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Research article

Exploring key factors associated with falls in people with multiple sclerosis: The role of trunk impairment and other contributing factors

Noura Alzahrani [a], Orjuwan Bamutraf [a], Shatha Mukhtar [a], Aseel Mazi [a], Adel Jawad [b], Areej Khan [c], Abdullah Mohammad Alqarni [a], Reem Basuodan [d], Fayaz Khan [a,*]

[a] Department of Physical Therapy, Faculty of Medical Rehabilitation Sciences, King Abdulaziz University, Jeddah, Saudi Arabia
[b] Department of Physical Therapy, King Fahad Hospital, Jeddah, Saudi Arabia
[c] Department of Nursing, King Fahad Hospital, Jeddah, Saudi Arabia
[d] Department of Rehabilitation Sciences, College of Health and Rehabilitation Sciences, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia

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ABSTRACT

Background: Falls are a common and consequential concern for persons with multiple sclerosis (PwMS), with trunk impairment frequently observed even in the early stages of the disease. However, the relationship between falls and trunk impairment using the trunk impairment scale in this population remains unclear. This study aims to explore this association and identify potential factors contributing to falls in PwMS.
Method: Sixty-four patients were assessed for falls or near falls in the past 6 months, trunk impairment using the Trunk Impairment Scale (TIS), balance and gait using the Performance-Oriented Mobility Assessment (POMA), depression and anxiety using the Hospital Anxiety and Depression Scale (HADS), fatigue using the Modified Fatigue Impact Scale (MFIS), and fear of falling using the Modified Falls Efficacy Scale (MFES).
Results: Simple binary logistic regression revealed significant associations for TIS (OR = 0.75, p = 0.001, 95 % CI: 0.63 to 0.88), POMA (OR = 0.75, $p \leq 0.001$, 95 % CI: 0.65 to 0.87), MFES (OR = 0.96, $p \leq 0.001$, 95 % CI: 0.93 to 0.98), MFIS (OR = 1.05, p = 0.002, 95 % CI: 1.02 to 1.08), and HADS (OR = 1.09, p = 0.01, 95 % CI: 1.02 to 1.17). The multiple logistic regression model identified TIS (OR = 0.78, p = 0.007, 95 % CI: 0.66 to 0.94) and MFES (OR = 0.96, p = 0.005, 95 % CI: 0.93 to 0.98) as significant factors of falls.
Conclusion: This study confirms the significant impact of trunk impairment, tested by the trunk impairment scale and fear of falling as factors of falls among PwMS. Additionally, it highlights the roles of balance, gait, fatigue, and depression as factors that contribute to fall risk. These findings suggest that a comprehensive assessment incorporating these elements may be crucial for developing effective fall prevention strategies in this population. This research underscores the need for targeted interventions that address both physical and psychological aspects to mitigate the risk of falls in PwMS.

* Corresponding author. Department of Physical Therapy Faculty of Medical Rehabilitation Sciences King Abdulaziz University Jeddah, 22254, Saudi Arabia.
E-mail address: fayazrkhan@gmail.com (F. Khan).

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List of abbreviations:

MS	Multiple Sclerosis
PwMS	People with Multiple Sclerosis
POMA	Performance Oriented Mobility Assessment
MFES	Modified Falls Efficacy Scale
MFIS	Modified Fatigue Impact Scale
HADS	Hospital Anxiety Depression Scale
TIS	Trunk Impairment Scale

1. Introduction

Multiple sclerosis (MS) is a prevalent chronic autoimmune disease that affects the central nervous system [1]. Depending on the location of the lesions, MS presents with various physical and cognitive symptoms, leading to diverse disease manifestations [2]. These symptoms include spasticity, weakness, fatigue, altered sensation, and vision impairment [3]. In Saudi Arabia, the prevalence of MS has risen to 61.95 per 100,000 individuals, with central regions reporting more cases, although fewer than neighboring countries such as Kuwait and Qatar [4]. A higher incidence of MS is associated with being female and younger [4]. However, it is essential to note that these factors alone do not determine the development of MS, as the disease is complex and multifactorial. Other genetic, environmental, and lifestyle factors also play significant roles in its onset and progression [2,5].

Falls are common among people with MS (PwMS). Nilsagård et al. (2009) found that 63 % of PwMS reported falling at least once in the previous three months [6]. More recently, data from 2024, 56 % of 965 PwMS reported falls within the past six months [7]. When comparing PwMS to healthy controls, fall frequencies were 71 % and 41 %, respectively [8]. Mazumder et al. (2014) found that loss of balance was the primary cause of falls in 43 % of PwMS in the mild and moderate stages of the disease [8]. Other risk factors for falls include reduced cognition, impaired balance, the use of walking aids, progressive MS subtypes [9], muscle weakness, fatigue, environmental factors, performing multiple tasks at the same time [10], and fear of falling [11,12]. MS can impair the vestibular system, eye movements, muscle function, and proprioception [2]. Dysfunction of some of these systems, or their integration, can lead to falls [13]. In the following sections, we will introduce several factors pertaining to falls.

Gait is affected by MS, leading to reductions in speed and step length [14,15]. Furthermore, ankle movement is reduced, and abnormal muscle activation is observed when compared to healthy controls [16,17]. Additional gait characteristics such as stride length, double support time, muscle weakness [10], and swing duration are also impaired, which may increase the risk of falls [18]. The relationship between gait speed and falls is mediated by balance, with fatigue further amplifying this effect [19]. Fear of falls also had an impact on gait changes like reduced gait speed and decreased stride length [12]. A 10-year cohort study by Pittock et al. (2004) showed that approximately 50 % of PwMS with an Expanded Disability Status Scale (EDSS) score above 3 required assistive devices or wheelchairs [20], likely due to problems affecting balance and gait.

Fatigue is another prevalent symptom reported by most PwMS across all stages of the disease [21,22]. It is associated with balance issues and a fear of falling, both of which increase the risk of serious falls [23,24]. Additionally, both fatigue and depression are linked to a reduced quality of life, irrespective of the level of disability [25,26]. Depression may also act as a secondary cause of fatigue [27], and affects over 50 % of PwMS [28,29]. A study conducted in Saudi Arabia reported similar findings, with 58 % of PwMS experiencing depression [30]. Furthermore, Depression has been shown to decrease treatment adherence [31,32]and is associated with cognitive decline and an increased risk of falls [33,34].

Trunk impairment has been observed in PwMS, even in the early stages of the disease [35,36], including greater lateral trunk sway in both static and dynamic conditions when compared to healthy controls [37]. In high-level balance, the trunk and ankle muscles play a key role in maintaining a stable posture [38]. The trunk also stabilizes the spine, providing a stable base for smooth movement [39,40]. Therefore, Trunk training is a crucial component of rehabilitation, with benefits extending to improved balance, mobility, and upper-limb activities [41–43]. Trunk function can be measured in multiple ways; one reliable tool is The trunk impairment scale (TIS), a measuring tool that was generated for stroke patients [44] and was utilized for both Parkinson's [45] and multiple sclerosis populations [36]. It is a clinical tool that is reliable, simple, fast, and free that can be administered in any setting. However, there is no study to investigate the relationship between the TIS and falls in MS.

Previous studies have identified balance, gait, fatigue, depression, and fear of falling as factors influencing fall risk in PwMS [10,12,34,46,47]. However, to our knowledge, no study has specifically investigated the association between trunk control, assessed by the TIS, and falls in PwMS. Therefore, this study aims to investigate the diagnostic utility and relationship between trunk impairment, as measured by the TIS and falls in PwMS. Additionally, this study seeks to further explore the association and correlation among known fall risk factors within this population.

2. Materials and methods

2.1. Study design

This case-control study examined the impact of trunk impairment, using TIS, fear of falls, depression and anxiety, gait and balance, and fatigue on falls in PwMS. The study was approved on November 28, 2022, by the Ministry of Health (A01488; NCBE-KACST: (H-02-J-002), and the study period was from December 2022 to May 2023.

2.2. Sample size calculation

G*power (version 3.1; Heinrich Heine University) was used to calculate the sample size. Sixty subjects were required to reach a power of 80 % with a significant alpha level of 5 %, and a medium effect size for logistic regression analysis (0.15). Four factors were included in the regression model (trunk impairment, fatigue, depression and fear of falling).

2.3. Study participants and recruitment

Participants were recruited from King Fahad General Hospital in Jeddah, Kingdom of Saudi Arabia. The inclusion criteria were [1]: a clinical diagnosis of MS [2]; age between 20 and 60 years [3]; the ability to walk at least 5 m without assistance; and [4] the ability to provide informed consent. Exclusion criteria included [1]: an EDSS score of 7 or higher [2,48] a Mini-Mental State Examination (MMSE) score of 23 or lower [49](3) relapse in the month prior to the study.

2.4. Data collection

The data were collected in the outpatient clinic, where participants received their monthly intravenous (IV) medication. All participants signed consent forms, available in both Arabic and English. These forms outlined the assessment procedures, patients' rights, as well as the associated benefits and risks. Prior to the administration of IV medication, participants' personal information—including age, gender, marital status, trunk impairment, gait, and balance—was assessed. Patients were allowed to use orthosis and/or assistive devices (e.g., canes, walkers) if they were unable to complete the test without them. Additional questionnaires were administered while participants were receiving their IV medication.

2.5. Outcome measures

2.5.1. Trunk Impairment Scale (TIS)

This scale assesses trunk motor impairment in a sitting position and evaluates static and dynamic balance and coordination [44]. The TIS has a high interclass correlation coefficient (ICC) score of 0.95 and established construct validity [50]. The overall score ranges from 0 to 23, with higher scores indicating better performance [44].

2.5.2. Number of falls

A fall is defined as "an unexpected event in which the participant comes to rest on the ground, floor, or lower level" [51]. A near fall occurs when an individual regains balance after stumbling or tripping [52]. This study categorized both events as falls and grouped the participants into fallers and non-fallers. The number of falls was recorded retrospectively for the past six months.

2.5.3. Modified Falls Efficacy Scale (MFES/Arabic version)

MFES is an extended version of the 10-activity Falls Efficacy Scale (FES), designed to assess fear of falling [53]. The MFES includes additional items related to outdoor activities, providing a broader evaluation. The MFES has demonstrated strong reliability, with an overall ICC of 0.93. The scale consists of 14 items, each rated on a scale from 0 to 10, where higher scores indicate greater confidence and reduced fear of falling [53,54].

2.5.4. Performance-Oriented Mobility Assessment (POMA)

This assessment is used to evaluate balance and gait in the older population, helping to identify current capabilities and track changes over time. The test-retest reliability for the total scale is 0.93. The total score is 28, with 12 points allocated for gait and 16 for balance [55]. Higher scores reflect greater independence in these areas.

2.5.5. Hospital Anxiety and Depression Scale (HADS/Arabic version)

This instrument assesses anxiety and depression in patients and includes two subscales: anxiety and depression, each consisting of seven items [56]. The maximum possible score for each subscale is 21, with higher scores indicating a greater likelihood of psychiatric issues [57]. Internal consistency was evaluated using Cronbach's alpha, yielding values of 0.73 for anxiety and 0.77 for depression [57].

2.5.6. Modified Fatigue Impact Scale (MFIS/Arabic version)

This assessment evaluates the impact of fatigue across 21 items divided into cognitive, psychosocial, and physical function subscales. The Arabic version of the MFIS demonstrated strong test-retest reliability with an ICC of 0.92, and it has been validated as a reliable measure [58]. The maximum score is 84, with higher scores indicating a greater impact of fatigue on quality of life [59].

2.5.7. The Expanded Disability Status Scale (EDSS)

The EDSS is a widely used tool for measuring and assessing disability in PwMS, as well as for tracking changes in disability over time. The scale ranges from 0 to 10, with increments of 0.5, where higher scores indicate greater disability. EDSS scores from 1.0 to 4.5 apply to PwMS who are still able to walk without assistance, reflecting varying degrees of functional impairment and mobility [60].

2.6. Analysis

2.6.1. Descriptive statistics

All analyses were conducted using IBM SPSS Statistics for Windows, version 23 (IBM Corp., Armonk, NY, USA). The data was analyzed for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Descriptive statistics were employed to analyze the demographic data. Categorical variables were presented as frequencies and percentages, while continuous variables were expressed as median with maximum and minimum values. The descriptive data was categorized and presented for fallers and non-fallers.

2.6.2. Correlation

The correlation was used to analyze the correlation between the number of falls and determined independent variables. A correlation matrix was generated to illustrate the relationships between the outcome measures.

2.6.3. Regression analysis

Simple binary logistic regression analysis was performed to assess the association between falls (dependent variable categorized as fallers and non-fallers) and the independent variables. The odds ratios (p-values and 95 % confidence intervals(CI)) were presented in a forest plot. Those factors that were significant in simple binary logistic regression (POMA was excluded from the model as it will also assess the same domains of TIS) were further analyzed with multiple binary logistic regression to find the most significant factors for falls and to develop a model associating multiple variables with falls controlling for age, EDSS, and gender. The variables for multiple regression were checked whether they met the assumptions for logistic regression, cook distance was checked for any possible outliers, observations chosen were not from repeated measures, and multicollinearity between the factors was checked with correlation matrix ($r \leq 0.7$) and tolerance (≤ 0.1).

2.6.4. Receiver Operating Curve (ROC) analysis

ROC analysis was conducted to detect the TIS's diagnostic ability for determining falls. The Area Under the Curve (AUC) was determined, and the sensitivity and specificity of the cut-off value were determined using the Youden Index to distinguish fallers from non-fallers.

3. Results

3.1. Demographics

Seventy-two PwMS were screened for eligibility; Six were excluded for not meeting the criteria, and two withdrew due to time constraints. Consequently, 64 PwMS were included in the analysis. The median age of the subjects was 33 (20–60) years, with EDSS scores ranging from 1 to 6. Of the participants, 72 % were female, and 47 % were classified as fallers (Table 1).

Table 1
Participant characteristics. RRMS = Relapsing-Remitting Multiple Sclerosis; EDSS = Expanded Disability Status Scale; POMA = Performance Oriented Mobility Assessment; MFES = Modified Falls Efficacy Scale; MFIS = Modified Fatigue Impact Scale; HADS = Hospital Anxiety Depression Scale; TIS = Trunk Impairment Scale.

Variables	**Total (n=64)**	**Fallers (n=30)**	**Non fallers (n=34)**	**P value**
	Frequency (%)			
Gender (M/F)	18 (28.1)/46 (71.9)	10 (33.3)/20(66.7)	8(23.5)/26(76.5)	0.41
MS Type (RRMS)	65 (100)			
Falls (NO/YES)	34 (53.1)/30 (46.9)			
	Median (Range)			
EDSS	2 (1–6)	4.25 (1–6)	1.5 (1–5)	0.001
Age (Years)	33 (20–60)	35 (23–60)	32 (20–44)	0.63
POMA Balance	14 (6–19)	12 (6–16)	15.5 (11–19)	≤0.001
POMA Gait	11 (4–12)	9 (4–12)	12 (6–12)	0.07
POMA Total	25 (11–28)	20 (11–28)	27 (16–28)	0.002
MFES	109.5 (14–140)	97.5 (14–140)	125 (75–140)	≤0.001
MFIS	44 (0–86)	53 (16–86)	31.5 (0–73)	0.003
HADS Depression	6 (0–20)	8 (0–20)	4 (0–12)	0.001
HADS Anxiety	7.5 (0–18)	9 (1–15)	6 (0–18)	0.45
HADS Total	15 (0–33)	16.5 (2–33)	10 (0–27)	0.01
TIS	15 (4–23)	12.5 (4–21)	16 (9–23)	0.003

3.2. Correlation

Spearman's correlation was selected, as the data were not normally distributed. The correlation between the different outcome measures is presented as a matrix (Fig. 1).

3.3. Regression

The analysis revealed that the following factors were significantly associated with falls in PwMS: TIS (OR = 0.75, p = 0.001, 95 % CI; 0.63 to 0.88), POMA (OR = 0.75, $p \leq 0.001$, 95 % CI; 0.65 to 0.87), MFES (OR = 0.96, $p \leq 0.001$, 95 % CI; 0.93 to 0.98), MFIS (OR = 1.05, p = 0.002, 95 % CI; 1.02 to 1.08), and HADS (OR = 1.09, p = 0.01, 95 % CI; 1.02 to 1.17) (Fig. 2).

The multiple logistic regression model identified two significant factors related to falls: TIS (OR = 0.78, p = 0.007) and MFES (OR = 0.96, p = 0.005) (Table 2).

3.4. ROC curve

The area under the curve (AUC) for the TIS was 0.77, with a significant p-value of 0.0001 and a 95%CI of 0.65–0.89. The cut-off point of the TIS was 15.5, which had 73 % accuracy in detecting positive cases (fallers) and a specificity of 66 %. (Fig. 3)

4. Discussion

This study primarily aimed to identify the impact of trunk impairment using the TIS and other factors—including gait, balance, fatigue, fear of falling, and depression—on falls in PwMS. All identified factors are significantly associated with falls in PwMS. Notably, trunk impairment and fear of falling emerged as the most significant factors associated with fall in PwMS.

In line with this study, multiple others have demonstrated that PwMS classified as fallers exhibited balance impairments [61–63]. Notably, research has shown that balance can be improved through training interventions [64,65]. However, balance training alone may not significantly affect fall outcomes [66]. Therefore, incorporating balance training into a rehabilitation program, alongside addressing both the physical and psychological aspects of falls [10], could positively impact fall outcomes in PwMS.

Consistent with our findings, gait impairment has been linked to falls in neurological disorders. Decreased step length and reduced speed are the most robust predictors of falls [67], and these are prominent characteristics of PwMS [15]. PwMS likely adopt a reduced speed and shorter steps either to compensate for gait instability [16,68]or due to their fear of falling [69,70].

Fear of falling, a significant factor in the final model, has been associated with falls in previous studies[11,71,72]. It is linked with several motor changes, such as reduced gait speed, short stride, and increased sway [12], as well as coordination issues [73]. Additionally, fear of falling affects non-motor aspects, including sleep disorders and cognitive impairments [74], particularly in attention [75]. Diminished cognition can lead individuals to engage in risky behaviors, impair their situational judgment, and ultimately result in falls [76]. Individuals with a fear of falling often decrease their activity levels in an attempt to minimize falls [77,78], which could contribute to muscle function deterioration [79,80]. Consequently, it has been suggested that management of fear of falling should be incorporated into fall prevention programs [12,71]. Dual-task training is a potential method to reduce the fear of falling in older adults, combining cognitive exercises with motor components simultaneously [81]. In addition to behavioral changes, reductions in brain

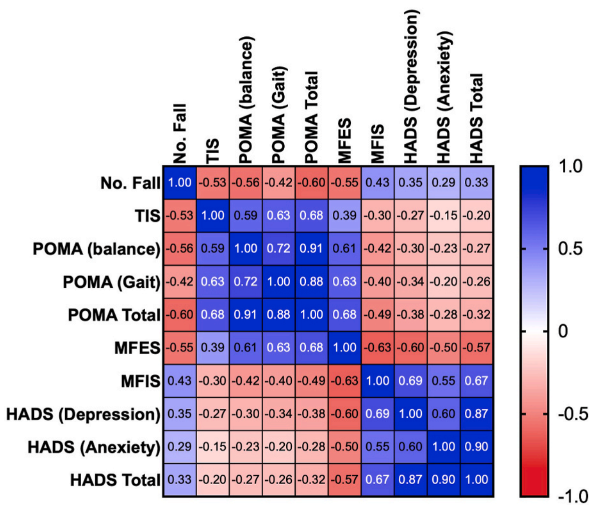

Fig. 1. Correlation matrix of the number of falls with different variables.
POMA = Performance Oriented Mobility Assessment; MFES = Modified Falls Efficacy Scale; MFIS = Modified Fatigue Impact Scale; HADS = Hospital Anxiety Depression Scale; TIS = Trunk Impairment Scale.

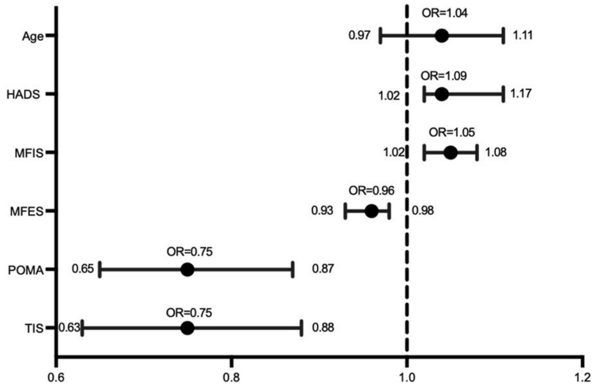

Fig. 2. Forest plot of factors affecting falls in PwMS.
POMA = Performance Oriented Mobility Assessment; MFES = Modified Falls Efficacy Scale; MFIS = Modified Fatigue Impact Scale; HADS = Hospital Anxiety Depression Scale; TIS = Trunk Impairment Scale.

Table 2
Multivariable logistic regression on the association between different factors affecting falls in PwMS.

Variable	B	95 % CI for B		SE B	β
		LL	UL		
Step 1					
Constant	4.76			1.46	
MFES	−0.05	0.93	0.98	0.01	0.95
Step 2					
Constant	7.76			2.07	
TIS	−0.24	0.66	0.94	0.09	0.78
MFES	−0.04	0.94	0.98	0.01	0.96

CI = Confidence Interval, LL = Lower Limit, UL = Upper Limit, MFES = Modified Falls Efficacy Scale; TIS = Trunk Impairment Scale.

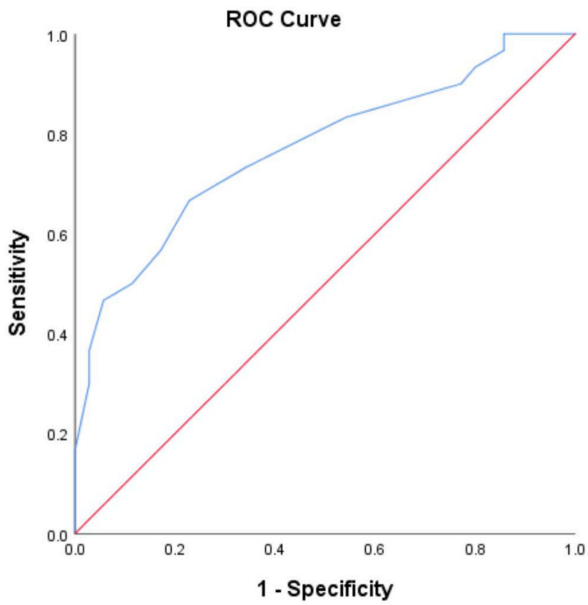

Fig. 3. ROC with AUC of TIS in determining falls.ROC = Receiver Operating Curve; AUC = Area Under the Curve; TIS = Trunk Impairment Scale.

volume have been observed in individuals fearful of falling, with notable negative correlations in areas related to executive and motor functions, as well as visual processing, in relation to falls [82]. These changes could perpetuate the cycle of falls and fear of falls.

Fear of falling and depression are considered psychological factors related to falls [79,82]. Depression has both direct and indirect relationships with falls, with the indirect relationship mediated through cognitive and motor slowing [34]. Additionally, in the current study, depression demonstrated a high correlation with fatigue, supporting findings by Sparasci et al. (2022) [83] and Ghajarzadeh et al. (2012) (21). PwMS who exhibit high levels of fatigue also show impaired balance, an increased fear of falling, reduced physical activity, and a higher risk of falls [24]. These relations show how factors related to falls are intertwined and contribute to falls in a vicious cycle [79,84].

In the current study, trunk impairment was linked to falls. The trunk provides distal body segments with a stable base for controlled movement [40] and acts as a force generator, where a small force generated at the trunk translates into a larger distal movement [40]. Movement and force generation is crucial when taking a step, serving as a normal balance strategy to prevent falls [85]. Deterioration in core stability is apparent in PwMS [86], along with alterations in trunk and foot acceleration [87], which may explain the challenges in withstanding gait perturbations in PwMS [88], potentially leading to falls. Balance training focused on core stability has been shown to improve balance, gait capacity, and reduce fear of falling in PwMS(43), thus highlighting the link between trunk, balance, and falls. Commonly used outcome measures for assessing balance, such as the Berg Balance Scale and POMA, include elements that test trunk function, which supports the premise of our findings. Moreover, the current study demonstrated that TIS could differentiate fallers from non-fallers with an AUC of 0.77, compared to an AUC of 0.71 reported by Hoang et al. (2014) for a three-factor model [89], underscoring the significance of the TIS in predicting a substantial proportion of falls.

The current study underscores the potential predictive value of various outcome measures related to MS on falls, using simple-to-administer and free-to-access, which can be utilized by clinicians caring for PwMS. By incorporating these factors into rehabilitation programs, clinicians can design tailored interventions to prevent falls. Additionally, this research provides a better understanding of the TIS and its interpretation in PwMS. However, several limitations of the study are noteworthy. Due to time constraints, a prospective cohort study design was not feasible. As participants were selected from a single location, the study did not include individuals with various types of MS. Furthermore, the researchers were not granted permission to access complete medical files, resulting in limited knowledge regarding the participants' medication regimens. Additionally, the study lacked an objective outcome measure for assessing gait speed, a crucial component affecting PwMS.

We recommend future research to explore these findings across different MS types. As evidenced in this and prior studies, numerous factors of falls have been identified. Further research could investigate the connection between these factors and brain imaging to yield more definitive insights into the factors contributing to falls.

5. Conclusion

This study highlighted the importance of trunk impairment, tested by the trunk impairment scale, and fear of falling as significant factors of falls in PwMS. Additionally, it demonstrated that fatigue, depression, balance, and gait also serve as factors related to fall risk in this population, which should be addressed during the assessment and management of PwMS.

CRediT authorship contribution statement

Noura Alzahrani: Writing – original draft, Software, Resources, Methodology, Data curation, Conceptualization. **Orjuwan Bamutraf:** Writing – original draft, Software, Resources, Methodology, Data curation, Conceptualization. **Shatha Mukhtar:** Writing – original draft, Software, Resources, Methodology, Data curation, Conceptualization. **Aseel Mazi:** Writing – original draft, Software, Resources, Methodology, Data curation, Conceptualization. **Adel Jawad:** Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Data curation. **Areej Khan:** Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Data curation. **Abdullah Mohammad Alqarni:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Reem Basuodan:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis. **Fayaz Khan:** Writing – review & editing, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

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Data availability statement

The data is not publicly available because further manuscripts are being prepared. Data for the present study will be made accessible upon reasonable request from the principal investigator or corresponding author.

Declaration of generative AI scientific writing

The authors have used AI to check for grammatical and spelling mistakes and to improve the flow of the text.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Reem Basuodan reports financial support was provided by Princess Nourah bint Abdulrahman University. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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