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Review Paper

Functional Balance Tests for Patients with Multiple Sclerosis: A Review Study

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ABSTRACT

Background: Knowledge of the functional balance tests for the patients with Multiple Sclerosis (PwMS) may provide useful and accurate information about the balance function of these patients under different situations.

Objectives: This study aims to review the functional balance tests for PwMS.

Materials and Methods: This is a systematic review. The search was conducted in PubMed, Scopus, LILACS, CINAHL, CENTRAL, Web of Science, PEDro, and Google Scholar databases on relevant studies published until November 2021.

Results: Twenty-five articles and 25 different tests were found to evaluate the functional balance of PwMS. It was found that the studies used 6 tests to assess the static balance, 13 tests to assess dynamic balance, and 6 multi-item tests to assess functional balance in PwMS. Single-leg stance test, balance error scoring system test and steady stance test is a test battery for static balance; six-spot step test, timed up and go test, and figure-of-8 hop test are better for dynamic balance, and the balance evaluation systems test is a better multi-item test to assess the balance of PwMS by examining the postural control components.

Conclusion: Single-limb standing test, balance error scoring system (BESS) test and steady stance test provide accurate data on static balance; six spot step test, Timed Get up and go test and figure-of-8 hop test provide valuable data on the dynamic balance and Balance Evaluation Systems Test (BESTest) is a valid test to assess the balance of PwMS from the perspective of the review of posture control components.

Keywords: Multiple Sclerosis, Postural balance, Neuropsychological tests

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Highlights

- Twenty-five functional tests were found to evaluate the functional balance of PwMS.
- Functional balance tests included static balance, dynamic balance and multi-item balance tests.
- Single-leg stance test, Balance Error Scoring System test and steady stance test is test battery for static balance of PwMS;
- Six-spot step test, timed up and go test, and figure-of-8 hop test is test battery for dynamic balance of PwMS;
- Balance evaluation systems test is a valid multi-item test for functional balance of PwMS

Introduction

Multiple Sclerosis (MS) is a common inflammatory disease of the central nervous system [1, 2]. The number of patients with MS is increasing such that there are 2.5 million people affected by this disease globally [3]. In Iran, 15-30 in 100,000 people are suffering from this disease. Women are twice as likely to have MS as men [4]. A systematic review and meta-analysis in 2019 on the epidemiology of MS in Iran showed that the high prevalence of MS in Iran [5]. The age at onset of MS is 20-40 years and may occur from age 20 to 80 [6]. The main cause of MS is unknown. Immunological, genetic and environmental factors seem to be effective in its occurrence [7]. The symptoms of MS include fatigue, tremors and diplopia, gait and mobility problems, and poor balance, which can be exacerbated by decreased physical activity [8]. Among these factors, poor balance is associated with the increased risk of falling or even fear of falling, which reduces self-satisfaction and self-confidence, and cause dependency in performing daily activities of life [9]. Therefore, the importance of balance in increasing the quality of life of people with MS should not be neglected, because balance is the basic precondition for most activities of daily living [10].

Inability to maintain balance affects the simplest daily activities of Patients with MS (PwMS) such that simple activities such as standing and walking become challenging and prevent them from using the locomotor system [11]. Balance tests are used for the identification and classification of balance disorders and subsequently, evaluate the effect of exercise programs on motor function and balance in MS patients. Therefore, knowledge of balance tests used to evaluate MS patients is essential.

Different studies use different tools and methods to measure the balance in different populations. Balance is measured quantitatively (quantitative posturography) or by functional tests [12]. The advantage of functional tests is that they require neither advanced and expensive equipment nor specialized and skilled staff for the interpretation and understanding of the outcome. The validity of these tests for assessing balance and their appropriateness for a particular group is very important. Therefore, in using these functional tests for balance, we should be very careful and have a clear understanding of the study group, because if the selected test is not appropriate for assessing the balance in a particular group, incorrect data can be reported. It is, therefore, important to determine what kind of functional tests could assess functional balance in PwMS. Studies have had a general look at the functional balance tests in PwMS; this general perspective can lead to more detailed and better knowledge of these tests to determine which of them provides more accurate data and have higher validity in functional evaluation of balance in PwMS. Therefore, this review study aims at compile functional balance tests in PwMS.

Materials and Methods

Search strategy

A search was conducted in eight databases of PubMed, Scopus, LILACS, CINAHL, CENTRAL (Cochrane Central Register of Controlled Trials), Web of Science, PEDro, and Google Scholar on studies published until November 2021. A manual search and a full review of the reference section of the found articles were also performed. Search was performed in databases using the following keywords: "balance control" or "center of pressure" or "balance" or "postural stability" or "postural balance" or "postural sway" or "stability" or "static balance" or "dynamic balance" and "functional tests" or "physical examination" or "functional performance tests" or "lower extremity tests" and "Multiple Sclerosis" or "MS" or "demyelinating diseases". After searching, the titles and abstracts of articles were examined based on meeting inclusion criteria and relevance to the research objectives.

Inclusion and exclusion criteria

First, the titles and abstracts of found articles (descriptive studies in English or Persian on functional balance tests that were performed without advanced tools and methods to assess the balance in PwMS) were screened. Then, the articles' full texts were examined according to the study variable (functional balance tests) and target population (PwMS). The final list of selected articles were re-checked to ensure that they were in line with the research objective. The studies that had not been conducted on PwMS, those with poor methodology, performed on other functional tests (physical fitness tests), used questionnaire to assess the balance in individuals, and those used laboratory tools that could not be classified as functional tests were excluded from the study. Figure 1 presents the flowchart diagram of screening process.

Exclusion criteria consisted of articles that had not used the statistical population of PwMS, articles in which the methodology was not well described, articles that were performed on other functional tests (physical fitness tests), articles that used questionnaire to assess the balance in these individuals, and articles that used precision laboratory tools and could not be classified as functional tests.

Quality assessment and data extraction

Risk of bias was evaluated by two reviewers using the Newcastle-Ottawa Scale (NOS) for cross-sectional studies Error! Hyperlink reference not valid.based on Herzog et al.'s [13] form. Quality of studies was classifiedError! hyperlink reference not valid. as very good (9-10 stars), good (7-8 stars), satisfactory (5-6 stars), and unsatisfactory (0-4 stars). Data from studies were extracted independently by researchers which included: the name of functional test, validity, reliability, description of functional tests, and quality based on NOS (Table 1).

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Results

The initial search in online databases yielded 456 titles. Manually searching and reviewing the resources led to the finding of 10 more titles. After removing duplicates, 301 articles were remained. After checking the titles and abstracts of articles, 76 articles were removed and 225 were selected for examining the full texts. Finally, 21 articles that evaluated the functional balance of PwMS were selected for review (Figure 1). Based on results of NOS, studies that were systematically reviewed had desirable qualities: 10 study (40%) had very good quality; 8 studies (32%) had good quality, and 7 studies (28%) had satisfactory quality. Therefore, the articles that were systematically reviewed in this study had very good to satisfactory quality. By careful examination of the tests used to assess the functional balance of PwMS, it was found that studies had used 6 tests to assess static balance, 13 tests to assess dynamic balance, and 6 multi-item tests to assess functional balance in PwMS. The test results are detailed in Table 1.

Discussion

The purpose of the present study was to review the functional balance tests in PwMS to determine what kind of balance tests are suitable for assessing static, dynamic, and functional (from the perspective of postural control systems) balance in PwMS. Twenty-five articles were found that had examined the functional balance in PwMS using 25 tests; 6 static balance tests, 13 dynamic balance tests, and 6 multi-item balance tests.

In general, the purpose of static balance tests is to evaluate three sensory systems (visual, vestibular, and somatosensory) that have a major role in postural control. Different tests use different methods to evaluate each of these systems, but it is necessary to consider the target population; some of these tests may not be able to accurately assess the static balance in a population. The test conditions may be either too hard to be performed by a target population or too easy and may not accurately assess their static balance. Various methods have been used in PwMS for evaluating each sensory systems. In some tests, the patient is asked to be in heel-to-toe position [14], stand on one leg [12], or be in a tandem stance (right foot in front of the left foot) [15]. There were some studies that examined the balance in all three mentioned states together in different sensory states [12, 16].

The central nervous system is impaired in PwMS [34], any sensory systems with a role in postural control may be impaired [35]. Therefore, to assess balance

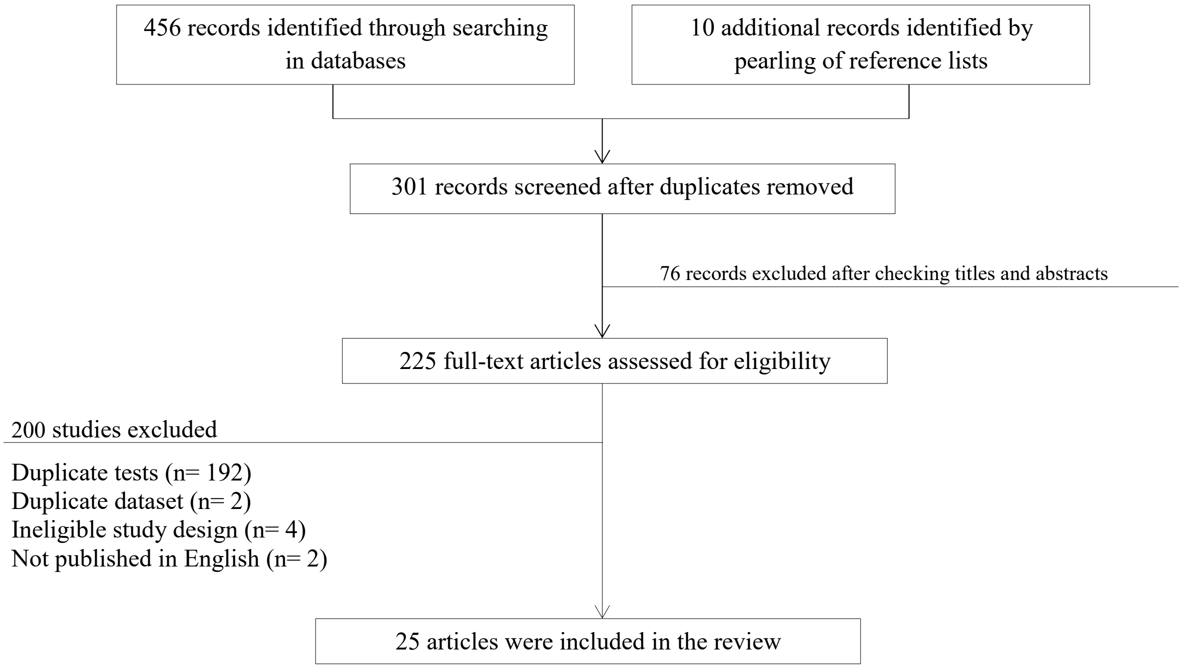

Figure 1. Flowchart of screening process

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in this population, it is better to use static balance tests that are separately conducted to examine the sensory systems so that the therapist could have more detailed information about the involvement of these systems in PwMS. Single-leg stance test, Balance Error Scoring System (BESS) test, and steady stance test are some tests that separately evaluate the sensory systems of PwMS. Therefore, this test battery seems to provide more accurate information about the static balance of PwMS. One of the complexities of functional tests is that they can be manipulated. In reviewing 6 static balance tests, we found that one test had been used differently in multiple articles. Some studies had considered the standing time as a balance score for the patient, while other studies considered the number of errors in 30 or 20 seconds as the score of static balance. Therefore, extreme care should be taken in comparing and interpreting the balance performance in different populations.

Reviewing the dynamic balance tests for PwMS, we found that the tests had not been performed under sensory system manipulation; all had been performed in a state where the somatosensory system was available. Dynamic balance tests can further assess neuromuscular coordination and locomotor control [36]. One method for assessing the neuromuscular system and the locomotor control is the gait test. Several gait tests had been used to assess gait speed, neuromuscular coordination, and the control system of PwMS [23, 26-28, 33]. Among the gait tests, some take into account the low extremity muscle endurance, such as the 6-minute walk test [27], or 10-meter and 12-meter walk tests aimed to examine the muscle strength of the lower limbs and individual speed [23, 26-28, 33]. There were also some gait tests to assess the cognitive system and locomotor function in PwMS [24, 29, 31]. Since one of the reasons for reduced locomotor function and falling is the dysfunction of the cognitive system [37], some dynamic balance tests for PwMS are designed to assess this system. It seems that all dynamic balance tests have the same validity and reliability in evaluating the locomotor function of PwMS, but the Six-spot step test, timed up and go test, and figure-of-8 hop test not only evaluate the locomotor function, but also challenge the cognitive system. These tests provide more valuable data about the dynamic balance of PwMS.

Multi-item balance tests are functional tests that postural control components using several items. These tests are selected with respect to the target population. One of these tests for PwMS was the Berg Balance Scale [20]. It is the most commonly used clinical test that has many items similar to the Tinetti test [38]. This scale, however, has some limitations such as not assessing the reactive postural control (e.g., response to a disturbance) [39], poor responsiveness [40, 41], only 53% sensitivity (number of correctly detected falls) and ceiling effect [40]. This test cannot be used to assess the balance function of active PwMS, those with high motor activity. The Dy-

Table 1. Functional balance tests for PwMS reported in reviewed studies

Static Balance Test	Reliability	Validity	Descriptions	Quality
Romberg Test [14]	0.87	0.87	The person is asked to stand for 30 seconds on two parallel legs with eyes open and closed. The balance time and the number of sways are assessed in the same situation and excessive sways are considered as abnormal balance or gait abnormality. If a person can maintain balance with eyes open but not with eyes closed, it indicates a problem in using sensory-physical information. The time that the person is able to maintain balance is considered as the test score.	Good
Sharpened Romberg Test [15]	0.90-0.91	0.78	The person stands on a flat surface with bare feet where the dominant foot is in front of the non-dominant foot (heel-to-toe position). The arms are crossed over the chest with open palms resting on opposite shoulders. This test is performed with the eyes closed and open. The time that the subject is able to maintain balance with eyes closed is considered as the test score.	Very good
Steady stance test [16]	0.86	0.79	Steady stance tests are assessed using a digital stopwatch. These tests are performed when the patient balanced for up to 30 seconds without external support. These tests are performed with eyes open and closed and bare feet.	Very good
Single-leg stance test [12]	0.91	0.87	This test measures the efficiency of sensory system involved in postural control. The subjects are tested for postural control in four different sensory states. The four different sensory states in this test include the following: one-leg stance on a stable surface with eyes open without any sensory interference, one-leg stance on an unstable foam surface performing hyper-extension of the head, one-leg stance on a stable surface with eyes closed and hyper-extension of the head, and one-leg stance on an unstable foam surface with eyes closed. In each position, the subject's hands are placed on the waist. Each position is performed for 20 seconds and the total number of errors is considered as the test score.	Satisfactory
Balance error scoring system (BESS) [12]	0.50-0.82	0.76	In BESS, three different standing positions are selected on two hard and soft surfaces. The duration of each postural balance is 20 seconds with a 15-second rest interval between repetitions. The total number of errors in performance is considered as the test score.	Satisfactory
One-leg stance test [12]	0.95	0.69	In this test, the subject stands on one leg for 30 seconds and the total number of errors is calculated as the test score. It has been found that the number of errors on a sprained ankle is different from that of a healthy ankle.	Good
Multi-item balance tests	**Reliability**	**Validity**	**Description**	**Quality**
Dynamic gait index [17]	0.98	0.89	The tool includes 8 common items: Changing speeds, head turns in horizontal and vertical directions, stepping over and around obstacles, stair ascent and descent, and walking and turning 180 degrees to stop. Each item is rated on a 4-point ordinal scale as 3=normal gait, 2=minor impairment, 1=moderate impairment, and 0=severe impairment. The highest possible score is 24. The dynamic gait index takes about 10 minutes to complete with no need for more equipment. The subjects perform the movements in an 6-m area, with 9-cm length and 38-cm width.	Very good
Balance evaluation systems test (BESTest) [18]	0.89	0.79	The BESTest has 27 tasks in 6 parts for both sides of the body and a total of 36 items. Each item is scored from 0 to 3; higher score shows the better performance. The maximum score for this test is 108. Equipment required for BEStest includes a 10-degree ramp, a 60×60 cm box with an average density of 10 cm, a DVD containing exercises and a 17-cm high stair step and a 25-cm high obstacle. A 2.5-kg weight is also used for arm raise while standing in different positions.	Satisfactory
Tinetti balance and gait assessment tool [19]	0.91	0.87	The tool has 16 items, 9 for balance and 7 for gait assessment. The items are scored on a three-point ordinal scale from 0 to 2 where 0 indicates the most damage, and 2 indicates independence. The maximum total score of the test is 28.	Satisfactory

Multi-item balance tests	Reliability	Validity	Description	Quality
Berg balance scale (BBS) [20]	0.98	0.99	The BBS assesses the functional performance of balance with 14 items related to simple movements (such as moving, standing unsupported, sitting, and etc.) as well as more difficult movements (such as standing, turning 360 degrees, and one-leg standing). The total score is 56, indicating the balance at the highest level.	Satisfactory
Fullerton advanced balance scale [21]	0.93	0.86	This test has 10 items with a total score of 40 and cut-off point of 25, indicating its sensitivity and specificity in predicting the risk of falling in the elderly. There is a 5-point scale (0-4) where a high score indicates better performance.	Satisfactory
Activities-specific Balance Confidence (ABC) scale [22]	0.92	0.87	The ABC scale determines the confidence of person in performing 16 activities of daily living without losing balance. The scoring is from 0 (no confidence) to 100 (full confidence).	Very good
Dynamic balance tests	Reliability	Validity	Description	
Functional gait assessment [23]	0.84	0.77	In this test, scoring is based on maintaining normal gait speed, walking with normal steps and staying at a 0.83-cm width walkway without stumbling.	good
Figure-of-8 hop test [24]	0.86	0.75	In this test, the subject hop in figure-of-8 over 5-m distance. The total execution time is recorded at the end; shorter time indicates better performance.	good
Crossover hop test [25]	0.87	0.88	In this test, a line with a width of 0.5 cm and a length of 5 m is first specified. The person starts once with the dominant foot and once with the non-dominant foot behind the line. S/he performs four consecutive jumps with maximum force to cross over the line. Then the length of jump is recorded. The person is emphasized to move more along the specified line and try to have less deviation. At the starting point, the person stands on the opposite side of the test foot with respect to the transverse line (obstacle). In order to measure the distance for hop on the left lower limb, the person should stand on the dominant foot. This test is performed three times with an interval of one minute and the maximum distance is recorded. The distance from the starting point to the landing point in four consecutive jumps is considered as the distance traveled.	good
Self-generated perturbation test [16]	0.81	0.76	The method consists of three tests: functional reach test, arm raise test, and step test. In functional reach test, a person stands against a wall and brings one hand forward without bending. The distance is then marked. Next, the person is asked to stretch his/her hand forward as far as s/he can without moving. The difference between first and second reached distances is considered as the final distance. The arm raise test is used to measure the function of both upper limbs. The person stands with feet 10-cm apart and arms by their sides. The person is asked to life the arms and then back down to their side in 15 seconds. The number of arm raises is considered as the test score. The person should not upset his balance during this test. In the step test, the person is asked to climb up and down the stairs as much as s/he can in 15 seconds. The person first places one foot on the stair and then off the stair. The number of completed steps in 15 seconds is considered a the test score.	Very good
Timed 25-foot walk (25TFW) test [26]	0.96	0.92	The 25TFW is used to measure walking speed. In this test, the subject travels 25 feet and the amount of time is measured in seconds. A shorter time indicates a better performance.	Very good
6-minute walk test [27]	0.98	0.84	This test is very suitable for assessing balance because of its ease of execution and similarity to daily activities. This test is known as a valid tool for assessing the performance capacity. The person walks for six minutes and the maximum distance traveled is measured by a meter.	Good
Stair climbing test [16]	0.82	0.68	The subject is asked to stand on a step with 12.5 cm (5 inches) height and climb up and down the stairs as many times as possible for three minutes. The number of steps is then recorded.	Very good

Multi-item balance tests	Reliability	Validity	Description	Quality
10-meter walk test [28]	0.91	0.88	The test is performed in a place with heating, cooling, and ventilation systems and safe and smooth floor. A distance of 10 m is defined. The subject with appropriate cloths and footwear runs at the maximum speed when it is said "go". The time the subject takes to complete 10 meters is recorded using a stopwatch as the test score.	Very good
Six-spot step test (SSST) [29]	0.95	0.92	The SSST is a quantitative assessment of lower limb function over time. The size of the test field is 5 ×1 m; two lines are drawn one meter apart each with a length 5 m. The two lines should be parallel. As each side-line, two circles with a diameter of 20 cm at a distance of 1 and 3 m from end line, and two circles with a diameter of 20 cm at a distance of 2 and 4 m from end line are marked. Inside each circle, there is a block with a diameter of 8 cm, a height of 4 cm and a weight of 134 g; the starting and ending point of each circle is between the two lines. The person is instructed verbally to go in a crisscross pattern, with the inside and outside of the foot to shove the blocks out of the circle and reach the end point. The time for this test is considered as the test score. During the test, assistive devices can be used to perform the test safely, if needed.	Good
Functional reach test [30]	0.93	0.91	In this test, the patient stands against a wall and outstretch the arm forward. The reached distance is recorded. This distance indicates the risk of falling; a distance less than six inches indicates more risk for fall.	Satisfactory
Timed up and go test [31]	0.99	0.91	In this test, the subject stands up from a sitting position in a chair without armrests; after walking a three-meter distance in a straight route as fast as possible (without running), s/he returns and sits back on the chair. The time is recorded when the subject is instructed verbally to "go" and ends when s/he returns and sits back on the chair.	Very good
Sit-to-stand test [32]	0.95	0.84	In this test, the subject first sits in the middle of a chair without arms with a seat height of 17 inches (43.2 cm). The foot is approximately shoulder-width apart to help maintain balance. The arms are crossed over the chest. The subject is asked to practice once or twice before the test. If the subject used the arms to complete the test, s/he gets a score of 0. The subject is encouraged to perform the test as many stands as possible in 30 seconds. The person should sit fully. The number of correct stands in 30 seconds is counted. Wrong stands are not counted.	Good
12-m walking test [33]	0.87	0.90	In this test, the subject starts by standing behind the line and is asked to travel a distance of 12 m by the verbal command of "go" at a safe speed until reaching the line. The time takes to complete the distance is recorded. A shorter time, indicates better balance and physical performance.	Very good

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namic Gait Index was another multi-item test for PwMS [17]. It measures a person's ability to adapt to changes in environment, speed and head position while walking. This test has been designed based on a large number of gait adjustments that should occur when walking indoor and outdoor, and is the most challenging gait test for PwMS [42]. However, it is not superior to other scales in predicting the risk of falling in terms of properties [42]. The most recent multi-item test for balance assessment is the Fullerton Advanced Balance Scale [21]. This test is able to identify various balance problems and examines the systems that may be involved in these problems (e.g., sensory, musculoskeletal, and neuromuscular). This test uses more difficult static and dynamic balance items to avoid being influenced by the ceiling effect when used by more active patients. It is also more sensitive when is used to assess the effectiveness of an intervention [21]. If the purpose of balance test is to identify and treat the causes of balance impairment, it is important to examine a number of balance control tasks. The balance evaluation systems test (BESTest) is an example of a balance test with different tasks. This test was introduced by Horak et al. [43]. The test uses 6 main tasks to assess the posture control: Biomechanical constraints, stability limits, anticipatory postural adjustments, sensory orientation, postural responses, and gait stability. This test emphasizes the importance of these tasks in evaluation of balance [43]. The systems approaches in the clinical balance assessment seek to identify impaired components and mechanisms in balance control. Understanding the strategies used by the central nervous system to control the balance is important for the systematic analysis of balance impairment that affect each patient. This test can also help identify the causes of balance impairment. The framework of postural control system is useful in selecting tests to assess the balance and effectiveness of therapeutic interventions [44]. This framework is based on the need for evaluation of each component and case-by-case treatment [43]. Therefore, it seems that the BESTest is a better test to assess the balance in PwMS since it provides a complete review of posture control components.

This review study used a systematic search method but lacked quantitative evaluation of articles; therefore, the quality of the study depends on the quality of reviewed articles. Although most of the reviewed articles had been published in reputable international journals with acceptable quality, the necessary precautions should be taken in generalizing the results. Moreover, only articles in English and Persian were reviewed; there may be other relevant articles in other languages. Considering these limitations, it seems that future studies in this field should examine the quality of articles.

Conclusion

There were 25 tests to evaluate the functional balance of PwMS which include static balance, dynamic balance and multi-item balance tests. Single-leg stance test, the BESS, and steady stance test is a test battery that can separately evaluate the sensory systems involved in balance and can provide more accurate data about the static balance of PwMS. The six-spot step test, timed up and go test, and figure-of-8 hop test not only can evaluate the locomotor function, but also challenge the cognitive system and provides more valuable data about the dynamic balance of PwMS. Finally, the BESTest seems to be a better multi-item test to assess the balance of PwMS and examine the postural control components.

Ethical Considerations

Compliance with ethical guidelines

Since this is a review study, there was no need for ethical approval. The principles in writing the article were observed according to the COPE regulations.

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Authors' contributions

Conceptualization and Resources: All authors; Methodology and Investigation: Gita Asgharzadeh and Hamed Zarei; Writing-original draft, Writing-review & editing, Supervision: Parisa Sedaghti and Hamed Zarei; Funding Acquisition: Gita Asgharzadeh.

Conflict of interest

The authors declared no conflict of interest.

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