Use of the Mini-BESTest to Measure Balance
in People with Multiple Sclerosis

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Abstract

Balance impairments are common in Multiple Sclerosis (MS). The Berg Balance Scale (BBS) is widely used measure of balance in People with MS (PwMS), however it may not capture all domains of balance. The novel Mini-BESTest (MBT) assesses additional balance domains but relatively little research has been carried out investigating its use in PwMS. Therefore, we aimed to investigate the inter-rater reliability of the MBT and also to compare it to the BBS, as a measure of balance post treatment, in ambulatory PwMS.

Fifty-two PwMS receiving out-patient physiotherapy were included. All mobilised independently with or without an aid and gave demographic details, prior to completion of the MBT with two different raters. Participants then completed the BBS and five other secondary measures before and after 8 weeks of routine physiotherapy.

For the inter-rater reliability analysis of the MBT, the intra class correlation coefficient was high, the standard error of the measure was less than 10% of the scale, and the Minimal Detectable Change (MDC) was 7. Reasons for a higher MDC in this study compared to other studies may be the difference in populations investigated, sample sizes used, means reported or the difference in experience or number of raters used, for the MBT

Using pre and post treatment data for the BBS and MBT, the MBT demonstrated less ceiling effects, larger effect sizes, higher standard response mean values and higher correlation coefficients for each secondary measure after treatment. These data suggests there is a strong agreement between two raters for the MBT and also provides preliminary evidence that the MBT may be a better measurement for detecting balance change in ambulatory PwMS, compared to the BBS.
Declaration

I declare that this thesis is entirely my own work and that it has not been submitted as an exercise for a degree at this or any other University. I am the author of this thesis and the principle author of the two articles, which form the core of the thesis.

________________________________________ (Printed Name)

________________________________________ (Signature) Date / /
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List of Abbreviations

Activities specific Balance Confidence (ABC) Scale
Analysis of Variance (ANOVA)
Area under Curve (AUC)
Confidence Intervals (CI)
Dynamic Gait Index (DGI)
Effect Size (ES)
Falls Efficacy Scale (FES)
Functional Reach Test (FRT)
Global Rating of Change scales (GRC)
Intra Class Correlation coefficient (ICC)
Minimally Clinical Important Difference (MCID)
Minimal detectable change (MDC)
Multiple Sclerosis (MS)
Multiple Sclerosis Impact Scale -29 (MSIS-29)
Parkinson Disease (PD)
People with Multiple Sclerosis (PwMS)
Rater one (R1)
Rater two (R2)
Receiver Operating Characteristic (ROC)
Relapse-Remitting Multiple Sclerosis (RRMS)
Standard Deviation (SD)
Standard Error of Measurement (SEM)
Standard Response Mean (SRM)
The Balance Evaluations Systems Test (BT)
List of Abbreviations

The Berg Balance Scale (BBS)
The Dizziness Handicap Inventory (DHI)
The Four Step Square Test (FSST)
The Mini-BESTest (MBT)
The Modified Fatigue Impact Scale (MFIS)
The Multiple Sclerosis Walking Scale-12 (MSWS-12)
The Six-Minute Walking Test (6MWT).
Timed Up and Go Test (TUG)
World Health Organization (WHO)
United Kingdom (UK)
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Chapter 1: Introduction to thesis
1.1 Introduction

The aim of this introduction chapter is to provide an overview of balance and its outcome measures in Multiple Sclerosis (MS). The first section of this introduction concentrates on balance including prevalence, causes, outcome measures and interventions. The second section gives an overview of important components to consider when choosing an outcome measure, including reliability, validity and ability to detect change (responsiveness). Therefore, this introduction will provide a platform to present the two papers of this thesis. Paper I is titled “The inter-rater reliability of the Mini-BESTest (MBT) in ambulatory people with MS (PwMS)”. Paper II is titled “Comparison of the MBT and Berg Balance Scale (BBS) in ambulatory PwMS”. The thesis will conclude with a conclusion chapter that makes recommendations for clinical and research practice.

1.2 Balance

Prevalence

In a sample of Irish PwMS (n=293), balance was the most commonly reported problem (Coote et al. 2010). Similarly, an UK longitudinal cohort study (Zajicek et al. 2010) found that 75% of their sample of PwMS (n=267) reported balance impairment. In another survey of PwMS (n=1011), loss of balance was also a common symptom (Larocca 2011). Therefore, balance impairment is common in MS. Interestingly, balance impairment can occur even in mildly impaired PwMS (Martin et al. 2006, Findling et al. 2011). Balance improvement is an important goal of rehabilitation as not only do PwMS commonly cite balance impairment as a key problem it also has be shown to be significantly associated with falls status (Gunn et al. 2013).
Balance or postural instability is “the ability to control the center of mass in relationship to the base of support” (Shumway-Cook and Woollacott 2012). Postural orientation is defined as “the ability to maintain an appropriate relationship between body segments” (Shumway-Cook and Woollacott 2012). The postural control system aims to control our body’s position in space in order to maintain postural stability and orientation, which is dependent on the interplay of the individual, the task and the environment (Shumway-Cook and Woollacott 2012).

MS, including its primary impairments and secondary consequences, can affect various body functions such as motor, sensory and cognition, all of which may negatively affect postural control (Cameron and Nilsagard 2013). Balance is complex and involves many interacting systems (Shumway-Cook and Woollacott 2012) which can be grouped into the three following main processes: (A) Neuromuscular processes (i.e. motor processes through the neuromuscular synergies and the musculoskeletal system), (B) Sensory/perception processes involving integration between various sensory systems and (C) Higher level processes (i.e. cognitive influences such as attention, motivation, intent, adaptive and anticipatory mechanisms).

(A) Neuromuscular processes

A systematic review by Cameron and Nilsagard (2013) reported the following four altered neuromuscular processes for postural control in MS: (1) Impaired spontaneous sway and decreased ability to maintain postural control in static positions (Corradini et al. 1997, Cattaneo and Jonsdottir 2009, Soyuer et al. 2006, Frzovic et al. 2000, Jacobs and Kasser 2012), (2) Impaired ability to activate postural muscles in
anticipation of movement (i.e. anticipatory postural adjustments (Soyuer et al. 2006, Jacobs and Kasser 2012, Frzovic et al. 2000, Martin et al. 2006)), (3) Impaired ability to modify, coordinate and adapt movements (i.e. reactive postural responses) (Frzovic et al. 2000, Diener et al. 1984)) and (4) Changes in perceived stability/vertical limits (Karst et al. 2005, Jacobs and Kasser 2012).

Furthermore, many altered gait parameters present in PwMS, such as abnormal muscle recruitment, reduced stride length, step and gait initiation which all may affect postural control (Cameron and Nilsagard 2013). It is also important to note other various impairments such as biomechanical constraints (Jacobs and Kasser 2012, Shumway-Cook and Woollacott 2012) when considering balance. Altered strength (Kasser et al. 2011), spasticity (Sosnoff et al. 2010, Nilsagard et al. 2009) and reduced joint mobility (Kelleher et al. 2010) additionally affect balance, falls risk and dynamic gait in PwMS. In summary, all the aforementioned neuromuscular processes, specific gait parameters and various other neuromuscular/musculoskeletal factors all affect postural instability (Shumway-Cook and Woollacott 2012).

(B) Sensory/perception processes

Impaired sensory perception and intergration processes affect postural control in PwMS (Cattaneo and Jonsdottir 2009, Daley and Swank 1983). Impaired sensory systems may include the visual, vestibular or somatosensory systems (Shumway-Cook and Woollacott 2012). Slowed somatosensory conduction (Cameron et al. 2008), reduced lower limb touch sensation, proprioception (Cattaneo and Jonsdottir 2009) and reduced visual inputs (Daley and Swank 1983) are all associated with impaired postural control in PwMS. Sensory impairments further may affect walking
and other functional tasks in PwMS (Cameron and Nilsagard 2013) though more research in this area is needed.

(C) Higher level processes

Impaired cognitive processes additionally affect postural stability (Shumway-Cook and Woollacott 2012). Many studies have suggested dual tasking (i.e. an addition of a secondary task) may result in reduced balance control and alteration of various gait parameters in PwMS (Cameron et al. 2008, Wajda et al. 2013, Hamilton et al. 2009, Jacobs and Kasser 2012). Impaired central integration (Cameron and Nilsagard 2013) has further been reported in PwMS. Sosnoff et al. (2013) demonstrated that PwMS classified as recurrent fallers exhibited slower cognitive processing speed than single time fallers, when assessed with the Paced Auditory Serial Addition Test and the Symbol Digit Modalities Test. Therefore, difficulties in prioritizing balance and slowed cognitive processing speed may reduce a PwMS ability to maintain postural control and result in increased falls (Wajda et al. 2013).

In summary, postural control facilitates the organization and integration of sensory systems, leading to selection, adaption and execution of appropriate motor strategies through the neuromuscular/musculoskeletal systems, leading to actions aiming to maintain postural control (Shumway-Cook and Woollacott 2012). In PwMS, it is important to consider various body functions, activity limitations and participation restrictions and to apply contextual factors, including environmental and individual personal factors when investigating balance (Cameron and Nilsagard 2013).
Outcome measures

This section will give an overview of the current balance outcome measures used in PwMS. One recent review (Sibley et al. 2014) reported that over sixty-six balance outcome measures are available for all populations. Many clinical, self-reported and instrumented balance measurements have too been used in PwMS (Cameron and Nilsagard 2013). A systematic review (Paltamaa et al. 2012) reported that the most common measures used in studies of PwMS were the Timed Up and Go test (TUG) (Podsiadlo and Richardson 1991), the BBS (Berg et al. 1992), Timed One-Leg Stance (Bohannon 1989), Functional Reach Test (FRT) (Duncan et al. 1990), Dynamic Gait Index (DGI) (Shumway-Cook and Woollacott 1995), The Dizziness Handicap Inventory (DHI) (Jacobson and Newman 1990), Activities Specific Balance Confidence (ABC) Scale (Powell and Myers 1995) and Falls Efficacy Scale (FES) (Tinetti et al. 1990). The BBS is currently the most commonly used measure in MS (Cameron et al. 2013). It's psychometric properties will be outlined at the end of this chapter.

Other less common measures used in PwMS, cited in another review (Cameron and Nilsagard 2013) include the Four Step Square Test (FSST) (Dite and Temple 2002), the Balance Evaluation Systems Test (BESTest) (Horak et al. 2009), the Mini-BESTest (MBT) (Franchignoni et al. 2010), the Physiological Profile Assessment (Lord et al. 2003), the TUG Cognition (Shumway-Cook et al. 2000) and the Tinetti Balance Scale (Tinetti et al. 1986). Additional instrumented devices such as Force Platform Measures have also been suggested as potential ways of measuring balance in MS (Prosperini and Pozzilli 2013).

Despite the large number of aforementioned balance tests used in PwMS, many authors (Cameron and Nilsagard 2013, Paltamaa et al. 2012) highlight many
limitations in the current balance measures. Force Platform Measures are suggested as a gold standard for measuring balance in neurological populations (Prosperini and Pozzilli 2013). However, debate exists with this consensus (Tyson and Connell 2009) as they don’t consider dynamic or functional tasks and their costs may also be prohibitive. Additionally, many clinically useful measures do not consider all the potential complex systems involved in postural control in PwMS (Sibley et al. 2014, Shumway-Cook and Woollacott 2012).

Sibley et al. (2014) found in the sixty-six balance measures they reviewed, all assessed motor systems, 71% assessed anticipatory postural control, 67% dynamic stability, 64% static stability, 48% sensory integration, 27% functional stability limits, 23% reactive postural control, 17% cognitive influences, and 8% verticality. Only one measure, the BESTest was reported to evaluate all components of balance. Cameron et al. (2013) suggested physical therapists in conjunction with other health care professionals use the World Health Organization (WHO) Classification of Functioning, Disability and Health (ICF) model, as a comprehensive way of investigating balance in PwMS. However, as the complex nature of postural control is continuing to be understood and developed (Shumway-Cook and Woollacott 2012), alternative and more comprehensive ways of measuring balance also need to be investigated. A systems approach to assessing balance appears feasible (Sibley et al. 2014) and for this reason the MBT, which address all systems, required for dynamic balance, is the focus of this thesis.
Psychometric properties of the BBS and MBT

As the MBT and BBS are both the focus of this thesis, this following section provides a brief overview of both measures current psychometric properties in MS. More details on this topic will be discussed in chapter 2 and 3 of this thesis.

The BBS

The BBS is a 14-item balance test. The total BBS ranges from a minimum score of 0 points to a maximum score of 56 points. The BBS demonstrated good test-re-test reliability (ICC=0.96) and inter-rater reliability (ICC=0.96) in a PwMS (Cattaneo et al. 2007). The BBS also demonstrated acceptable concurrent validity in MS (Cattaneo et al. 2006).

The MBT

The MBT (Franchignoni et al. 2010) is a 14-item balance test. The total MBT score ranges from a minimum of 0 to a maximum of 28 points. One study (Padgett et al. 2012) investigated inter-rater reliability in a mixed neurological population (n=20) including only four PwMS. ICC values of 0.985 for the BESTest, and 0.995 (.988 – .998) for the MBT were demonstrated. To the best of the authors’ knowledge no studies have investigated the inter-rater reliability of the MBT exclusively in ambulatory PwMS. The MBT has also shown acceptable concurrent validity (Cameron et al. 2014), with various outcomes measures including the ABC Scale (r = 0.70, p < 0.001), the MS Walking Scale-12 (MSWS-12) (r = 0.69, p < 0.001), the
Timed 25 foot walk test \( (r = 0.67, p < 0.001) \), Motor Control Test \( (r = 0.30, p = 0.04) \), Sensory Organization Test \( (r=0.65, p<0.001) \), and EDDS Scale \( (r = 0.61, p < 0.001) \) in PwMS \( (n=56) \).

**Interventions**

This section will consider the various balance interventions evaluated in PwMS. It will use the framework outlined by Shumway-Cook and Woollacott (2012) where a task orientated balance approach to improving balance, restoring function and maximizing participation is recommended. This approach aims to: (i) Address impaired body functions required for balance (e.g. strength training), (ii) Develop task specific strategies (motor/ sensory/ cognitive) and (iii) Retrain functional tasks during varying postural control demands under different environments. The following sections are divided into these three areas of balance interventions.

**(i) Impaired body functions required for balance**

Studies that have aimed to improve muscular strength in PwMS have reported improvements in balance. One study, (Sabapathy et al. 2011) investigating the effects of strengthening and endurance exercise interventions in PwMS, demonstrated both interventions significantly improved balance, as measured by the FRT, FSST and TUG. Another study (DeBolt and McCubbin 2004) included various lower limb strengthening tasks, such as raising from a chair, forward lunges, step ups, heel toe raises and leg curls. The intervention group \( (n=19) \) demonstrated significant improvements in lower limb strength and also a non significant balance improvement.
(i.e. on postural sway measures) when compared to a control group (n=17). The finding that exercise interventions incorporating resistance training results in an improvement in balance is confirmed by Paltamaa et al. (2012) in a systematic review and meta-analysis investigating the effects of physiotherapy interventions on balance in PwMS. The authors in that review concluded out-patient (OPD) and home exercise aerobic and resistance programmes compared to no treatment demonstrated a small but significant effect on balance.

(ii) Task specific strategies (motor, cognitive and sensory)

Task specific training is important in balance rehabilitation, as demonstrated by Gervasoni et al. (2014) where treadmill training did not augment balance improvements, as measured by the BBS and the DGI, compared to 12 weeks of conventional physiotherapy. The authors in that study suggested a potential reason for the adjunct of the treadmill training not influencing dynamic balance, was because subjects held onto the handrails during the treatment. Thus, dynamic balance was not challenged. This study therefore supports the need for interventions that focus on dynamic balance tasks if dynamic balance is the desired outcome. Therefore this next section considers various task specific strategies (i.e. motor, sensory and cognitive strategies) used in balance interventions.

The following studies have used either sensory or motor strategies or both. Prosperini et al. (2010) and Gandolfi et al. (2014) incorporated sensory strategies (i.e. computer visual feedback and sensory integration training) in balance intervention programmes which lead to improvements in balance. Hebert et al. (2011) investigated the effect of a vestibular rehabilitation program consisting of upright postural control, eye
movement exercises and dynamic balance exercises. The intervention group performed better on static balance testing (stabilometric platform) post intervention compared to control.

Cattaneo et al. (2014) evaluated balance rehabilitation incorporating motor and sensory strategies. The results showed an improvement in stabilometric platform measures and a reduction of falls in the challenging sensory context and not in the control group who received rehabilitation without a focus on sensory strategies. Cattaneo et al. (2007) randomly assigned inpatients with MS into two intervention groups (E1 and E2) and a control group which did not receive a specific balance rehabilitation intervention. E1 received balance exercises, focusing on sensory and motor strategies, while E2 received balance exercises, focusing on motor strategies only. E1 and E2 both demonstrated a small but significant effect on balance improvement compared to the control group on their BBS score. However, DGI scores only statistically improved in E1. The authors suggested sensory strategies may be important to include when aiming to improve dynamic balance.

In relation to cognitive strategies, one study (Kramer et al. 2004) compared three groups of PwMS. One group of PwMS, trained using a combination of Nintendo Wii Fit® while standing on unstable surfaces, the second group of PwMS trained only on unstable surfaces and the third PwMS group only trained with traditional balance exercises. Despite, all of the three groups demonstrating improved dynamic balance and gait parameters after three week intervention, only the group treated with Nintendo Wii Fit® training on unstable surfaces showed improvement in step to step variability during a dual task paradigm. The authors concluded rehabilitation strategies with a dual task paradigm appear thus a promising approach to increase dynamic balance. Therefore the above data presented in this section, suggests task
specific training involving various strategies (sensory, motor and cognitive) leads to balance improvements in PwMS as measured by a range of outcomes.

(iii) Functional tasks during varying postural control demands under different environments

This next section will discuss studies that have demonstrated positive effects on balance outcome due to various physiotherapy and exercise interventions, in different environments. Hogan et al. (2014) had three intervention groups (yoga, group exercise and one to one physiotherapy sessions) for PwMS who required a bilateral support for mobility. All groups demonstrated significant improvements in balance as measured on the BBS scale. The group physiotherapy intervention focused on balance and strengthening exercises using functional positions with the aim of targeting transitions and elements of walking. Sosnoff et al. (2014) devised a home-based exercise programme to reduce fall risk in PwMS, of whom 13 used no mobility aid, 14 unilateral and/or bilateral aids. Their home based exercise programme included lower limb/core muscle strength, balance and walking. Statistically significant improvements were seen in the intervention group compared to the control group for the BBS and timed 25 foot walk test. Thus, this section highlights that the use of functional tasks such as walking, transitional movements and functional balance exercises in various environments are important to consider when devising a balance intervention for a PwMS.

Other potential balance interventions such as whole-body vibration (WBV) training combined with exercises (Broekmans et al. 2010, Lord et al. 1998) and neurotherapeutic approaches, are outlined in a systematic review by Paltamaa et al.
(2012). However, Paltamaa et al. (2012) concluded that the current evidence for improving balance following such interventions in PwMS is insufficient.

In summary, balance treatments generally lead to positive outcomes and appear to be well tolerated by the PwMS. The optimal type of intervention for PwMS remains unclear and the majority of the research has been carried out in mild to moderately disabled PwMS. The evidence assembled here suggests that there is a need for more research incorporating balance rehabilitation programs that include all the specific motor, sensory and cognitive strategies. As discussed, balance is complex, thus rehabilitation interventions must include comprehensive strategies addressing all the appropriate impaired systems involved in achieving postural control in PwMS, in the context of the individuals’ environment and task. The effect of balance intervention on improving a PwMS participation in activities of daily living and on falls prevention is important, but outside the scope of this thesis.

1.3 Outcome measures

The psychometric properties of an outcome measure are important to investigate prior to clinical use. The reliability, validity and the ability to detect change are discussed in this next section.

Reliability

Reliability/agreement can be defined as the ability of a measurement to differentiate between subjects or objects and to which degree the scores or ratings are identical (Kottner et al. 2011). Reliability has been described as relative and absolute (Finch et al. 2002). A reliable measure is one that tends to produce the same results when
administered on two or more occasions under identical conditions (Fletcher et al. 1988).

The relative reliability of an instrument can be reported in three ways, inter-rater reliability, intra-rater reliability and internal consistency. The inter-rater reliability of a measure is discussed in Paper I of this thesis. The inter-rater reliability requires the same group of subjects to be measured at the same time by different observers. The inter-rater reliability of a measure can be analyzed using a two way random, single measure with absolute agreement Intraclass Correlation (ICC (2,1)) with 95% Confidence Interval (95%CI) and Bland and Altman analysis (Bland and Altman 1986). The ICC is an indication of variance due to error and Bland and Altman report an accurate method of assessing the degree of error between the sets of data either between raters or at different points in time over the full range of reported scores (Stokes 2011). Higher ICC value indicates higher agreement between measures (Portney and Watkins 2009). Values for ICC measures can be interpreted, for group comparisons, using the Portney and Watkins guidelines (Portney and Watkins 2009) where below .50 represents poor reliability, coefficient from .50 to .75 represent moderate reliability and above .75 suggests good reliability.

Absolute reliability is expressed as the Standard Error of Measurement (SEM), which is expressed in terms of the actual unit of the original instrument (Finch et al. 2002, Stokes 2011). The SEM can be calculated using the following equation: \( \text{SEM} = \frac{\text{SDdiff}}{\sqrt{2}} \). The SEM is a clinically applicable value based on the mean difference between raters and enables to determine the amount of change that is due to an intervention itself as opposed to measurement error. The SEM can be used to calculate the minimal detectable change (MDC), which is the minimal amount of change in the score of an instrument that must occur in an individual in order to be
sure that the change is not due to measurement error (Stokes 2011). MDC values are reported at 90% and 95% confidence levels. The MDC (95) can be calculated using the following equation: MDC = SEM × 1.96√2.

Additionally in relation to inter-reliability, the kappa coefficient (k) can be calculated. It corrects for chance agreement by calculating the extent of agreement that could exist between raters by chance. The weighted kappa (Cohen’s Kappa, Kw (Cohen 1988)) and percentage agreement extends this concept and allows for partial agreement between raters (Stokes 2011). Percentage agreement and weighted kappa were used in Paper I of this thesis to investigate levels of agreement for individual items of the MBT. ICC (3,1) values can be computed and expressed as the quadratic weighted kappa, as outlined by Fleiss and Cohen (1973). The classification of reliability for categorical data proposed by Landis and Koch (1977) can be used for Kappa <0: poor, 0.00-0.20: slight, 0.21-0.40: fair, 0.41-0.60: moderate, 0.61-0.80: substantial, 0.81-1.00: almost perfect agreement.

Percentage agreement can also be used in reporting reliability. For percentage agreement, the Landis and Koch (1977), as cited in Portney and Watkins (2009), recommended classification can be used: values below 40% represent poor to fair agreement, from 40% to 60% moderate agreement, above 60% substantial level of agreement and above 80% excellent agreement (Landis and Koch 1977).

In summary, reliability is an important psychometric property to investigate as it gives an indication of the amount of error that may exist in a measure (Stokes 2011). Reliability between physiotherapists is particularly important as a range of physiotherapists may assess PwMS over the course of their lives.
Validity

The validity of a measure is its ability to measure what it is intending to measure (Finch et al. 2002). Many types of validity exist such as criterion, construct, convergent, face and content validity (Finch et al. 2002, Stokes 2011). The face validity of a measure is whether or not it does assess what it intends to assess (Stokes 2011). The content validity of a measure is its items ability to reflect the overall aim of the measure (Stokes 2011). Construct validity, including convergent and discriminant validity may be useful in developing various ongoing hypotheses about the measure where a series of constructs may be used (Stokes 2011). Criterion validity (concurrent or predictive) investigates the performance of the measure compared to a gold standard. When a gold standard does not exist, well-established accepted measures may be used (Stokes 2011). The output of criterion validity and convergent validity is correlation coefficients which range from -1 to +1. Various correlations can be processed such as Pearson-product moment correlation, Spearman’s rank order correlation, Kendall’s rank order correlation and Phi Coefficient, depending on the data used. The ability of a measure to determine whether the absence (specificity) or presence (sensitivity) of a disease/disorder/condition exists is part of criterion validity. In summary the validity of a measure is an important psychometric property to consider when using a measure clinically (Stokes 2011).

Measuring change

Debate exists over the definition and use of the term responsiveness. Some argue that sensitivity may be a more appropriate term to use, and also suggest it may be a type of
a validity instead of an individual psychometric property (Stokes 2011). For the purpose of this introduction the term responsiveness will be used. There are various ways to study responsiveness. Stokes et al. (2011) outlines the following four ways of reporting responsiveness: (A) Standard response mean (SRM), (B) Effect size (ES), (C) Relative efficiency and (D) Receiver operator characteristic cure (ROC).

The SRM is the mean change in scores taken at two time points, divided by the standard deviation of changes (Liang (1985), as cited in Stokes (2011)). SRM values of 0.20, 0.50, and 0.80 or greater have been proposed to represent small, moderate, and large responsiveness, respectively (Liang et al. (1990), as cited in Husted et al. (2000)). The ES is a quantitative measure of the strength of a phenomenon (Kelley and Preacher 2012). The equation used to calculate the ES is outlined in Paper II of this thesis. Guidelines (Cohen 1988) state that ES values of less than 0.3 suggest a small effect, 0.5 a medium effect and greater than 0.8 a large effect. The ROC and the Area under the Curve (AUC) with its 95% confidence interval are used (Hanley and McNeil 1982) to investigate the specificity and sensitivity of the change scores in comparison to an external gold standard or criterion of important change (Stokes 2011). An AUC below 0.5 indicates no accuracy in detecting improved from unimproved whereas 1 indicates perfect accuracy (Stokes 2011). Thus, the higher AUC value indicates the more responsive a measure is in detecting a change (Hanley and McNeil 1982). Assessment for possible floor and ceiling effects is also included in responsiveness, as they indicate limits to the range of detectable change beyond which no further improvement or deterioration can be noted (Finch et al. 2002). In summary, it is important to know the responsiveness of an outcome measure, and also to determine if that change is clinically relevant to the individual being measured (Stokes 2011).
1.4 Conclusion

In conclusion, this introduction chapter has shown that balance is a common complex phenomenon in PwMS. There are many causes of balance impairment with many ways of measuring and treating it. When using a balance measure, its psychometric properties are important to investigate. Therefore this thesis will now present data on the following balance outcome measures, the MBT test and the BBS in ambulatory PwMS. The aim of Paper I is to investigate the inter-rater reliability of the MBT in PwMS. The aim of Paper II is to compare this novel MBT to the commonly used BSS. To the best of the authors’ knowledge no literature has previously addressed either of the above aims, exclusively in PwMS.
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Chapter 2: Paper I

Inter-rater reliability of Mini-BESTest in ambulatory People with Multiple Sclerosis.
Abstract

**Background:** Balance impairments are common and complex in people with Multiple Sclerosis (PwMS). Current balance measures do not consider many of the components required for functional balance. A novel test, the Mini-BESTest (MBT) may be more clinically useful, as it considers additional balance domains. To the best of the authors’ knowledge no literature has investigated the inter-rater reliability of the MBT, exclusively in ambulatory PwMS.

**Objective(s):** To investigate the inter-rater reliability of MBT in ambulatory PwMS.

**Method(s):** A sample of convenience (n=52) was recruited. All participants were out-patients referred for physiotherapy with a primary diagnosis of MS, medically stable, greater than 18 years of age and able to ambulate independently with/without an aid. Participants’ demographic data was collected prior to completing the MBT with Rater 1 (R1). Rater 2 (R2) then repeated the MBT. Statistical analyses were undertaken using IBM SPSS® Statistics V. 20

**Results:** The mean MBT score of R1 and R2 were 19.1 (SD 5.75) and 18.8 (SD 6.01) respectively. The mean difference between raters was 0.27 (SD 1.8; CI -2.5 +2.02; p=.816). The intra class correlation coefficient (ICC) was .976 (CI .92-97). The standard error of the measure (SEM) was 2.56. The minimum detectable change (MDC) of the MBT was calculated to be 7 points.

**Conclusion:** Despite the high MDC shown in this study, the high ICC values suggest there was a strong agreement between two raters for the MBT in an ambulatory PwMS.

**Key words:** Balance, Mini-BESTest, Multiple Sclerosis
**Introduction**

Multiple sclerosis (MS) is a chronic progressive disorder of the central nervous system (McDonald and Compston 2006). Balance and mobility impairments are common in people with MS (PwMS) (Kister et al. 2013, Cameron and Nilsagard 2013) and can occur even in the early stages of the condition (Findling et al. 2011, Martin et al. 2006).

Imbalance, or reduced postural control in PwMS may be due to impairments in many underlying, interactive body functions (Horak et al. 2009, Shumway-Cook and Woollacott 2012). These include impaired vestibular function, somatosensory function, vision, motor strategies, proprioception, muscle strength and altered tone (Cameron et al. 2008, Cattaneo and Jonsdottir 2009, Chung et al. 2008, Daley and Swank 1983, Huisinga et al. 2012, Rougier et al. 2007, Sosnoff et al. 2010).

A systematic review (Cameron and Nilsagard 2013) highlighted that PwMS may demonstrate the following balance related activity limitations: (i) Decreased ability to maintain postural control in static positions, (ii) Decreased ability to maintain postural control during proactive tasks, such as leaning and reaching and (iii) Decreased ability to respond to external perturbations and/or when displaced.

Further studies with PwMS suggest that many balance limitations may also affect participation in daily living, such as walking (Jacobs and Kasser 2011, Fanchamps et al. 2012, Martin et al. 2006) and dual tasking (Boes et al. 2012, Hamilton et al. 2009, Negahban et al. 2011). The World Health Organization (WHO) International classification of functioning, disability and health (ICF) model additionally outlines various other health conditions, body function(s)/structure(s), activity, participation and contextual factors (environment and personal) that may potentially be used as a
framework to describe the many causes and consequences of balance impairment (Stucki et al. 2002) Therefore, due to the aforementioned wide range of causes and consequences of balance impairment, it is important to accurately measure all of these contributing elements in PwMS (Cameron and Nilsagard 2013).

Many balance outcome measures are used throughout MS literature including clinical, self-reported and instrumented measurements (Cameron and Nilsagard 2013). Various limitations of these individual tests have been suggested (Cameron and Nilsagard 2013, Sibley et al. 2014). The Berg Balance Scale (BBS) (Berg et al. 1992), one of the most commonly administered balance outcome measure in PwMS, does not assess all potential body function and balance specific activities (Cameron and Nilsagard 2013) and demonstrates ceiling/floor effects for PwMS and for those with other health conditions such as stroke and in community dwelling older adults (Cameron and Nilsagard 2013, Blum and Korner-Bitensky 2008, Pardasaney et al. 2012).

A novel balance test the Balance Evaluations Systems Test (BESTest) (Horak et al. 2009) may be a more clinically useful balance measure for PwMS because it considers a broader range of balance domains. Franchignoni et al. (2010) used psychometric analysis, expert opinion and Rasch analysis on relevant items of the BESTest, to develop a shorter version called the mini-BESTest (MBT). The MBT takes 10-15mins to administer while the BESTest takes up to 30-35 minutes. Franchignoni et al. (2010) describe the MBT as “a unique, brief clinical rating scale for dynamic balance” and further suggested that the MBT may enable therapists to comprehensively assess functional balance, and guide more appropriate therapeutic treatment. The MBT has also demonstrated acceptable concurrent validity with various gait and balance outcome measures in PwMS (n=56) (Cameron et al. 2014).
The inter-rater reliability of the MBT in other neurological populations such as stroke and Parkinson Disease (PD) has been shown to be high (Leddy et al. 2011, Tsang et al. 2013). One study (Padgett et al. 2012) investigated inter-rater reliability in a heterogeneous population (n=20) including only four PwMS. They found ICC values of 0.985 for the BESTest, and 0.995 (.988 – .998) for the MBT. To the best of the authors’ knowledge no studies have investigated the inter-rater reliability of the MBT exclusively in ambulatory PwMS.

The between rater reliability of a measure is an important psychometric property to investigate prior to its clinical use (Portney and Watkins 2009, Finch et al. 2002) as PwMS may encounter many different physiotherapists throughout their life long condition. The level of agreement between raters is needed to distinguish between true change in the patient’s condition and variability in scores due to different raters. Therefore, the primary aim of this study is to investigate the inter-rater reliability of the MBT in ambulatory PwMS.

**Methods**

**Recruitment/participants**

Over a three-month period, of the 62 PwMS approached, 53 expressed an interest and 52 PwMS receiving out-patient physiotherapy were eligible and volunteered for the study. All participants were referred by a consultant neurologist, for routine out-patient physiotherapy care at a large academic teaching hospital. All participants had a primary diagnosis of MS, were medically stable, greater than 18 years of age, and ambulated independently with or without an aid. All participants provided informed
consent prior to the testing. Participants were excluded if they were, unable to give consent, not medically stable, under 18 years and/or unable to mobilise independently. This study was approved by, the local Research Ethics Committee.

**Outcome measures**

**The Mini-BESTtest**

The 14 item Mini-BESTest (Franchignoni et al. 2010) includes the following four systems of dynamic balance: (i) Anticipatory postural adjustments (i.e. sit to stand, rise to toes, stand on one leg), (ii) Postural responses to perturbation (i.e. stepping in four different directions), (iii) Sensory orientation (i.e. stance - eyes open; foam surface - eyes closed; incline - eyes closed) and (iv) balance during gait with and without a cognitive task (i.e. gait during change speed, head turns, pivot turns, obstacles; timed ‘Get Up and Go’ with dual task). All items are scored on an ordinal scale where 0 is severe impairment, 1 is moderate impairment and 2 is normal performance. For item 3 (stand on one leg) and item 6 (lateral compensatory stepping reactions) only the worst leg score is used when the total score is calculated. The total MBT score ranges from a minimum of 0 to a maximum of 28 points. A higher score on the MBT indicates a better balance. The MBT has shown to be reliable in various neurological populations (Leddy et al. 2011, Tsang et al. 2013, Padgett et al. 2012, Dahl and Jørgensen 2014, Godi et al. 2013).
The Raters

The two raters were physiotherapists with seven and one year of clinical experience respectively. Prior to testing, the raters practiced administering and scoring the MBT on healthy controls and PwMS, using MBT standard protocol guidelines (Horak et al. 2009, Franchignoni et al. 2010).

Procedure

Participants attended for the first day of testing as part of their routine physiotherapy care. The space was organized to facilitate transitions from one test to the next in order to minimize fatigue and mobility requirements. Participants initially provided demographic data (e.g. age, gender, medical history, MS history, mobility status, self-reported falls/near falls in the last three months and current medications) and then completed the MBT (approx. 15-20 minutes duration) with the lead investigator (Rater 1). A 5-10 minute rest was allowed to limit fatigue. The second investigator (Rater 2) then repeated the MBT independently on each participant. The MBT was completed with shoes off. Raters were blind to each others scores, scoring of the MBT was not discussed and the total score of the MBT was not totalled until the end of the study.

Data analysis

IBM SPSS® Statistics V. 20 (Armonk, New York, USA) and Microsoft Excel were used for data analysis and management. Participant demographic data were expressed
using descriptive analysis presenting means, medians, interquartile ranges and standard deviations (SD). In this study, the inter-rater reliability of the total MBT score between raters was analysed using a two-way random, single measure with absolute agreement Intraclass Correlation (ICC [2,1]) and Bland and Altman analysis (Bland and Altman 1986). Values for ICC measures in this study were interpreted using the Portney and Watkins guidelines (Portney and Watkins 2009) where below .50 represents poor reliability, between .50 and .75 represent moderate reliability and above .75 suggests good reliability.

Percentage agreement and weighted kappa were used to investigate levels of agreement for individual items of the MBT. ICC (3,1) values were computed and expressed as the quadratic weighted kappa as outlined by Fleiss and Cohen (1973). The classification of reliability for categorical data proposed by Landis and Koch (1977) was used for Kappa <0: poor, 0.00-0.20: slight, 0.21-0.40: fair, 0.41-0.60: moderate, 0.61-0.80: substantial, 0.81-1.00: almost perfect agreement. For percentage agreement, we used the Landis and Koch (1977), as cited in Portney and Watkins (2009) recommended classification: values below 40% represent poor to fair agreement, from 40% to 60% moderate agreement, above 60% substantial level of agreement and above 80% excellent agreement. In order to compare the scores of the two raters, we used non-parametric Kruskal-Wallis test, as data were not normally distributed. $P$ values $\leq.05$ were considered significant.

Absolute reliability is expressed as the standard error of the measure (SEM), which is expressed in terms of the actual unit of the original instrument (Stokes 2011). The SEM was calculated using the following equation: $SEM = SD_{diff}\sqrt{2}$. The minimal detectable change (MDC) was calculated using the following equation in this study: $MDC = SEM \times 1.96 \sqrt{2}$. 
Results

Fifty-two out of fifty-three participants who volunteered to take part met the inclusion criteria and were tested. The participants’ demographics are presented in Table 1. The mean MBT score of Rater 1 was 19.1 (SD 5.75). The mean MBT score of Rater 2 was 18.8 (SD 6.01). The mean difference between the raters was 0.27 (SD 1.8; CI -2.5 +2.02), which was not significantly different (p= .816). The scatter and Bland and Altman Plots of Raters 1 and 2 MBT scores are presented in Figure 1 and 2, demonstrating strong agreement between raters. The intra class correlation coefficient (ICC) was .976 (CI .92-97).

The agreement between raters for each MBT item is presented in Table 2. As not all options were used in Item 1 (no participant scored 0 from either rater) only the percentage agreement is presented, as Kappa is invalid for that item. The lowest percentage agreement and Kappa value (k) was Item 5, the backwards compensatory stepping item. The lateral compensatory stepping (Item 6) and the walk with head turns (Item 11) have the next lowest percentage agreement. There was total agreement for Item 14, the TUG with interference. The SEM was 2.56 and the MDC value was 7.

Discussion

This study examined the inter-rater reliability of the MBT in an ambulatory PwMS. The ICC value for the MBT scores was 0.976, indicating good reliability. The MBT has also been shown to have good inter-rater reliability in other neurological populations such as people with PD (inter-rater ICC=0.91(Leddy et al. 2011)), stroke
(inter-rater ICC=0.93 (Dahl and Jørgensen 2014), inter-rater ICC=0.96 (Tsang et al. 2013)) and in various other balance disorders (inter-rater ICC=0.98 (Godi et al. 2013), inter-rater ICC=0.99 (Padgett et al. 2012)) including polyneuropathies, hereditary ataxias and neuromuscular disorders respectively. Therefore, the findings in this study are consistent with other literature in demonstrating that MBT total scores have good levels of inter-rater reliability.

When considering the agreement between raters for the individual items (Items: 1-14) of the MBT, Kappa values (k) ranged from 0.48 to 1 in this study, indicating levels of moderate to complete agreement. The majority of items (1-4, 7-10, 12-14) on the MBT had Kappa values greater than 0.51 with Item 14 (iTUG) demonstrating complete agreement (k=1). The percentage agreement for individual questions ranged from 69% to 100% in this study, confirming the substantial to excellent levels of agreement. Similarly, another study Tsang et al. (2013) found Kappa values from different MBT items varying from 0.36 to 1 in their mild to moderate stroke population. Dahl et al. (2014) reported Kappa values for stroke individuals and found the majority of items demonstrated a kappa value greater the 0.52, indicating greater than moderate agreement. Therefore, in line with other studies, this study suggests that the majority of individual items on the MBT have demonstrated moderate to almost perfect agreement levels for inter-item, inter-rater reliability.

Of note, in this study, Item 5 backwards compensatory stepping (k=0.48), item 6 lateral compensatory stepping (k=0.62) and item 11 walk with head turns (k=0.63) respectively had the lowest Kappa value (k) for individual items of the MBT, Similarly, Dahl et al. (2014) found lower agreement for MBT items 6 and item 11. The authors in that study suggested potential reasons for the lower agreement for these items, were that the amount of force applied by the rater during the MBT item 6
may have varied and during MBT item 11 the raters’ position observing the participants may have also varied. It may be necessary to review the current MBT instructions and recommendations used (Horak et al. 2009, Franchignoni et al. 2010) when completing the above potentially less reliable items.

The absolute reliability of the MBT was also investigated in this study. The SEM was low (2.56 points) which equates to 9.1% error on this scale from 0 to 28. Other authors (Leddy et al. 2011, Godi et al. 2013) have demonstrated lower SEM values for the MBT (i.e. 1.26 and 1.99 respectively in various neurological populations and in PD). The MDC was calculated to be 7 points, in this study. Dahl et al. (2014), Godi et al. (2013) and Leddy et al. (2011) further reported a MDC of less than or equal to 3.2, 3.5 and 5.52 points respectively.

The reasons for our study potentially demonstrating a higher MDC may be the difference in sample sizes used, MBT means (SD) reported, or the difference in experience and number the raters used in the other studies. Our participants had MBT mean (SD) scores of 19.1(5.75) and 18.8(6.01) in comparison to other studies demonstrating the following lower MBT means (SD) values, 13.8(6.1), 13.4(6.9), 13.3(6.7) (Dahl et al. 2014) and 12.8(6.9), 11.1(7.6) (Godi et al. 2013). Additionally, our study is the first to only consider PwMS who predominately ambulated independently with or without a unilateral aid and who have a range of impaired body functions that result in balance limitations. The other studies investigated stroke, PD and various health conditions such as vestibular and age related balance disorders thus, making it difficult to compare this study’s findings to other studies. Therefore, despite the high ICC levels demonstrated in this study being similar to other studies, the MDC was higher in this study. Therefore, highlighting the importance of considering both the absolute and relative reliability of the measure.
A suggested change greater than 7.0 points on the MBT may be required to conclude the difference was due to the intervention rather than the measurement error between two raters in ambulatory PwMS. This requires clarification in additional studies that consider using more raters and also stratifying the reliability estimates for different mobility categories, as estimates may differ depending on the level of balance and mobility limitations of the participants.

Interestingly, the raters differed on their amounts of physiotherapy working experience (e.g. novice versus experienced). Thus, the high levels of relative reliability demonstrated in this study therefore suggest scoring maybe independent of years of working experience. Similarly, Dahl et al. (2014) also demonstrated high levels of inter-rater reliability for the MBT comparing raters with different levels of work experience. This is relevant to clinical practice as both experienced and less experienced physiotherapists may use the MBT at different time points at different reviews, when assessing ambulatory PwMS. However, it is important to note, the high MDC shown in this study confirms additional studies need to clarify this finding.

**Limitations**

The majority of our sample had Relapse-Remitting MS (RRMS) and required no aid or a unilateral aid to mobilise. Thus, our findings may not applicable to those with progressive MS or to those who require a bilateral aid to mobilise. However clinically, the majority of the PwMS tend to be ambulatory with RRMS (McDonald and Compston 2006) which was similar to the majority of our subjects used in this study. Other limitations in this study include the small sample size and the use of a
convenience sample from a single hospital setting. This may limit the extent to which
the results can be generalized to other settings.

Conclusion

The findings in this study suggest there is a strong agreement between two raters
(experienced and novice) for the MBT in an ambulatory PwMS. High ICC scores and
low mean differences were demonstrated. This preliminary evidence supports the use
of the MBT clinically as a balance measure in ambulatory PwMS and suggests that
more than 7 points difference between two raters is needed to be confident that the
change is greater than measurement error.
Paper I tables

Table 1: Participant Demographic Data

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since MS onset (years) Mean (SD)</td>
<td>10.87</td>
<td>8.48</td>
</tr>
<tr>
<td>N=52; %=percentage; SD= Standard deviation; MS=Multiple Sclerosis; DS=Dictus Splint foot device; AFO=Ankle-foot-orthosis device; FES=Functional electrical stimulation foot drop device; MHX=Medical History.</td>
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<table>
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<tr>
<th>Type of MS diagnosed (N;%):</th>
<th>3</th>
<th>5.7</th>
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<tr>
<td>Benign MS</td>
<td>42</td>
<td>80.8</td>
</tr>
<tr>
<td>Relapse-Remitting MS</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>Secondary progressive MS</td>
<td>4</td>
<td>7.7</td>
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<tr>
<td>Primary progressive MS</td>
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</table>

<table>
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<tr>
<th>Walking aid used (n)</th>
<th></th>
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<tbody>
<tr>
<td>None</td>
<td>32</td>
<td>61.5</td>
</tr>
<tr>
<td>Zimmer Frame</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Rollator</td>
<td>3 (1 plus DS)</td>
<td>5.8</td>
</tr>
<tr>
<td>Walking stick/cane</td>
<td>11 (1 plus AFO; 1 plus FES, 2 plus DS)</td>
<td>21.1</td>
</tr>
<tr>
<td>Elbow crutch</td>
<td>2</td>
<td>3.8</td>
</tr>
<tr>
<td>Two elbow crutches</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Tripod</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>AFO</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Dictus</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Other (e.g. FES only)</td>
<td>1</td>
<td>1.9</td>
</tr>
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</table>

<table>
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<tr>
<th>Other relevant MHX (n)</th>
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<tr>
<td>None</td>
<td>43</td>
<td>82.7</td>
</tr>
<tr>
<td>Heart problem</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Blood pressure problem</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>5</td>
<td>9.6</td>
</tr>
<tr>
<td>Diabetes</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Heart problem and epilepsy</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Heart problem and asthma</td>
<td>1</td>
<td>1.9</td>
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## Paper I tables

### Table 2: Inter-Rater Reliability of Items

<table>
<thead>
<tr>
<th>Q</th>
<th>Item</th>
<th>N</th>
<th>(%) Agreement</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sit to Stand</td>
<td>50</td>
<td>96.15</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Rise to Toes</td>
<td>42</td>
<td>80.77</td>
<td>0.66</td>
</tr>
<tr>
<td>3</td>
<td>Stand on 1 Leg</td>
<td>45</td>
<td>86.54</td>
<td>0.69</td>
</tr>
<tr>
<td>4</td>
<td>Compensatory Forward</td>
<td>42</td>
<td>80.77</td>
<td>0.63</td>
</tr>
<tr>
<td>5</td>
<td>Compensatory Backward</td>
<td>36</td>
<td>69.23</td>
<td>0.48</td>
</tr>
<tr>
<td>6</td>
<td>Compensatory Lateral</td>
<td>39</td>
<td>75.00</td>
<td>0.62</td>
</tr>
<tr>
<td>7</td>
<td>Eyes Open Firm</td>
<td>50</td>
<td>96.15</td>
<td>0.81</td>
</tr>
<tr>
<td>8</td>
<td>Eyes Closed Foam</td>
<td>47</td>
<td>90.38</td>
<td>0.51</td>
</tr>
<tr>
<td>9</td>
<td>Incline Eyes Closed</td>
<td>44</td>
<td>84.62</td>
<td>0.64</td>
</tr>
<tr>
<td>10</td>
<td>Change in Gait Speed</td>
<td>45</td>
<td>86.54</td>
<td>0.70</td>
</tr>
<tr>
<td>11</td>
<td>Walk Head Turns</td>
<td>39</td>
<td>75.00</td>
<td>0.63</td>
</tr>
<tr>
<td>12</td>
<td>Walk Pivot Turns</td>
<td>43</td>
<td>82.69</td>
<td>0.70</td>
</tr>
<tr>
<td>13</td>
<td>Step over obstacles</td>
<td>45</td>
<td>86.54</td>
<td>0.79</td>
</tr>
<tr>
<td>14</td>
<td>iTug</td>
<td>52</td>
<td>100.00</td>
<td>1.00</td>
</tr>
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</table>

N=52; %=percentage; iTUG=Inference Timed up and go item. Mod=Moderate; V=Very; Kappa and PABAK: <0: poor, 0.00-0.20: slight, 0.21-0.40: fair, 0.41-0.60: moderate, 0.61-0.80: substantial, 0.81-1.00: almost perfect agreement (Landis and Koch 1977). Percentage agreement values below 40% represent poor to fair agreement, from 40% to 60% moderate agreement, above 60% substantial level of agreement and above 80% excellent agreement (Landis and Koch 1977).
Paper I Figures

Figure 1: Scatterplot for Rater 1 and Rater 2 scores on the MBT
Paper I Figures

Figure 2: Bland and Altman Plot
References


Chapter 3: Paper II

Comparison of the Berg Balance Scale and the Mini-BESTest in ambulatory people with Multiple Sclerosis
Abstract

**Purpose:** To compare the Berg Balance Scale (BBS) and the Mini-BESTest (MBT) ability to detect balance changes in ambulatory people with Multiple Sclerosis (PwMS).

**Relevance:** Balance is complex and prevalent in PwMS. The BBS is a commonly used and the MBT is a newer alternative. Comparisons of these measures in other populations have demonstrated more favorable results for the MBT, though this hasn’t been evaluated exclusively in PwMS.

**Participants:** 52 PwMS receiving out-patient physiotherapy were recruited. All had a primary diagnosis of MS mobilised independently with or without aid.

**Method:** Each participant gave demographic details, self-reported history of falls and near falls, completed the MBT, the Multiple Sclerosis Impact Scale -29 (MSIS-29), The Multiple Sclerosis Walking Scale -12 (MSWS-12), the BBS, The Modified Fatigue Impact Scale (MFIS) and the six-minute walking test (6MWT) pre and post eight weeks of routine physiotherapy.

**Results:** The following effect sizes (ES)(BBS=0.37;MBT=0.70), standard response mean values (SRM)(BBS=0.74;MBT=1.52), statistically significant changes in BBS (-1.4(1.9)) (p=0.01) and MBT (-5.31(3.5)) (p=0.01) scores were demonstrated post treatment. 38% (n=20) started with a baseline BBS maximum score of 56. No participant started with a baseline MBT maximum score of 28. The areas under the curve (AUC) for the MBT and BBS were (0.88 (p>0.01); 0.77(p=0.03) for detecting mobility device use and (0.88 (p>0.01); 0.75(p=0.03) for self report near falls. The MBT demonstrated higher correlation coefficients for each secondary measure than the BBS.
**Conclusion:** The MBT demonstrated less ceiling effects, greater responsiveness and performed slightly better at detecting near fallers and mobility aid users compared to the BBS. These findings suggest that the MBT may be a better outcome measure for detecting balance improvements in ambulatory PwMS.

**Key words:** Mini-BESTest, Berg Balance Scale
Introduction

Multiple sclerosis (MS) is a chronic, progressive disorder of the central nervous system that commonly affects young adults (Compston and Coles 2002, McDonald and Compston 2006). Many people with MS (PwMS) report balance problems (Coote et al. 2010, Larocca 2011). Such balance problems and impairments may occur early on and even in PwMS with minimal clinical disability (Martin et al. 2006, Findling et al. 2011). Balance is a complex phenomenon involving many systems and domains in PwMS (Shumway-Cook and Woollacott 2012). Martin et al. (2006) suggest that early detection of balance impairment in PwMS is essential in order to optimally manage this life long condition.

Various balance measurements have been used in studies involving PwMS (Cameron and Nilsagard 2013). One commonly used clinical balance measurement is the Berg Balance Scale (BBS) (Berg et al. 1992). While studies have reported favorable psychometric properties of the BSS in PwMS (Cattaneo et al. 2006, Cattaneo et al. 2007), it has been reported to demonstrate many limitations such as ceiling effects (Blum and Korner-Bitensky 2008, King et al. 2012) reduced responsiveness (King et al. 2012) and reported problems with its rating scale design (Kornetti et al. 2004). The BBS also does not assess many balance elements, such as reacting to external perturbations, dynamic gait and dual tasking, all required for functional balance in PwMS (Cameron and Nilsagard 2013, Franchignoni et al. 2010, Horak et al. 2009). Such limitations are important to consider when choosing the appropriate measure in clinical and research practice.
An alternative to the BBS is the novel 36-item balance measure, The BESTest (BT) (Horak et al. 2009). However, the main limitation of the BT is it can take up to 30 minutes to administer. A shorter version of the BT, called the Mini-BESTest (MBT) (Franchignoni et al. 2010) only takes 10-15 minutes. The MBT is a 14-item test that focuses on dynamic balance, including anticipatory transitions, postural responses, sensory orientation, and dynamic gait all required for functional balance (Franchignoni et al. 2010). The MBT has demonstrated good psychometric properties in various neurological conditions (Leddy et al. 2011, Tsang et al. 2013, Godi et al. 2013, Padgett et al. 2012, Dahl and Jørgensen 2014). The MBT may be more appropriate to use clinically than the BBS, as its wider system-specific assessment may ensure a meaningful or high-level deficit is not overlooked and that changes in these domains are detected post treatment.

Recent literature (Godi et al. 2013, Duncan et al. 2012, King et al. 2012) has compared various psychometric properties of the MBT and the BBS, in people with Parkinson Disease (PD) and mixed neurological conditions. All of the above studies demonstrated more favorable results (i.e. responsiveness, validity, reliability, sensitivity/specificity) for the MBT than for the BBS. To the best of authors' knowledge, comparison of the BBS and MBT in ambulatory PwMS exclusively has not been assessed.

Therefore, this study aimed to compare the MBT to the BBS in assessing balance in ambulatory PwMS. Specifically, our objectives were to investigate (i) which balance measure is better at detecting change in balance after routine physiotherapy care, (ii) whether each measure can distinguish those who report falls, near falls, and/or use of mobility device(s), (iii) whether a change in balance score is associated with
participant and/or physiotherapist impression of change and finally (iv) whether each measure is associated with other clinical measures (i.e. concurrent validity).

Methods

Participations/recruitment

Over a three-month period, of the 62 PwMS approached, 53 expressed an interest and 52 PwMS receiving out-patient physiotherapy were eligible and volunteered for the study. All participants had a primary diagnosis of MS, were medically stable, mobilised independently with or without an aid and were over 18 years of age. Participants were given an information leaflet and signed a consent form. The local Research Ethics Committee approved this study.

Experimental design/procedure

This was a pre and post single group longitudinal study. Each participant attended the first testing day as part of routine physiotherapy care and provided demographic data (i.e. age, gender, medical history, MS history, mobility status, self-reported falls/near falls history and current medications). The lead investigator, a senior physiotherapist in MS with seven years clinical experience carried out the testing. Each participant undertook the MBT prior to completion of the Multiple Sclerosis Impact Scale -29 (MSIS-29), The Multiple Sclerosis Walking Scale-12 (MSWS-12), the BBS, The Modified Fatigue Impact Scale (MFIS) and the six-minute walking test (6MWT). Each participant completed eight weeks of routine physiotherapy, which included one
and one sessions, prescribed home exercise programmes and/or group classes incorporating neuromuscular stimulation, Nintendo Wii Fit® games, specific strengthening and aerobic training, individually prescribed as needed by the lead investigator. The number of self reported near falls and falls over the last three months were also recorded. After this episode of care, all participants completed the outcome measures again in the same order. The lead investigator and participant then rated their Global rating of change scales (GRC) in relation to participants’ balance.

**Outcome measures**

**The BBS**

The BBS is a 14-item balance test that takes approximately 10-15 minutes to administer. Performance is rated from 0 (cannot perform) to 4 (normal performance) on each item. The total BBS ranges from a minimum score of 0 points to a maximum score of 56 points. A higher score in the BBS indicates better balance. The BBS demonstrated good test-re-test reliability (ICC=0.96) and inter-rater reliability (ICC=0.96) in a PwMS (Cattaneo et al. 2007). The BBS also demonstrated acceptable concurrent validity with other balance measures such as Timed Up and Go Test (TUG), Dynamic Gait Index (DGI), Hauser Deambulation Index (DI), Dizziness Handicap Inventory (DHI), and Activities-specific Balance Confidence (ABC) in PwMS (Cattaneo et al. 2006).
The MBT

The 14-item MBT (Franchignoni et al. 2010) investigates the following dynamic balance domains (i) Anticipatory postural adjustments, (ii) Postural responses to perturbation, (iii) Sensory orientation and (iv) Balance during gait with and without a cognitive task. All items are scored on an ordinal scale where 0 is severe, 1 is moderate and 2 is normal performance. The standard protocol for administrating the MBT was used in this study (Franchignoni et al. 2010, Horak et al. 2009). The total MBT score ranges from a minimum of 0 to a maximum of 28 points. A higher score on the MBT indicates better balance. Preliminary evidence supports the psychometric properties of the MBT in heterogeneous neurological populations, which included PwMS (Chapter 2 of this thesis, Cameron et al. 2014, Godi et al. 2013, Padgett et al. 2012).

The MSIS-29

The MSIS-29 is a 29-item self-reported questionnaire assessing the impact of MS on a series of physical (20 items) and psychological (9 items) domains over the past four weeks in a PwMS (Hobart et al. 2001). Each item has 5 potential responses: 1 “not at all” to 5 “extremely”. Both domains of the scale are then scored by summing all the responses across items, then converting to a 0-100 scale where 100 indicates higher impact of disease on daily function (worse health). The MSIS-29 has demonstrated acceptable psychometric properties in PwMS (Riazi et al. 2003).
The MSWS-12

The MSWS-12 (Hobart et al. 2003) is a 12-item self-report questionnaire that asks the participant to rate the impact their MS has on a series of walking domains over the last two weeks. The scoring includes 1-5 options for each item with 1 meaning no limitation and 5 meaning extreme limitation for each individual walking item. A higher score indicates a greater impact of MS on walking ability. The MSWS-12 has been shown to be reliable and valid for PwMS (Hutchinson et al. 2009).

The MFIS

The MFIS (Fisk et al. 1994) is a 21-item self-reported questionnaire where the participant rates the impact of their MS on physical, cognitive and psychological domains of fatigue. It takes 5-10 minutes to complete. Each item is rated on a 5-point likert scale (0-4). Total score (0-84) and subscales for physical (0-36), cognitive (0-40) and psychosocial functioning (0-8) are totaled and converted to a score out of 100. Higher numbers/percentages indicate greater fatigue. The MFIS is commonly used in PwMS (Rietberg et al. 2005, Dalgas et al. 2008) and has shown acceptable validity (Flachenecker et al. 2002).

The 6MWT

The 6MWT (Brooks et al. 2003, Goldman et al. 2008) is a submaximal measure of gait velocity and endurance. Participants walk as far as possible in 6 minutes up and
down along a 30-m hallway, turning around cones at each end with their habitual assistive device if indicated. The distance walked is documented. Walking improvement on the 6MWT is indicated by positive change scores (meters). Values for normal healthy individuals are on average 900 meters. The 6MWT has shown to be reliable and valid in PwMS (Marrie and Goldman 2007, Paltamaa et al. 2005).

GRC scales

GRC scales are designed to quantify a participant’s impression of their improvement or deterioration over time, usually either to determine the effect of an intervention or to chart the clinical course of a condition (Kamper et al. 2009). Two 7-point scales were designed in this study for both the lead investigator and participant to quantify the participants’ change in balance after routine physiotherapy care. The response categories were: very much worse, much worse, minimally worse, no change, minimally improved, much improved, very much improved.

Statistical analysis

IBM SPSS® Statistics V. 20 (Armonk, New York, USA) and Microsoft Excel were used for data analysis. Demographic data was expressed using descriptive analysis presenting means, standard deviations (SD), medians and interquartile ranges. P values of less than 0.05 were considered significant.
Non-parametric tests (Wilcoxon signed ranks tests) were used to calculate MBT and BBS change. The frequency of participants demonstrating maximum or minimum scores was documented and converted to a percentage of ceiling and/or floor effects. The Standard response mean (SRM) and effect size (ES) were also used to investigate each measures ability to detect change (Stokes 2011). The SRM is the mean change in scores taken at two time points, divided by the standard deviation of changes. SRM values of 0.20, 0.50, and 0.80 or greater have been proposed to represent small, moderate, and large responsiveness, respectively (Liang et al. 1990).

The equation used to calculate ES was $\eta^2 = \frac{t^2}{t^2 + N - 1}$ where $t$ = test statistics value and $N$ = sample size. Guidelines (Cohen 1988) state that values of 0.2 to 0.3 = small effect, 0.5 = medium effect and 0.8 = large effect.

In order to investigate the specificity and sensitivity of each pre balance measurement scores ability to detect, if a participant reported a change in their balance, reported a history of falls or near falls, or was a mobility aid user (Stokes 2011), the receiver operating characteristic curve (ROC) and the area under this curve (AUC) with its 95% confidence interval were calculated (Hanley and McNeil 1982). The AUC can range from 0.5-1.0. 0.5 indicates no accuracy in detecting improved from unimproved whereas 1 indicates perfect accuracy (Stokes 2011), thus indicating the more responsive a measure is (Hanley and McNeil 1982).

ANOVA was used to calculate the mean difference between GRC categories to compare therapist and participant’s impression of balance change. Non Parametric Spearman’s rank order correlation was used to compare baseline balance score measurements with each other and also for comparing baseline and change scores on the MBT and BBS with all the aforementioned secondary measures in this study.
Results

Data for 52 participants at baseline (mean age 45.73 (5.65); 37 female) and for 47 participants (mean age 41.09 (5.65), 33 female) at follow up were analysed. Baseline demographic details are presented in Table 3. Reasons for dropouts (n=5, 9.6%) included family commitments (n=2), transport (n=1), work (n=1) and other medical issues (n=1). Descriptive statistics for MBT and BBS baseline, change and post scores are presented in Table 4.

20 (38%) of participants started off with a baseline BBS max score of 56. The 20 participants, who scored a maximum BBS score of 56, had MBT baseline scores ranging from 12-27 points. No participant demonstrated a maximum baseline MBT score of 28. All 47 participants who completed the study, improved on their MBT score. Only 27 (57%) improved on the BBS. 19 (33.9%) participants did not change their baseline BBS score after intervention. 16 of these 19 participants remained at their maximum 56 BBS score.

There was a statistically significant improvement in the MBT scores 5.31 (3.5) (p=0.01) and in the BBS scores 1.4 (1.9) (p=0.01) post treatment. The ES for the MBT and BBS change were 0.70 and 0.37 respectively. The SRM of the MBT and BBS were 1.52 and 0.74 respectively. ROC analysis was unable to be completed for the MBT change score as all responded positively. When considering the ability of the BBS change to detect a participants’ impression of balance change (GRC score indicating improvement), the area under the curve (AUC) was 0.56, which was not significant (p=0.59).

When considering the ability of the MBT and BBS to distinguish between those who do and don’t use a mobility device, the areas under the curve (AUC) were 0.88
A MBT score of below 19.5 classifies requiring a mobility aid with a sensitivity of 0.850 and specificity of 0.812. A BBS score of below 54.5 classifies requiring a mobility aid with a sensitivity of 0.850 and specificity of 0.781.

65% (34 of 52) of participants reported a history of near falls. The AUC for the MBT and BBS scores were 0.77 (p=0.01) and 0.75(p=0.03), which were both significant in relation to self-reported near falls. A MBT score of below a cut-off of 22.5 classified a near faller with a sensitivity of 0.794 and specificity of 0.722. A BBS score of below a cut-off of 55.5 classified a near faller with a sensitivity of 0.735 and a specificity of 0.611.  

35% (13 of 52) of our sample reported a history of falls. The MBT and BBS AUC were 0.67 and 0.63 and not significant (p=0.07, p=0.18) in relation to self-reported falls.

Table 5 presents the frequency of reported GRC scores for both physiotherapist and participant. There was no statistical difference in the means of either MBT or BBS scores between the GRC categories (ANOVA). There was a trend for an increasing participants’ GRC balance rating scores and physiotherapist GRC balance rating scores to be associated with an increasing improvement in MBT balance score. This linear trend with the MBT change was not replicated with the BBS.

Baseline MBT mean score was significantly associated with baseline mean BBS score (r=0.78, p=0.01). Both balance measures at baseline were statistically significantly correlated with all five secondary outcome measures. The MBT baseline score demonstrated overall higher correlation coefficients for each secondary measure compared to the BBS (See Table 6).

The association between MBT, BBS change scores and secondary measure changes scores are presented in Table 7. Change on the BBS was not significantly associated
with changes on any of the secondary measures. Change in the MBT was significantly associated with change in MSIS-29 (physical) (r=0.355; p=0.14).

Discussion

Both balance measures demonstrated a statistically significant change in balance post intervention. There was a tendency for the BBS to demonstrate greater ceiling effects, a smaller effect size, and a lower standard response mean, compared to than the MBT. Furthermore the change in BBS was not linearly associated with the overall participants’ impression of balance change. Other studies (Godi et al. 2013, King et al. 2012) comparing the MBT and BBS report similar more favorable findings for the MBT in PD and people with other mixed neurological conditions. Therefore, this study suggests that the MBT may demonstrate better ability to detect balance change after physiotherapy, compared to the BBS, in PwMS, who predominately mobilised independently or with a unilateral aid.

Both balance measures were similarly able to determine those who reported near falls and/or use mobility devices but neither could detect those who reported falls. The cut off points for walking aid use are similar to that of King et al. (2012) who compared the BSS and MBT in the ability to detect those with and without postural responses in PD. They reported cut-off points for the MBT at 21, yielding sensitivity, specificity (89%, 81%) and the BBS at 52 points yielding sensitivity, specificity (77%, 74%). Another study (Leddy et al. 2011) reported a cut off score of 20 for the MBT, yielding sensitivity, specificity=(88%, 78%) in identifying those with a history of falls in PD. We acknowledge the limitation of using self-report falls and near falls in this study and future studies are needed using prospective falls monitoring in PwMS. To the best
of the authors’ knowledge this study is the first to compare both balance measures’ ability to detect near falls and/or mobility aid use in ambulatory PwMS exclusively. There was a positive non-significant trend for participants and physiotherapists GRC balance scores to be associated with an increasing MBT score that was not seen for the BBS. Godi et al. (2013) also demonstrated more favorable results for the MBT in determining those who reported a balance improvement on their GRC compared to the BBS. This finding therefore suggests a change on the MBT may be better associated with the participant’s impression of improved balance. Further studies with larger sample sizes are needed to use this GRC to calculate the minimum clinically important difference for the MBT.

There was a high correlation (0.78) between the baseline MBT score and the baseline BBS score. This concurs with King et al. (2012) who also found a high correlation (0.78) between the MBT and BBS in people with PD. Both balance measures were significantly correlated with all five secondary outcome measures. Thus, the above findings support the concurrent validity of both the MBT and the BBS with the MBT. Interestingly, the MBT demonstrated higher correlation compared to the BBS for two of the secondary measures (i.e. the 6MWT and MSWS-12). Both the 6MWT and MSWS-12 investigate dynamic balance during gait. Thus these findings suggest that the MBT may be more associated with dynamic balance and is supported by the fact that the MBT assesses additional systems required for postural stability in PwMS.

**Limitations**

This sample was one of convenience with all out-patient participants independently ambulating with or without an aid and therefore may not be applicable to the whole
MS population. Retrospective data was collected for near falls and falls history. Prospective data would give a more accurate account of falls status. It was not possible to calculate the Minimally Clinical Important Difference (MCID) of the MBT, in this study, due to the small sample size. This study also did not compare reliability estimates of both measures. Also, there was lack of blinding in the intervention and outcome assessment.

**Conclusion**

Both measures performed similarly in some areas with a tendency for the MBT to demonstrate less ceiling effects, better responsiveness and a slightly better ability to detect near fallers and mobility aid users compared to the BBS. MBT scores at baseline were also more correlated to secondary measures than the baseline BBS data, thus adding to the validity of the novel MBT. These findings may suggest that the MBT is better placed to detect balance change due to physiotherapy in ambulatory PwMS, who mobilised independently with or without an aid.
## Paper II Tables

### Table 3: Participant Demographic Data

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since MS onset (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>10.87</td>
<td>8.48</td>
</tr>
<tr>
<td>Descriptor</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Type of MS diagnosed (N;%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benign MS</td>
<td>3</td>
<td>5.7</td>
</tr>
<tr>
<td>Relapse-Remitting MS</td>
<td>42</td>
<td>80.8</td>
</tr>
<tr>
<td>Secondary progressive MS</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>Primary progressive MS</td>
<td>4</td>
<td>7.7</td>
</tr>
<tr>
<td>Walking aid used (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>32</td>
<td>61.5</td>
</tr>
<tr>
<td>Zimmer Frame</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Rollator</td>
<td>3 (1 plus DS)</td>
<td>5.8</td>
</tr>
<tr>
<td>Walking stick/cane</td>
<td>11 (1 plus AFO; 1 plus FES, 2 plus DS)</td>
<td>21.1</td>
</tr>
<tr>
<td>Elbow crutch</td>
<td>2</td>
<td>3.8</td>
</tr>
<tr>
<td>Two elbow crutches</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Tripod</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>AFO</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Dictus</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Other (e.g. FES only)</td>
<td>1</td>
<td>1.9</td>
</tr>
</tbody>
</table>

N=52; %=percentage; SD= Standard deviation; MS=Multiple Sclerosis; DS=Dictus Splint foot device; AFO=Ankle-foot-orthosis device; FES=Functional electrical stimulation foot drop device.
## Paper II Tables

**Table 4: Summary Statistics for Pre, Post and Change BBS and MBT values.**

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Median (IRQ)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBT Pre (n=52)</td>
<td>18.8 (6.0)</td>
<td>22 (10.5)</td>
<td>4-27</td>
</tr>
<tr>
<td>MBT Post (n=47)</td>
<td>23.6 (3.8)</td>
<td>25 (7.0)</td>
<td>15-28</td>
</tr>
<tr>
<td>MBT Change (n=47)</td>
<td>-5.31(3.5)</td>
<td>-5.0 (4.0)</td>
<td>1-17</td>
</tr>
<tr>
<td>BBS Pre (n=52)</td>
<td>53.3 (3.2)</td>
<td>55 (4.5)</td>
<td>45-56</td>
</tr>
<tr>
<td>BBS Post (n=47)</td>
<td>54.5 (2.6)</td>
<td>55.5 (2.25)</td>
<td>44-56</td>
</tr>
<tr>
<td>BBS Change (n=47)</td>
<td>-1.4 (1.9)</td>
<td>-1.0 (2.0)</td>
<td>0-6</td>
</tr>
</tbody>
</table>

BBS=Berg Balance Scale; MBT=Mini-BESTest; IRQ=Interquartile range
# Paper II Tables

## Table 5: Means and Standard Deviations of MBT and BBS Change score and number of Inter-item responses on Participant and Physiotherapy GRC Balance Scales.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRC (Participant)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>19</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>(BBS change)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.8</td>
<td>1.7</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>1.9</td>
<td>2.3</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(MBT change)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>4.0</td>
<td>4.9</td>
<td>6.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>2.4</td>
<td>3.1</td>
<td>4.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GRC (Physiotherapist)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>29</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>(BBS change)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.7</td>
<td>1.4</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>1.9</td>
<td>1.8</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(MBT change)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>4.2</td>
<td>5.1</td>
<td>6.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>2.4</td>
<td>3.1</td>
<td>4.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1= Very much Dis-improved, 2=Much Dis-improved, 3= Minimally Dis-improved, 4= No Change, 5= Minimally Improved, 6= Much Improved, 7= Very much Improved

GRC=Global rating of change, N=Number; SD=Standard deviation, BBS=Berg Balance Scale, MBT=The Mini-BESTest.

**Note:** Overall Participant GRC balance Scale=Mean (SD), Range =5 (1.41), 4-7
Overall Physiotherapist GRC Balance Scale=Mean (SD) Range=4.5(0.7), 4-6

Participant GRC Balance Scale Descriptor= “With respect to your balance due to your Multiple Sclerosis, how would you describe yourself now compared to the beginning of this intervention period?”

Physiotherapist GRC Balance Scale Descriptor= “Compared the beginning of this intervention period, how would you describe the participant’s balance due to their Multiple Sclerosis now?”

---

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**Paper II Tables**

**Table 6: Correlation Coefficients for MBT and BBS pre scores between five secondary outcome measures pre scores**

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>1. MBT PRE</td>
<td>--</td>
<td>.788**</td>
<td></td>
<td>.643**</td>
<td></td>
<td>.390**</td>
<td></td>
</tr>
<tr>
<td>2. BBS PRE</td>
<td>.788**</td>
<td>--</td>
<td></td>
<td>.488**</td>
<td></td>
<td>.285**</td>
<td></td>
</tr>
<tr>
<td>3. MSISphys PRE</td>
<td>.643**</td>
<td></td>
<td></td>
<td>--</td>
<td></td>
<td>.815**</td>
<td></td>
</tr>
<tr>
<td>4. MSISpsych PRE</td>
<td>.390**</td>
<td></td>
<td></td>
<td>.285**</td>
<td></td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>5. MFIS PRE</td>
<td>.495**</td>
<td></td>
<td></td>
<td>.427**</td>
<td></td>
<td>.799**</td>
<td></td>
</tr>
<tr>
<td>6. MSWS PRE</td>
<td>.766**</td>
<td></td>
<td></td>
<td>.676**</td>
<td></td>
<td>.834**</td>
<td></td>
</tr>
<tr>
<td>7. 6MWT PRE</td>
<td>.810**</td>
<td></td>
<td></td>
<td>.790**</td>
<td></td>
<td>.623**</td>
<td></td>
</tr>
</tbody>
</table>

MBT=Mini-BESTest; BBS=Berg balance scale; MSISphys=Multiple Sclerosis Impact Scale (physical); MSISpsych=Multiple Sclerosis Impact Scale (psychological); MFIS=Modified Fatigue Impact Scale; MSWS=Multiple Sclerosis Walking Scale-12; 6MWT=Six Minute Walk Test.

Spearman's rho; n=52 subjects

**.** Correlation is significant at the 0.05 level (2-tailed).

**.** Correlation is significant at the 0.01 level (2-tailed).
### Paper II Tables

Table 7: Correlation Coefficients for MBT and BBS change scores between five secondary outcome measures change scores

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MSISphys (change)</td>
<td>--</td>
<td>.630**</td>
<td>.343</td>
<td>.648**</td>
<td>-0.19</td>
<td>.355</td>
<td>.155</td>
</tr>
<tr>
<td>2. MSISpsych (change)</td>
<td>.630**</td>
<td>--</td>
<td>.354</td>
<td>.382**</td>
<td>.116</td>
<td>-116</td>
<td>-.078</td>
</tr>
<tr>
<td>3. MFIS (change)</td>
<td>.343*</td>
<td>.354*</td>
<td>--</td>
<td>.426**</td>
<td>-.235</td>
<td>-.094</td>
<td>-.066</td>
</tr>
<tr>
<td>4. MSWS (change)</td>
<td>.648**</td>
<td>.382**</td>
<td>.426**</td>
<td>--</td>
<td>-.142</td>
<td>.188</td>
<td>.153</td>
</tr>
<tr>
<td>5. 6MWT (change)</td>
<td>0.19</td>
<td>.116</td>
<td>-.235</td>
<td>-.142</td>
<td>--</td>
<td>-.013</td>
<td>.020</td>
</tr>
<tr>
<td>6. MBT (change)</td>
<td>.355*</td>
<td>-.116</td>
<td>-.094</td>
<td>.188</td>
<td>-.013</td>
<td>--</td>
<td>.469**</td>
</tr>
<tr>
<td>7. BBS (change)</td>
<td>.155</td>
<td>-.078</td>
<td>-.066</td>
<td>.153</td>
<td>.020</td>
<td>.469**</td>
<td>--</td>
</tr>
</tbody>
</table>

MBT=Mini-BESTest; BBS=Berg balance scale; MSISphys=Multiple Sclerosis Impact Scale (physical); MSISpsych=Multiple Sclerosis Impact Scale (psychological); MFIS=Modified Fatigue Impact Scale; MSWS=Multiple Sclerosis Walking Scale-12; 6MWT=Six Minute Walk Test.

Pearson's; n=47 subjects

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).
References


Hutchinson, B., Forwell, S., Bennett, S., Brown, T., Karpatkin, H. and Miller, D. (2009) 'Toward a consensus on rehabilitation outcomes in MS: gait and


Chapter 4: Conclusion of Thesis
Conclusion

The overall aims of this thesis were to investigate the inter-rater reliability of the Mini-BESTest (MBT) and to compare this novel measure to the commonly used Berg Balance scale (BBS). This chapter will summarize and discuss the limitations of and key findings obtained from the introductory chapter, Paper I and Paper II of this thesis, making the recommendations for future clinical research and practice.

Discussion

The introductory chapter of this thesis contains an overview of the literature surrounding balance and the importance of outcome measures in Multiple Sclerosis (MS). Balance impairment is common and complex in people with MS (PwMS) (Cameron and Nilsagard 2013, Larocca 2011). It can be a result of various interacting impaired systems (Shumway-Cook and Woollacott 2012). Many current balance measures do not capture all balance domains (Sibley et al. 2014) and also may demonstrate ceiling effects (Paltamaa et al. 2012). Thus, leading to potentially inappropriate assessment and management of balance in PwMS. Therefore alternative and more comprehensive ways of measuring balance in PwMS are recommended.

Various interventions addressing impaired body functions and incorporating task specific strategies (i.e. motor, sensory and cognition) and functional tasks under different environments, have all lead to balance improvements in PwMS (Paltamaa et al. 2012, Shumway-Cook and Woollacott 2012). Despite the above positive findings of various interventions on balance, to date the majority of research has been carried out in people with mild to moderate MS. Thus, more trials are required investigating...
PwMS with greater mobility limitations. Furthermore, continued understanding and knowledge needs to grow in relation to our understanding of balance, prevalence, causes, outcome measures and interventions. The ability to assess all balance domains, various psychometric properties, including reliability, validity and responsiveness all need to be investigated when using these novel measures, in order to optimise physiotherapist assessment and subsequent treatment interventions of this common impairment in PwMS.

The next section outlines the key findings from the two papers in this thesis. Results from Paper I suggest there is a strong agreement between two raters for the total MBT and inter-item MBT scores in an ambulatory PwMS. A change of 7 points may be required to ensure a change is not due to measurement error or for it to be a potential meaningful change in ambulatory PwMS, particularly when the ratings of novice and experienced practitioners are used. Results from Paper II suggests that the MBT may have a tendency to demonstrate better ability to detect balance change after physiotherapy, compared to the BBS, in ambulatory PwMS who predominately mobilised independently and/or with an unilateral aid. Both measures were shown to distinguish between a near faller or mobility aid user similarly but neither for self reported falls.

The clinical implications of the above findings from both papers, for practice and research will now be discussed. Both papers were the first of their kind to investigate the inter-rater reliability of the MBT and compare this novel balance measure to the commonly used BBS, exclusively in ambulatory PwMS.

Paper I demonstrated preliminary evidence for the reliability of the MBT as a balance measure in ambulatory PwMS and suggests that more than 7 points difference between two raters is needed to be confident that the change is greater than
measurement error. Furthermore, Paper I has outlined various suggestions regarding potential ways to address the least reliable MBT items (i.e. item 5, 6 and 11) when using the MBT clinically. The Minimal Detectable Change (MDC) of 7 points between a novice and experienced rater is particularly relevant as often PwMS encountered different therapists throughout their long life condition.

Of note, the finding of a high ICC and a high MDC in this study, highlight the importance of investigating both relative and absolute inter-reliability of a measure when investigating the inter-rater reliability of a measure. The high MDC in this study may be due to the variance in MBT scores in the sample or the difference in experience of the raters. Additional future studies with larger sample sizes should also consider stratifying the reliability estimates for different mobility categories, as MDC estimates may differ depending on the level of balance and mobility limitations of the participants.

Paper II adds to the validity and responsiveness of the MBT and suggests it is an appropriate measure to use in high level PwMS. Interestingly, findings from Paper II also support a tendency for the MBT to be more associated with dynamic gait domains as measured on secondary measures (six minute walk test (6MWT) and the MS walking scale (MSWS-12)), compared to BBS. Cameron et al. (2014) concurs with these findings in relation to the MBT being also highly correlated with the MSWS-12 ($r = 0.69, p < 0.001$) in PwMS. Therefore the MBT appears to be more comprehensive in assessing additional systems required for functional balance in PwMS, who predominantly were independent or used a unilateral aid to mobilise.

Appropriate detection and an accurate measurement of balance may not only improve outcomes but may maximize PwMS adherence to balance interventions thorough goal setting and demonstrating change to the participant. Furthermore, A MBT score of
below a cut-off of 19.5 points on the MBT classified those requiring a mobility aid with a sensitivity of 0.850 and specificity of 0.812. The use of this cut off score of 19.5 points on the MBT maybe clinically useful in detecting those who may need to transition to a walking aid. It may also be useful as part of goal setting in future balance and mobility programs.

More trials also investigating other forms of reliability (i.e. intra-rater reliability and internal consistency), validity and performance in relation to other gold standard measures (e.g. force platform measures) are indicated for the MBT. It was not possible to calculate the Minimally Clinical Important Difference (MCID) due to the small data set used in this thesis. Therefore this also should be addressed in future studies. Furthermore, prospective data collection of falls and near falls history would also be more useful when determining whether each measure can distinguish those who falls or nearly falls. Of note 65% (34 of 52) of our participants reported a history of near falls compared 35% (13 of 52) of our sample that reported a history of falls. Therefore it may be important to investigate both factors in high-level ambulatory PwMS in future research.

Limitations

Though many key findings can be taken from the two papers outlined in this thesis, certain limitations must be acknowledged.

Recruitment

The small sample size and the use of a convenience sample from a single hospital setting may limit the application of this thesis to other settings. Not all the people who
were invited to partake in the study enrolled in the study. This may have introduced a non-inclusion bias into the results. Those that participated in the study may be a more motivated subset and thus the results may not represent the wider MS population.

**Testing**

The intra-rater reliability involved only two raters (i.e. one novice and one experienced). Therefore the MBT may be less reliable when multiple raters are used.

**Participants**

The majority of our sample had RRMS and required no aid (n=32; 61.5%) or a unilateral aid to mobilise (n=11; 21.1%). Thus, our findings may not applicable to those with progressive MS or to those who require a bilateral aid to mobilise. However clinically, the majority of the PwMS tend to be ambulatory with RRMS (McDonald and Compston 2006) which was similar to the majority of our subjects used in this study.

**Concluding statement**

In conclusion, growing evidence for the novel balance measure the MBT exists. The studies in this thesis aimed to evaluate whether it is of clinical use in ambulatory PwMS. The inter-rater reliability of this measure was high in this population and the MBT appeared to be a better measure than the commonly used BBS in detecting
balance change. Further psychometric and comparison studies are needed particularly involving PwMS who demonstrate greater mobility limitations.
References


List of Appendices
June 19th 2013

Re: Responsiveness of the Berg Balance Scale and Mini BESTest for Ambulatory People with Multiple Sclerosis.

Please quote this reference in any follow up to this letter: 2013/06/12 Chairman’s Action

Dear Elaine,

Thank you for your recent submission of the above proposal to the SJH/AMNCH Research Ethics Committee.

The Chairman has reviewed your study on behalf of the Ethics Committee and has given ethical approval.

Yours sincerely

Ms. Ursula Ryan
Secretary,
SJH/AMNCH Research Ethics Committee
Volunteer Information Sheet

Use of the Mini-BESTest to Measure Balance
in People with Multiple Sclerosis

What is the study about?
The project aims to develop a greater understanding of how physiotherapists detect balance problems in people with multiple sclerosis (MS).

What will I have to do?
You will be asked to attend St. James’s hospital physiotherapy department. On the first day of the visit, we will do a short interview to get information about you and your MS. You will then do two balance tests (One once and a second one twice) and a walking test, that assesses your walking over six minutes (You can use whatever you normally use to walk). You will also be asked to fill out three questionnaires which look at how quality of life, fatigue and walking are affected by your MS.
You will then come back to St. James’s hospital physiotherapy department after eight weeks of physiotherapy treatment (i.e. either exercise classes, one and one sessions and/or your own home exercise programme)and then you will be asked to repeat the same balance tests once, the walking test and three questionnaires again.

What are the benefits to you?
At the end of the study we will tell you if your balance tests, walking test and/or quality of life, fatigue and walking questionnaire scores have changed. You will be contributing to our research in the area of assessing balance in MS. We hope to identify the best test between the two balance tests in assessing balance problems in people with MS. This will hopefully have an influence on future assessments and management plans for those with MS. Your involvement in this study may also get you thinking about addressing your balance problems, if any.

What are the risks?
The risks are negligible as the physical tests are routinely done by physios, and the others are questionnaires. You may be slightly fatigued following testing, but a rest period will be provided during tests to allow for recovery. While some of the questions in the questionnaires may be sensitive, you will not be required to answer any questions you do not wish to.

What if I do not want to take part?
Participation in this study is voluntary and you can choose not to consent or withdraw your consent and stop participating in this study at any time. If you decide not to take part it won’t influence any other treatments.

**What happens to the information?**
All your information will be kept anonymously and any results that are presented will be averages rather than individual results that could identify you. You will be assigned a study code, and only this will be used on any paperwork.

**Who else is taking part?**
Other volunteers that have been recruited through St. James’s Hospital physiotherapy department will also be taking part in this study.

**What is something goes wrong?**
In the unlikely event that something goes wrong during testing, the procedure will be immediately stopped and emergency procedures will be followed. A fully qualified, Chartered Physiotherapist will be present for the duration of all the testing.

**What happens at the end of the study?**
At the end of the study the information will be used to present results at presentations to professional groups and the MS Society of Ireland, but the information will be completely anonymous. All data gathered from the research will be held by the project supervisor for up to 7 years at St. James’s Hospital physiotherapy department.

**What if I have more questions or do not understand something?**
If you have any questions related to any aspect of the study you may contact the researcher. It is important that you feel that all your questions have been answered.

**What happens if I change my mind at any stage during the study?**
At any stage should you feel that you want to discontinue being a participant, you are free to stop and take no further part. There are no consequences for changing your mind about participating in the study.

**Contact name and number of Project Investigators.**
Principal investigator:  
Ms. Elaine Ross, St. James’s Hospital, Physiotherapy Dept, St. James’s Street, Dublin 8.  
(01) 4162503

Other investigator:  
Dr. Susan Coote, Physiotherapy Dept, University of Limerick.  
(061) 234278

*This study has been approved by St. James Hospital/Tallaght Hospital Research Ethics Committee. If you have any concerns about this study and wish to contact someone independent, you may contact The St. James Hospital/Tallaght hospital Research Ethics Contact Point in Tallaght Hospital. Tel: (01 414200*
Dear ________________

You have been invited to partake in the following research study:

**Use of the Mini-BESTest to Measure Balance in People with Multiple Sclerosis**

As part of this study you are invited to an initial assessment on ___ the ________ at ______pm. This assessment will help determine if you are suitable for the study and following exercise classes. Please wear comfortable clothing appropriate for light exercise. The class itself is expected to commence on _____ the _____ at ____ pm and will run for eight weeks.

Please find enclosed further information about this research study, your appointment card with our location and details of how to contact us. If you are unable to attend, please contact our department as soon as possible.

Yours sincerely,

__________________________

Elaine Ross
Senior Physiotherapist
MISCP; GDN
Dear __________________

You have been invited to partake in the following research study:

**Use of the Mini-BESTest to Measure Balance**

**in People with Multiple Sclerosis**

As part of this study you are invited to your initial assessment on Friday the _____ at ___ pm. This assessment will help determine if you are suitable for the study and following exercise classes. Please wear comfortable clothing appropriate for light exercise. The class itself is expected to commence on Friday the _____ at 14.30 pm and will run for eight weeks.

Please find enclosed further information about the research study, your appointment card with our location and details of how to contact us. If you are unable to attend, please contact our department as soon as possible.

Yours sincerely,

_____________________
Elaine Ross
Senior Physiotherapist
MISCP; GDNR
Dear ___________________

You have been invited to partake in the following research study:

**Use of the Mini-BESTest to Measure Balance**

**in People with Multiple Sclerosis**

As part of this study you are invited to an initial assessment on Friday the ______ at ______pm. This assessment will help determine if you are suitable for the study and following physiotherapy. Please wear comfortable clothing appropriate for light exercise.

Please find enclosed further information about this research study, your appointment card with our location and details of how to contact us. If you are unable to attend, please contact our department as soon as possible.

Yours sincerely,

___________________________
Elaine Ross
Senior Physiotherapist
MISCP; GDN
Verbal consent  Rater 1  Participant

Code:

GENERAL INFORMATION
Assessment date _______________________
Age __________/ D.O.B ________________ Male / Female
Neurologist / Physiotherapist

MEDICAL HISTORY
Diagnosis/Type of MS (if known)
_________________________________________________
Number of steroid treatments this year:

Most recent relapse:

Previous Medical History
☐ Heart problem
☐ Blood pressure
☐ Epilepsy
☐ Asthma
☐ Diabetes

Medications:
☐ Interferon beta-1b (Betaferon ®)
☐ Interferon beta-1a (Rebif ®)
☐ Interferon beta-1a (Avonex ®)
☐ Glatiramer acetate (Copaxone ®)
☐ Natalizumab (Tysabri)
☐ Mitoxantrone (Novantrone)
☐ Fampyra/Fampridine
☐ Fingolimod
☐ Steroids
☐ IVIG
☐ Other

Current mobility level
☐ No aid
☐ zimmer frame
☐ rollator
☐ W/s
☐ ECX1
☐ EC X2
☐ Tripod
☐ AFO
☐ Dictus Splint
☐ Other _____________________

Self-reported falls/near falls history (over last 3/12’s)
No of near falls: ________________________________
No of falls____________________________________
Title of study

Use of the Mini-BESTest to Measure Balance in People with Multiple Sclerosis

• I understand that my participation in this study is voluntary and that my future treatment will not be affected by taking part.
• I understand that information from my physiotherapy notes may be used in collecting data for this study.
• I understand that my results will be made anonymous and shared with researchers in the University of Limerick and Don Gnocci Foundation Italy for further analysis and processing.
• I understand that I have the option to withdraw from this study at any time as I so wish for any particular reason and that it won't influence my physiotherapy treatment in any way.
• This study and this consent form have been explained to me. The research physiotherapist has answered all my questions to my satisfaction. I believe I understand what will happen if I agree to be part of this study.
• I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.

PARTICIPANT’S NAME:

_________________________________________________

PARTICIPANT’S SIGNATURE:

_________________________________________________
**Modified Fatigue Impact Scale (MFIS)**

Fatigue is a feeling of physical tiredness and lack of energy that many people experience from time to time. But people who have medical conditions like MS experience stronger feelings of fatigue more often and with greater impact than others.

Following is a list of statements that describe the effects of fatigue. Please read each statement carefully, then circle the one number that best indicates how often fatigue has affected you in this way during the past 4 weeks. Please answer every question. If you are not sure which answer to select, chose the one answer that comes closest to describing you.

Name: ___________________________ Date: ___________________________

<table>
<thead>
<tr>
<th>Because of my fatigue during the past 4 weeks I have...</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Almost Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 been less alert</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2 had difficulty paying attention for long periods of time</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3 been unable to think clearly</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4 been clumsy and uncoordinated</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5 been forgetful</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6 had to pace myself in my physical activities</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7 been less motivated to do anything that requires physical effort</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8 been less motivated to participate in social activities</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9 been limited in my ability to do things away from home</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10 trouble maintaining physical effort for long periods</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11 had difficulty making decisions</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12 been less motivated to do anything that requires thinking</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13 been feeling as though my muscles are weak</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>14 been physically uncomfortable</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>15 had trouble finishing tasks that require thinking</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>16 had difficulty organizing my thoughts when doing things at home/work</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>17 been less able to complete tasks that require physical effort</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>18 been thinking more slowly</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>19 had trouble concentrating</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>20 limited my physical activities</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>21 needed to rest more often or for longer periods</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
12-Item MS Walking Scale (MSWS-12)

- These questions ask about limitations to your walking due to MS during the past 2 weeks.
- For each statement, please circle the one number that best describes your degree of limitation.
- Please answer all questions even if some seem rather similar to others, or seem irrelevant to you.
- If you cannot walk at all, please tick this box. □

<table>
<thead>
<tr>
<th>TABLE</th>
<th>In the past two weeks, how much has your MS….</th>
<th>Not at all</th>
<th>A little</th>
<th>Moderately</th>
<th>Quite a bit</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Limited your ability to walk?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2. Limited your ability to run?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>3. Limited your ability to climb up and down stairs?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4. Made standing when doing things more difficult</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>5. Limited your balance when standing or walking?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6. Limited how far you are able to walk?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>7. Increased the effort needed for you to walk?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>8. Made it necessary for you to use support when walking indoors (e.g., holding on to furniture, using a stick, etc.)?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>10. Slowed down your walking?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>11. Affected how smoothly you walk?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>12. Made you Concentrate on your walking?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
The following questions ask for your views about the impact of MS on your day-to-day life during the past two weeks.

For each statement, please circle the one number that best describes your situation.

Please answer all questions.

<table>
<thead>
<tr>
<th>In the past two weeks, how much has your MS limited your ability to …</th>
<th>Not at all</th>
<th>A little</th>
<th>Moderately</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do physically demanding tasks?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2. Grip things tightly (e.g. turning on taps)?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3. Carry things?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In the past two weeks, how much have you been bothered by …</th>
<th>Not at all</th>
<th>A little</th>
<th>Moderately</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Problems with your balance?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5. Difficulties moving about indoors?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6. Being clumsy?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7. Stiffness?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8. Heavy arms and/or legs?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9. Tremor of your arms or legs?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10. Spasms in your limbs?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11. Your body not doing what you want it to do?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12. Having to depend on others to do things for you?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Question</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>In the past two weeks, how much have you been bothered by …</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Limitations in your social and leisure activities at home?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>14. Being stuck at home more than you would like to be?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>15. Difficulties using your hands in everyday tasks?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>16. Having to cut down the amount of time you spent on work or other daily activities?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>17. Problems using transport (e.g. car, bus, train, taxi, etc.)?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>18. Taking longer to do things?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>19. Difficulty doing things spontaneously (e.g. going out on the spur of the moment)?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>20. Needing to go to the toilet urgently?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>21. Feeling unwell?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>22. Problems sleeping?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>23. Feeling mentally fatigued?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>24. Worries related to your MS?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>25. Feeling anxious or tense?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>26. Feeling irritable, impatient, or short-tempered?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>27. Problems concentrating?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>28. Lack of confidence?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>29. Feeling depressed?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
**Berg Balance Scale**

The Berg Balance Scale (BBS) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research. The BBS has been evaluated in several reliability studies. A recent study of the BBS, which was completed in Finland, indicates that a change of eight (8) BBS points is required to reveal a genuine change in function between two assessments among older people who are dependent in ADL and living in residential care facilities.

**Description:**
14-item scale designed to measure balance of the older adult in a clinical setting.

**Equipment needed:** Ruler, two standard chairs (one with arm rests, one without), footstool or step, stopwatch or wristwatch, 15 ft walkway

**Completion:**
- **Time:** 15-20 minutes
- **Scoring:** A five-point scale, ranging from 0-4. “0” indicates the lowest level of function and “4” the highest level of function. Total Score = 56

**Interpretation:**
- 41-56 = low fall risk
- 21-40 = medium fall risk
- 0 –20 = high fall risk

A change of 8 points is required to reveal a genuine change in function between 2 assessments.
Berg Balance Scale

Name: ____________________________ Date: ____________________
Location: ____________________________ Rater: ____________________

ITEM DESCRIPTION

Sitting to standing
Standing unsupported
Sitting unsupported
Standing to sitting
Transfers
Standing with eyes closed
Standing with feet together
Reaching forward with outstretched arm
Retrieving object from floor
Turning to look behind
Turning 360 degrees
Placing alternate foot on stool
Standing with one foot in front
Standing on one foot

SCORE (0-4)

Total __________

GENERAL INSTRUCTIONS
Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- the time or distance requirements are not met
- the subject’s performance warrants supervision
- the subject touches an external support or receives assistance from the examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be a reasonable height. Either a step or a stool of average step height may be used for item # 12.
Berg Balance Scale

SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding on.
( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

TRANSFERS
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds
Berg Balance Scale continued...

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch your fingers and reach forward as far as you can. ( Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. ( Examiner may pick an object to look at directly behind the subject to encourage a better twist turn. )
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject’s normal stride width.)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold ≥ 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0 unable to try of needs assist to prevent fall

( ) TOTAL SCORE (Maximum = 56)
MINI BESTest- of DYNAMIC BALANCE
Balance Evaluation – Systems Test
Copyright 2009

Subjects should be tested with flat-heeled shoes OR shoes and socks off.
If subject must use an assistive device for an item, score that item one category lower. If subject requires
physical assistance to perform an item, score the lowest category (0) for that item.

1. SIT TO STAND
(2) Normal: Comes to stand without use of hands and stabilizes independently.
(1) Moderate: Comes to stand WITH use of hands on first attempt.
(0) Severe: Impossible to stand up from chair without assistance –OR- several attempts with use of hands.

2. RISE TO TOES
(2) Normal: Stable for 3 sec with maximum height
(1) Moderate: Heels up, but not full range (smaller than when holding hands)-OR-noticeable instability for 3 s
(0) Severe: < 3 sec

3. STAND ON ONE LEG
Left Time in sec Trial 1:________ Trial 2:________ Right Time in sec Trial 1:________ Trial 2:________
(2) Normal: 20 s (2) Normal: 20 s
(1) Moderate: < 20 sec (1) Moderate: < 20 sec
(0) Severe: Unable (0) Severe: Unable

4. COMPENSATORY STEPPING CORRECTION- FORWARD
(2) Normal: Recovers independently a single, large step (second realignment step is allowed)
(1) Moderate: More than one step used to recover equilibrium
(0) Severe: No step, OR would fall if not caught, OR falls spontaneously

5. COMPENSATORY STEPPING CORRECTION- BACKWARD
(2) Normal: Recovers independently a single, large step
(1) Moderate: More than one step used to recover equilibrium
(0) Severe: No step, OR would fall if not caught, OR falls spontaneously

6. COMPENSATORY STEPPING CORRECTION- LATERAL
Left Time in sec Trial 1:________ Trial 2:________ Right Time in sec Trial 1:________ Trial 2:________
(2) Normal: Recovers independently with 1 step (crossover or lateral OK)
(1) Moderate: Several steps to recover equilibrium
(0) Severe: Falls, or cannot step

7. EYES OPEN, FIRM SURFACE (FEET TOGETHER)
Time in sec:________
(2) Normal: 30s
(1) Moderate: < 30s
(0) Severe: Unable

8. EYES CLOSED, FOAM SURFACE (FEET TOGETHER)
Time in Sec:________
(2) Normal: 30s
(1) Moderate: < 30s
(0) Severe: Unable
9. INCLINE- EYES CLOSED

*Time in sec:________*

- **(2) Normal:** Stands independently 30 sec and aligns with gravity
- **(1) Moderate:** Stands independently <30 SEC -OR- aligns with surface
- **(0) Severe:** Unable to stand >10 sec -OR- will not attempt independent stance

10. CHANGE IN GAIT SPEED

- **(2) Normal:** Significantly changes walking speed without imbalance
- **(1) Moderate:** Unable to change walking speed or imbalance
- **(0) Severe:** Unable to achieve significant change in speed AND signs of imbalance

11. WALK WITH HEAD TURNS – HORIZONTAL

- **(2) Normal:** performs head turns with no change in gait speed and good balance
- **(1) Moderate:** performs head turns with reduction in gait speed
- **(0) Severe:** performs head turns with imbalance

12. WALK WITH PIVOT TURNS

- **(2) Normal:** Turns with feet close, FAST (< 3 steps) with good balance
- **(1) Moderate:** Turns with feet close SLOW (> 4 steps) with good balance
- **(0) Severe:** Cannot turn with feet close at any speed without imbalance

13. STEP OVER OBSTACLES

- **(2) Normal:** able to step over box with minimal change of speed and with good balance
- **(1) Moderate:** steps over shoe boxes but touches box OR displays cautious behavior by slowing gait.
- **(0) Severe:** cannot step over shoe boxes OR hesitates OR steps around box

14. TIMED UP & GO (ITUG) WITH DUAL TASK

- **(2) Normal:** No noticeable change between sitting & standing in backward counting & no change in gait speed for TUG.
- **(1) Moderate:** Dual task affects either counting OR walking.
- **(0) Severe:** Stops counting while walking OR stops walking while counting.
INSTRUCTIONS:

1. SIT TO STAND

**Examiner Instructions**: Note the initiation of the movement, and the use of hands on the arms of the chair or their thighs or thrusts arms forward.

**Patient**: Cross arms across your chest. Try not to use your hands unless you must. Don’t let your legs lean against the back of the chair when you stand. Please stand up now.

2. RISE TO TOES

**Examiner Instructions**: Allow the patient to try it twice. Record the best score. (If you suspect that subject is using less than their full height, ask them to rise up while holding the examiners’ hands.) Make sure subjects look at a non-moving target 4-12 feet away.

**Patient**: Place your feet shoulder width apart. Place your hands on your hips. Try to rise as high as you can onto your toes. I'll count out loud to 3 seconds. Try to hold this pose for at least 3 seconds. Look straight ahead. Rise now.

3. STAND ON ONE LEG

**Examiner Instructions**: Allow the patient two attempts and record the best. Record the no. of seconds they can hold posture up to a maximum of 30sec. Stop timing when subject moves their hand off hips or puts a foot down. Make sure subjects look at a non-moving target 4-12 feet ahead.

**Patient**: Look straight ahead. Keep your hands on your hips. Bend one leg behind you. Don't touch your raised leg on your other leg. Stay standing on one leg as long as you can. Look straight ahead. Lift now. (Repeat other side)

4. COMPENSATORY STEPPING CORRECTION-FORWARD

**Examiner Instructions**: Stand in front to the side of patient with one hand on each shoulder and ask them to push forward. (Make sure there is room for them to step forward). Require them to lean until their shoulders and hips are in front of their toes. Suddenly release your push when the subject is in place and providing constant pressure to a level just before the heels lift off. The test must elicit a step. NOTE: Be prepared to catch patient.

**Patient**: Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall.

**NOTE**: Be prepared to catch patient.

5. COMPENSATORY STEPPING CORRECTION - BACKWARD

**Examiner Instructions**: Stand in back to the side of the patient with one hand on each scapula and ask them to push backward. (Make sure there is room for them to step backward.) Require them to lean until their shoulders and hips are in back of their heels. Release your push when the subject is in place, and providing constant pressure to a level just before the heels lift off. Test must elicit a step. NOTE: Be prepared to catch patient.

**Patient**: Stand with your feet shoulder width apart, arms down at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall.

**NOTE**: Be prepared to catch patient.

6. COMPENSATORY STEPPING CORRECTION - LATERAL

**Examiner Instructions**: Stand behind the patient, place one hand on either the right (or left) side of the pelvis, and get them to lean their whole body into your hand. Require them to lean until the midline of pelvis is over the right (or left) foot and then suddenly release your hold. NOTE: Be prepared to catch patient if necessary!

**Patient**: Stand with your feet together, arms down at your sides. Lean into my hand beyond your sideways limit. When I let go, step if you need to, to avoid a fall.

**NOTE**: Be prepared to catch patient.
Sensory Orientation

7. Eyes Open, Firm Surface
Examiner Instructions: Record the time the patient was able to stand to a maximum of 30 seconds.

Patient: Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Each time, stay as stable as possible until I say stop.

8. Eyes Closed, Foam Surface
Examiner Instructions: Use medium density Temper® foam, 4 inches thick. Assist subject in stepping onto foam. Tell patient to “Close Eyes” Record the time the patient was able to stand in each condition to a maximum of 30 seconds. Have the subject step off the foam between trials. Include leaning or hip strategy during a trial as “instability.”

Patient: Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Each time, stay as stable as possible until I say stop.

(Shumway-Cook A and Horak FB. Assessing the influence of sensory interaction on balance. Physical Therapy. 66: 1548 1550, 1986.)

9. Incline, Eyes Closed
Examiner Instructions: Aid the patient onto the ramp. Once the patient closes their eyes, begin timing and record and average both times. Note if sway is greater than when standing on firm, level, surface with eyes closed (Item 15 B) or if there is poor alignment to vertical. Assist includes a cane or light touch any time during the trial.

Patient: I will be timing this next assessment. Please stand on the incline ramp with your toes toward the top. Place your feet shoulder width apart. Keep arms at your sides. Place your hand on your hips. I will start timing when you close your eyes.

10. Change in Speed
Examiner Instructions: Allow the patient to take 3-5 steps at their normal speed, and then say “fast”, after 3-5 fast steps once say “slow”. Allow 3-5 slow steps before they stop walking.

Patient: Begin walking at your normal speed, when I tell you “fast” walk as fast as you can. When I say “slow”, walk very slowly.

11. Walk With Head Turns- Horizontal
Examiner Instructions: Allow the patient to reach their normal speed, and give the commands “right, left” every 3-5 steps. Score if you see a problem in either direction. If patient has severe cervical restrictions allow combined head and trunk movements (enbloc).

Patient: Begin walking at your normal speed, when I say “right”, turn your head and look to the right. When I say “left” turn your head and look to the left. Try to keep yourself walking in a straight line.
Use of the Mini-BESTest to Measure Balance
in People with Multiple Sclerosis

Baseline Participant

Physiotherapy Assessment Sheet

☐ Verbal consent  Rater 1  Participant Code:

Date: ______________

6 Minute Walk Test

Number of laps:____(30 meters) Final partial lap:_____meters

Total distance walked in 6 minutes:_____meters

Assistive device and/or bracing used:

________________________________________________________

Notes:

________________________________________________________
Follow Up Participant Physiotherapy Assessment Sheet

☐ Verbal consent  Rater 1  Participant Code:

Date_______________

Intervention details

Mode: ____________________________________________

Frequency: _________________________________________

Time: _____________________________________________

Intensity: __________________________________________

Number of falls: _________________
Number of near misses: _________________
Use of the Mini-BESTest to Measure Balance

in People with Multiple Sclerosis

Follow Up Participant Physiotherapy Assessment Sheet

☐ Verbal consent  Rater 1  Participant Code:

Date_______________

Outcome measures

6 Minute Walk Test

Number of laps:____(30 meters) Final partial lap:_____meters

Total distance walked in 6 minutes:______meters

Assistive device and/or bracing used:

__________________________________________________

Notes:

__________________________________________________
INSTRUMENT NAME: 6 Minute Walk Test

REVIEWER: Kirsten Potter, PT, DPT, MS, NCS

GENERAL INFORMATION:
- The 6 Minute Walk Test (MWT) is a submaximal measure of gait velocity and durance – distance walked in 6 minutes
- Other versions include different time duration of test (2, 3, 5, 10, and 12 minutes)
- Minute walk tests have been used in various patient populations (e.g., neuromuscular, cardiopulmonary, peripheral vascular disease, cancer, amputation)

EQUIPMENT NEEDED:
- Stopwatch
- Two small cones to mark the turnaround point
- A chair that can be easily moved along the walking course
- Worksheets on a clipboard
- Sphygmomanometer

ADMINISTRATION INSTRUCTIONS:

Detailed instructions are provided in the American Thoracic Society: Guidelines for the Six-Minute Walk Test.¹

Time to administer and score:
- 6 minutes to administer the test plus time to set up the environment and provide instructions to the patient

General Rules:
- The 6MWT is a simple test that requires a 100-ft, quiet, indoor, flat, straight rectangular hallway. The walking course must be 30m in length. The length of the 30m corridor must be marked by colored tape at every 3m. The turnaround must be marked with a cone. Some studies have used 20 and 50m corridors
- The patient should:
  - Wear comfortable clothing
  - Wear appropriate walking shoes
  - Use their usual walking aids during the test
- The patient should be encouraged to:
  - Wear comfortable clothing

6 Minute Walk Test
Multiple Sclerosis Outcome Measures Taskforce
Compendium of Instructions for Outcome Measures

- Wear appropriate walking shoes
- Use their usual walking aids during the test (cane, walker, etc.)
- Take their usual medications
- Avoid engaging in vigorous exercise 2 hours prior to testing

- Goldman et al. found a lack of a practice effect when administering the 6 MWT to individuals with MS, indicating one trial is sufficient

Definitions:

Instructions:

- Do not provide a "warm-up" period.
- For at least 10 minutes before the beginning of the test, the client should sit in a chair located near the starting position. During this time, the clinician should review the contraindications, the appropriateness of the client’s clothing and shoes, and complete the first part of the worksheet (see below). (“ATS statement: guidelines for the six-minute walk test,” 2002)¹

- The following elements should be present on the 6MWT worksheet and report:
  Lap counter: ___________ ___________ ___________ ___________ ___________ ___________
  Patient name: __________________________ Patient ID# __________________________
  Walk # _______ Tech ID: ___________ Date: ___________
  Gender: M F Age: _____ Race: _____ Height: _____ft _____in, _____ meters
  Weight: _____ lbs, _____ kg Blood pressure: _____ / _____
  Medications taken before the test (dose and time): __________________________
  Supplemental oxygen during the test: No Yes, flow _____ L/min, type _____
  Baseline End of Test
  Time: ________:
  Heart Rate ___________
  Dyspnea _____ (Borg scale)
  Fatigue _____ (Borg scale)
  SpO2 _____% _____%
  Stopped or paused before 6 minutes? No, Yes, reason: __________________________
  Other symptoms at end of exercise: angina, dizziness hip, leg, or calf pain
  Number of laps: _____ (_60 meters) _ final partial lap: _____ meters __
  Total distance walked in 6 minutes: _______ meters
  Predicted distance: _______ meters Percent predicted: _____%
  Tech comments:
  Interpretation (including comparison with a pre-intervention 6MWT).

6 Minute Walk Test
A lap counter (or pen and paper) should be used to note the number of laps that the client is able to walk during the 6 minutes.

According to the American Thoracic Society (ATS) protocol, patients should be instructed in the following way:

- "The object of this test is to walk as far as possible for 6 minutes. You will walk back and forth in this hallway. Six minutes are a long time to walk, so you will be exerting yourself. You will probably get out of breath or become exhausted. You are permitted to slow down, to stop, and to rest as necessary. You may lean against the wall while resting, but resume walking as soon as you are able. You will be walking back and forth around the cones. You should pivot briskly around the cones and continue back the other way without hesitation. Now I’m going to show you. Please watch the way I turn without hesitation."
- Demonstrate by walking one lap yourself. Walk and pivot around a cone briskly. Then say:
  "Are you ready to do that? I will write down each time you turn around at this starting line. Remember that the object is to walk as far as possible for 6 minutes, but don't run or jog. Start now or whenever you are ready."
- The patient should be positioned at the starting line. The clinician should stand near the starting line during the test. As soon as the patient starts to walk, the timer should be started.
- No conversations should take place during the walk. An even tone of voice should be used when providing the standard phrases of encouragement (see below). The patient should be supervised. The clinician should remain focused and not lose count of the laps.
- After the first minute, the patient should be told the following (in an even tone):
  "You are doing well. You have 5 minutes to go.
- When the timer shows 4 minutes remaining, the patient should be told the following:
  "Keep up the good work. You have 4 minutes to go."
- When the timer shows 3 minutes remaining, the patient should be told the following:
  "You are doing well. You are halfway done."
- When the timer shows 2 minutes remaining, the patient should be told the following:
  "Keep up the good work. You have only 2 minutes left."
- When the timer shows only 1 minute remaining, the patient should be told the following:
  "You are doing well. You have only 1 minute to go."

Other words of encouragement or body language (eg. to speed up) should not be used.

6 Minute Walk Test
The test should be discontinued if the patient experiences:

- Chest pain
- Intolerable dyspnea
- Leg cramps
- Staggering (unusual in nature)
- Diaphoresis
- Pale or ashen appearance

Upon completion of the test:

- Clients should be asked to rate their post walk dyspnea and overall fatigue levels using the Borg scale.
- The following should be asked: "What, if anything, kept you from walking farther?"
- If using a pulse oximeter, measure SpO2 and pulse rate from the oximeter and then remove the sensor.
- The number of laps should be recorded on the worksheet.
- The total distance walked, rounded to the nearest meter, should be calculated and recorded on the worksheet.
- The client should be congratulated for good effort and should be offered a drink of water (if not on a liquid restricted diet due to dysphagia).

**Scoring:**

- The lap counter or pen and paper should be used to note the number of laps that the patient is able to walk during the 6MWT.
- Distance walked, and the number and duration of rests during the 6 minutes should be measured.
- Scores range from 0 meters or feet for patients who are non-ambulatory to the maximum biological limits for normal healthy individuals (approximately 900 meters or 2953 feet).

**INTERPRETATION GUIDELINES:**

- Longer distance walked indicates better performance
- Patient’s value can be compared to normative data

6 Minute Walk Test
Normative Data:
- Reference data in 53 healthy subjects aged 50 – 85 = 631±93 m; males walked 84 m greater than females; variability in walking distance related to subject height, age, and weight.
- Reference data in 65 people of Asian descent, mean age = 65: 624 m for males and 541 m for females.
- 6MWT values for 10 healthy individuals aged 36 – 69 (= 683 m; range 630 – 720 m).
- Reference values for 6 MWT according to age and gender.

Men:
Aged 20 – 40 (n = 19): 800 ± 83 m
Aged 41 – 60 (n = 12): 671 ± 56 m
Aged 61 – 80 (n = 10): 687 ± 89 m

Women:
Aged 20 – 40 (n = 15): 699 ± 37 m
Aged 41 – 60 (n = 13): 670 ± 85 m
Aged 61 – 80 (n = 10): 583 ± 53 m

- 6 MWT distances (mean in meters, SD, 95% CI) for community dwelling independent elders according to age and gender:

Age 60 – 69:
Male (n=15): 572 m; SD = 92; CI = 521 – 623
Female (n=22): 538 m; SD = 92; CI = 497 – 579

Age 70 – 79:
Male (n=14): 527 m; SD = 85; CI = 478 – 575
Female (n=22): 471 m; SD = 75; CI = 440 - 507

Age 80 – 89:
Male (n=8): 417 m; SD = 73; CI = 356 – 478
Female (n=15): 392 m; SD = 85; CI = 345 – 440

- Median distance walked during 6MWT = 576 m for males (median age 59.5 years) and 494 m for females (median age 62.0 years); reference equations to predict total distance walked during 6MWT in healthy adults.

Men: 6MWD = (7.57 x heightcm) – (5.02 x age) – (1.76 x weightkg) – 309 m
Alternate equation using BMI:

6 Minute Walk Test
6MWD = 1,140 m - (5.61 x BMI) – (6.94 x age)
To determine lower limit (using either equation), subtract 153

Women: 6MWD = (2.11 x height cm) – (2.29 x weight cm) – (5.78 x age) + 667 m
Alternate equation using BMI:
6MWD = 1,017 m - (6.24 x BMI) – (5.83 x age)
To determine lower limit (using either equation), subtract 139

COPYRIGHT INFORMATION:
- Not applicable

WEB BASED RESOURCES / INFORMATION:
- 

REFERENCES:
Use of the Mini-BESTest to Measure Balance
in People with Multiple Sclerosis

Participant code: _____

“With respect to your balance due to your MS, how would you describe yourself now compared to the beginning of this intervention period?”

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<th>Very much worse</th>
<th>Much worse</th>
<th>Minimally worse</th>
<th>No change</th>
<th>Minimally improved</th>
<th>Much improved</th>
<th>Very much improved</th>
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Use of the Mini-BESTest to Measure Balance

in People with Multiple Sclerosis

Participant code: _____

“Compared the beginning of this intervention period, how would you rate the participant’s balance due to their MS now?”

Very much worse  Much worse  Minimally worse  No change  Minimally improved  Much improved  Very much improved
Paper II: Figure 1: AUC values and ROC analysis for Pre BBS and Pre MBT in relation to Near Falls

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<thead>
<tr>
<th>Test Result Variable(s)</th>
<th>Area</th>
<th>Std. Error</th>
<th>Asymptotic Sig.</th>
<th>Asymptotic 95% Confidence Interval</th>
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The test result variable(s): MBT PRE, BBS PRE has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

AUC = Area Under Curve; ROC = Receiver operating Curve; MBT = MiniBESTest; BBS = Berg Balance Score; PRE = Pre Intervention
Paper II: Figure 2: AUC values and ROC analysis for Pre BBS and Pre MBT in relation to Mobility Devices

AUC

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The test result variable(s): MiniBESTest Score pre-intervention, BBSERPRE has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

AUC=Area Under Curve; ROC=Receiver operating Curve; MBT=MiniBESTest;

BBS=Berg Balance Score; PRE=Pre Intervention
**Paper II**: The negative (disimprovement), positive (improvement) and ties of change (no change) between pre and post BBS and MBT scores

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<th>Disapproved</th>
<th>Unchanged</th>
<th>Started at Max</th>
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*BBS=*Berg Balance Scale; *MBT=*The MiniBESTest