the 2 trials was calculated. The dual task cost of performance was calculated as follows: (single task- dual task) / (single task) $\times 100$ (Etemadi, 2016).

For the 2MW test, which measures walking endurance, participants were asked to walk for 2 min at their normal comfortable pace, then, the distance walked during this time was measured. The 2MW test is a valid and reliable measure of gait performance in MS patients (Gijbels et al., 2012, 2011). For the cognitive 2MW test, patients were asked to perform aloud backward counting task, while walking for 2 min. The dual task cost of performance was calculated as follows: (single task-dual task)/(single task) ×100.

2.2.1.2. PROs. The ABC is a self-report measure of balance confidence during activities of daily living (ADL). Participants rate their balance confidence during 16 daily activities from 0 to 100, with 0 representing no confidence and 100 indicating complete balance confidence in performing these activities. The reliability of the ABC scale has been shown to be high (test-retest reliability ICC = 0.92) in patients with MS (Cattaneo et al., 2006; Nilsagard et al., 2012).

The MSWS-12 is a 12- item self-report measure of the impact of MS on walking ability and is scored from 1 to 5, with 1 meaning no limitation and 5 meaning extreme limitation of walking ability. The total score ranges from 12 to 60, with higher scores indicating greater impact of MS on gait performance, hence, greater disability. It is a reliable and valid measure in patients with MS (Nakhostin Ansari et al., 2015).

In the present study, the FES-I was used to determine fear of falling. It measures the level of concern about falling during ADL and contains 16 items, with 10 items assessing basic activities and 6 measuring more demanding physical and social activities. Each item is scored on a scale from 1 (not at all concerned) to 4 (very concerned), and the total score ranges from 16 to 64, with higher scores indicating more concern about falling. This scale is a valid instrument for assessing fear of falling in patients with MS (van Vliet et al., 2013).

The MFIS was used as a measure of fatigue effects on ADL. It consists of 21 items and the total score is the sum of the scores for the 21 items. The Persian version of MFIS is a valid and reliable scale for assessing fatigue in Iranian patients with MS (Ghajarzadeh et al., 2013).

2.3. Follow-up assessment of falls

Each participant's fall incidence was monitored prospectively for a period of 6 months after initial testing. Participants were asked to record their falls each day for 6 months on fall calendars and return these calendars at the end of each month. It was explained to the participants that a fall is any unexpected event that results in ending up on the ground, floor, or any lower surface (Coote et al., 2014). Based on the previous studies, patients were classified as fallers if they had reported one or more falls during the 6 months follow- up period (Coote et al., 2014; Nilsagard et al., 2009).

2.4. Statistical analysis

For the main purpose of this study, the probability of any falls in the following 6 months was modeled using logistic regression analysis. First, univariate logistic regression was conducted to determine the predictive ability of each variable separately, then multiple logistic regression was conducted to investigate the predictive ability of the studied variables in a model. Odds ratios (OR) and 95% confidence intervals (CI) were calculated for each regression analysis. To allow comparison of regression coefficients and ORs between variables with different units, normalized values (z-scores) of the variables were used for univariate regression analysis. In addition, a series of independent *t*-tests were conducted to allow between group comparisons of fallers and non-fallers on all outcome measures of this study. Moreover, to get insight into the predictive accuracy of each variable, the area under the receiver operating characteristic (ROC) curve (AUC) was computed for each predictor. The ROC curve plots the true positive rate (predicted falls that actually occurred) against the false positive rate (predicted falls that did not actually occur). The AUC provides a summary measure of accuracy in the prediction, ranging from 0.5 (chance) to 1.0 (perfect accuracy).

To avoid the problem of multicollinearity (ie, intercorrelation between predictor variables) for the subsequent multiple logistic regression, principal component analysis (PCA) was conducted. PCA is a method of transforming the original independent variables (predictors) into new, uncorrelated variables. Extraction of variables was based on eigenvalues > 1.0. Varimax normalization was used as the rotation method. Then multiple logistic regression analysis, adjusted for clinical and demographic variables (EDSSs, BMI, type of MS and gender), was used to investigate the predictive ability of the factors extracted from PCAs. All analyses were conducted using the IBM SPSS statistics software (Version 22). Significance level was set at $P < 0.05$.

Table 1
Demographic and clinical characteristics of non-faller and faller groups.

Characteristics		Non- fallers	Fallers	P-value
Number of participants (%)		43 (51%)	41 (49%)	NA
Age (yr)		33.80 (7.83)	30.29 (8.87)	0.8
Gender (Female/male)		36/7	26/15	< 0.05
BMI (kg/m^2)		26.46 (5.30)	23.45 (4.08)	< 0.01
Disease duration (yr)		4.02 (4.15)	5.48 (5.19)	0.1
EDSS$_S$		3.03 (1.29)	4.14 (1.00)	< 0.01
Type of MS	Relapsing-remitting	43	31	< 0.01
	Secondary progressive	0	7	
	Primary progressive	0	3	

Note. Values are mean (standard deviation) or as otherwise indicated. EDSS$_S$, Self-administered expanded disability status scale. NA: not applicable.

3. Results

3.1. Participants and fall data

Prospective fall data were completed for 84 of the 90 included participants; 2 patients were unwilling to participate in the follow- up, 1 withdrew for personal reasons, and 3 were excluded due to MS relapses. With respect to prevalence of falling, 49% of participants (41 patients) reports 1 or more falls during the 6 months follow-up period (12% of the MS participants reported 1 fall and 37% reported 2 or more falls). Table 1 summarizes participants' characteristics including clinical and demographic data for the two patient groups (non-fallers and fallers).

3.1.1. Prediction of falls in the following 6 months

The results of univariate logistic regression models revealed that all variables, except the DTC of T25FW and 2MW tests, were significant fall predictors (Table 2). The summary statistics for the PROs and PBMs indicate worse performance by fallers in all 6 predictors (Table 3). Fallers had significantly lower balance confidence, more self-perceived gait difficulty, higher fatigue and fear of falling during daily activities in comparison to non-fallers. In addition, reduced walking speed (T25FW and TUG) and endurance (2MW) were observed at the time of assessment in patients classified as fallers. The odds of falling was approximately 2.3 times greater, with one standard deviation (SD) decrease in ABC than with one SD increase in MFIS (OR ABC = 0.060, 95% CI = 0.02–0.17; OR MFIS 7.32, 95% CI = 3.28–16.29). Among the studied PBMs, the odds of falling was approximately 1.7 times greater with one SD increase in T25FW test than with one SD increase in TUG test (OR T25FW = 3.77, 95% CI = 1.86–7.63; OR TUG = 2.24, 95% CI = 1.17–4.27). The ROC curves and accompanying AUCs were statistically significant for all 6 predictors. However, considering the AUCs, PROs had better accuracy in predicting falls than PBMs. The ABC had the highest AUC for fall prediction (AUC = 0.92), followed by the MSWS-12 (AUC = 0.91) and FES-I (AUC= 0.89). The lowest AUC was for the TUG (AUC = 0.65).

The results of PCA revealed that 2 PCs covered most of the variance (83%). The first PC included FES, ABC, MFIS, and MSWS and accounted for 46% of the variance. The second PC included 2 MW, TUG, and

Table 2
Univariate logistic regression analysis with fall incidence (no fall versus ≥ 1 fall) as the dependent variable.

Predictors	AUC	B	SE	Wald	df	p-value	Odds ratio (95% confidence interval)
ABC	0.92	−2.815	0.550	26.194	1	< 0.0001	0.060 (0.020. −0.176)
MSWS-12	0.91	2.473	0.484	26.119	1	< 0.0001	11.853 (4.592–30.593)
FES-I	0.89	2.227	0.439	25.794	1	< 0.0001	9.273 (3.926–21.902)
MFIS	0.87	1.991	0.408	23.787	1	< 0.0001	7.320 (3.289–16.290)
T25FW	0.79	1.327	0.360	0.595	1	< 0.0001	3.770 (1.862–7.633)
2MW	0.71	−0.823	0.272	9.180	1	0.002	0.439 (0.258–0.748)
TUG	0.65	0.807	0.330	5.980	1	0.014	2.241 (1.174–4.278)
DTC 2MW	0.49	0.102	0.221	0.212	1	0.645	1.107 (0.718–1.706)
DTC T25FW	0.48	−0.015	0.220	0.005	1	0.945	0.985 (0.641–1.515)

ABC: activities- specific balance confidence, FES-I: fall efficacy scale international, MSWS-12: 12-item multiple sclerosis walking scale, MFIS: modified fatigue-impact scale, T25FW: timed 25 foot walk test, 2MW: 2-min walk, TUG: timed up and go, DTC: dual task cost, AUC: area under the curve, B: regression coefficient; SE: standard error; df: degrees of freedom; OR: odds ratio; CI: confidence interval.

Table 3
Results of independent *t*-tests between faller and non-faller groups.

Predictors	Fallers Mean (SD) (n = 43)	Non-Fallers Mean (SD) (n = 41)	P-value Mean differences
ABC	49.04 (18.12)	85.64 (12.18)	< 0.01
MSWS-12	44.65 (17.71)	12.42 (11.95)	< 0.01
FES-I	41.63 (10.79)	23.79 (7.00)	< 0.01
MFIS	53.82 (20.00)	23.55 (14.30)	< 0.01
T25FW	5.87 (1.14)	4.88 (0.72)	< 0.01
2MW	122.43 (24.80)	139.51 (20.40)	< 0.01
TUG	8.61 (2.47)	7.48 (1.13)	< 0.01
DTC 2MW	14.88 (16.21)	13.43 (12.82)	0.65
DTC T25FW	−26.25 (37.74)	−25.69 (37.09)	0.94

ABC: activities- specific balance confidence, FES-I: fall efficacy scale international, MSWS-12: 12-item multiple sclerosis walking scale, MFIS: modified fatigue-impact scale, T25FW: timed 25 foot walk test, 2MW: 2-min walk, TUG: timed up and go, DTC: dual task cost.

Table 4
Principal component analysis (PCA), factor loadings of the first 2 PCs.

	PC1 (PROs)	PC2 (PBMs)
FES	**0.906**	0.184
ABC	**−0.888**	−0.255
MFIS	**0.854**	0.195
MSWS	**0.833**	0.383
2MW	−0.237	**0.891**
TUG	0.189	**0.879**
T25FW	0.307	**0.865**

FES-I: fall efficacy scale international, ABC: activities- specific balance confidence, MFIS: modified fatigue impact scale, MSWS-12: 12-item multiple sclerosis walking scale, 2MW: 2 min walk, TUG: timed up and go, T25FW: timed 25 foot walk test.

Table 5
Multivariate logistic regression with fall incidence (no fall versus ≥ 1 fall) as the dependent variable.

Predictors	B	SE	Wald	df	p-value	Odds ratio (95% confidence interval)
Factor 1 (PROs)	4.150	1.145	13.140	1	< 0.0001	63.414 (6.726–597.900)
Factor 2 (PBMs)	1.617	0.677	5.703	1	< 0.05	5.038 (1.336–18.992)

Adjusted for BMI, gender, $EDSS_S$ and type of disease. Factor 1 & 2 were extracted form principal component analysis.

T25FW and increased the explained variance to 83% (Table 4). Furthermore, the result of multiple logistic regression model with the first two factors extracted from PCA and after adjusting for EDSS, BMI, type of MS and gender variables revealed that both factors were significant fall predictors with a greater OR for factor 1 (factor 1: P = < 0.0001, OR = 63.41 (6.72–597.90)) than factor 2 (P < 0.05, OR = 5.03 (1.33–18.99)) (Table 5). Model performance was further assessed using the ROC curve. The AUC was 0.94 for the multiple regression model indicating excellent overall accuracy.

4. Discussion

In the present study, we examined the predictive validity with respect to fall incidence of a series of lower extremity PBMs (TUG, T25FW, DTC T25FW, 2MW and DTC 2MW) and PROs (ABC, MSWS-12, FES-I, MFIS) in a sample of MS patients who were ambulatory independent. The results of logistic regression analysis revealed that most of the studied variables except DTC of walking tests were significant fall predictors. Specifically, fallers had lower balance confidence, more self-perceived walking difficulty, fatigue, and fear of falling during daily activities. Moreover, reduced walking speed (T25FW & TUG) and endurance (2MW) were observed at the time of assessment in patients classified as fallers. However, considering the AUC of individual variable and the result of multiple logistic regression, it seems that PROs may offer more values as predictors of future falls. These results provide preliminary guidance for the use of these measures in the clinics to identify potential fallers and in trials regarding the efficacy of fall-prevention interventions.

While extensive evidences support the construct validity of the studied variables in patients with MS (Cattaneo et al., 2006; Ghajarzadeh et al., 2013; Nakhostin Ansari et al., 2015; van Vliet et al., 2013), little is known about the predictive validity of these instruments with respect to fall identification. As hypothesized, the result of multiple logistic regression showed that after adjusting for clinical and demographic variables (disability level, type of disease, sex and BMI), both factor 1 (PROs) and factor 2 (PBMs) were significant fall predictors with a greater OR for factor 1 than factor 2. Moreover, in terms of relative accuracy of predicting falls, all of the clinical tests and scales had AUC values greater than those associated with random assignment (50%); however, the TUG test possessed the lowest AUC (0.65) and the ABC had the highest AUC (0.92) value. Such findings suggest that the presence of mobility-related impairments particularly walking impairments contribute to the increased risk of falling in patients with MS. Previously, Cameron et al. investigated the ability of some instruments (fall history, ABC, MSWS-12, FES-I, and T25FW) to predict falls in patients with MS (Cameron et al., 2013). They reported that simply asking patients about their fall history had the greatest accuracy in predicting future falls, followed by T25FW and ABC. However, the AUCs of the above-mentioned variables ranged from 0.69 to 0.75, which may not warrant their use in isolation (Cameron et al., 2013). Similarly in another prospective study of fall risk factors in patients with MS, the ABC scale was able to distinguish between fallers and non-fallers and had acceptable predictive accuracy level while TUG test was not able to predict future falls (Dibble et al., 2013). Smaller sample size of the above mentioned studies in comparison to our study, heterogeneity in the definition of fallers and different duration of follow-up may have accounted for the different results of AUCs. Future studies shall follow recommendations made by the international MS falls prevention research network regarding the definitions of falls, fallers and methods of measuring falls to allow valid comparisons between results of different studies (Coote et al., 2014).

We expected higher predictive validity of the PROs in comparison to PBMs. There are several possible explanations for such finding. One explanation is that PROs such as the ABC and MSWS-12 reflect an individual's perception of ability across a broad range of activities in relevant contexts while PBMs reflect performance of isolated activities without a functional context (Bean et al., 2011; Beauchamp et al., 2015). In addition, most commonly used PBMs such as TUG, T25FW and 2MW assess performance of one dimension of impaired mobility such as reduced gait speed or endurance while most patient-reported questionnaires (eg, ABC, FES-I, MFIS) assess different dimensions of mobility as well as psychological aspects of impaired mobility (Landers et al., 2016). Similar findings have been found in other populations prone to falling such as elderly and patients with stroke (Bean et al., 2011; Beauchamp et al., 2015; Beninato et al., 2009). For instance, it has been shown that in patients with stroke, the ABC Scale (AUC = 0.92) and the stroke impact scale (AUC = 0.86) had stronger associations with falls than the BBS (AUC = 0.76) and sit to stand task (AUC = 0.66) (Beninato et al., 2009). Taken together these findings, it seems that clinical measures of more-global states of physical functioning such as the studied PROs, are potentially useful fall screening tools and need to be further examined in MS population.

Among the PBMs used in this study, cognitive-motor interference as measured by DTC of walking tests, was not predictive of future falls in patients with MS. The rationale for investigating DTC was the high prevalence of cognitive impairments in MS patients, which may interfere with functions and increase the risk of falling (Gianni et al., 2014; Gunn et al., 2013b; Kalron, 2014). However, our results revealed that DTC of walking tests failed to predict future falls. The effects of specific cognitive deficits on risk of falls in MS patients have previously been explored (Kalron, 2014). Moreover, various studies have shown that dual tasking effects are greater among the MS population compared with healthy individuals (Hamilton et al., 2009; Negahban et al., 2011), nonetheless, the evidence on its association with future falls is still controversial (Etemadi, 2016; Wajda et al., 2013; Wajda and Sosnoff, 2015). In a recent study by Etemadi et al., it was found that DTC of walking speed was predictive of future falls in MS patients (Etemadi, 2016). However, in their study, walking speed was assessed using an electronic walkway, moreover, complexity of the cognitive task was higher than our study (serial 7 subtraction)(Etemadi, 2016). Therefore, further studies with more complex tests are needed to examine the relationship between cognitive-motor interference and falls in MS patients.

Although this study provided insight into fall risk screening tools, several limitations need to be considered. The study sample was restricted to patients with MS, who were ambulatory independent and had mild to moderate disability. Thus, generalizability of the results is restricted to this subgroup of ambulatory active patients. In addition, the predictor variables used in the present study cannot directly inform choices about the content of fall prevention and management protocols, however, they are clinically applicable as fall risk screening tools. Future studies with larger sample size are required to include a more heterogeneous sample of patients.

5. Conclusion

In conclusion, for the purpose of fall screening among patients with MS, PROs and PBMs of this study seem to be able to predict future falls in patients with MS. However, PROs including ABC, MSWS-12, FES-I and MFIS were more accurate in identifying patients at high risk of falling than commonly used PBMs such as T25FW, TUG and 2MW. The results of this study provide preliminary guidance for the use of these measures in the clinics to identify potential fallers and in trials regarding the efficacy of fall-prevention interventions.

Conflicts of interest

None of the authors had any financial or other interests relating to the manuscript to be submitted for publication in multiple sclerosis and related disorder journal.

Acknowledgment

This study is a part Ph.D. project of Shirin Tajali (grant no. pht_9437). Special thanks to Ahvaz Jundishapur University of Medical Sciences for financial support.

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