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**Poster Abstracts from the Fifth International Symposium on Gait and Balance
in Multiple Sclerosis:
*Fall Detection and Prevention***

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(1) VALIDATION OF THE FOUR SQUARE STEP TEST (FSST)

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Background and Purpose: The Four Square Step Test (FSST) has received interest as an outcome measure for ambulatory people with multiple sclerosis (MS). Concurrent validity has been reported between the FSST and Berg Balance Scale (BBS) ($r_s = -0.84$) and Dynamic Gait Index (DGI) ($r_s = -0.81$) using a small sample ($n = 25$). A correlation at -0.77 with the DGI was also reported in 81 people with MS. The aim of this study was to confirm the validity of the FSST. **Methods:** Using baseline data from three clinical trials, correlations between the FSST

and BBS and the Timed Up and Go test (TUG) were calculated. Known group validity was investigated by comparison between nonfallers and fallers (>1); and single and multiple fallers (≥ 2). The joint inclusion criteria were adults (aged 18–75 years) with MS who retained the ability to walk 100 m. **Results:** FSST and TUG ($n = 219$): 117 (53%) had RRMS, 82 (37%) SPMS, and 20 (9%) PPMS. Ninety-eight reported falls. The mean age was 51 years (SD 11). The mean value for the TUG was 14.9 (SD 8.4). FSST and BBS ($n = 157$): Eighty-one (51.5%) had RRMS, 59 (37.5%) SPMS, and 17 (11%) PPMS. Seventy-seven (49%) reported falls. The mean value for the BBS was 47.8 (SD 7.5). The FSST showed high ($r_s > 0.60$) correlation with both tests. The correlation was higher between the TUG and the FSST ($r_s = 0.80$) than between the BBS and the FSST ($r_s = 0.680$). The mean time to perform the FSST was lower for nonfallers (19.86; SD 16.31) compared to single fallers (20.89; SD 14.70) and multiple fallers (28.66; SD 26.47). There were statistically significant differences (< 0.001) in FSST performance between nonfallers and fallers (≥ 1 fall) but not ($P > .566$) between single and multiple fallers (≥ 2 falls). **Conclusion:** The FSST is a valid measure for ambulatory people with MS and discriminates between nonfallers and fallers.

(2) EXAMINING UPPER AND LOWER BODY SEGMENTAL MOTION DURING WALKING IN HEALTHY CONTROLS AND PEOPLE WITH MULTIPLE SCLEROSIS

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Background and Purpose: People with multiple sclerosis (MS) display altered gait patterns that may lead to increased fall risk. The aim of this study was to use wireless inertial sensors to

examine segmental coordination during walking in people with MS and age-matched healthy controls (HCs). **Methods:** Forty people with MS and 40 HCs walked on a treadmill at a self-selected pace for 3 minutes while wearing inertial sensors on their right ankle and sternum. Approximate entropy (ApEn) and root mean square (RMS) were calculated from trunk and foot acceleration time series in frontal and sagittal planes. A 2×2 (position \times plane) ANOVA was performed on the ApEn and RMS values. Pearson correlations assessed the relationship between sensor positions within the same plane. **Results:** In both groups, there was a significant main effect of position and plane for ApEn where values at the trunk were significantly higher than the foot, and values in the frontal plane were significantly higher than in the sagittal plane. Both groups also showed significant main effects of position and plane for RMS where values at the trunk were significantly lower than at the foot, and values in the frontal plane were significantly lower than in the sagittal plane. Both groups showed a significant positive correlation between trunk and foot sagittal plane ApEn values (MS: $r = 0.350$; HCs: $r = 0.603$). In people with MS only, there was a significant correlation in the frontal plane ($r = 0.340$). Both groups showed a significant positive correlation between trunk and foot RMS values within the frontal (MS: $r = 0.732$; HCs: $r = 0.811$) and sagittal plane (MS: $r = 0.791$; HCs: $r = 0.883$). In both groups, the trunk shows a lower amount of variability but less predictable acceleration patterns compared to the feet. **Conclusion:** The relationship between foot and trunk acceleration is different between groups, which indicates that further examination of frontal plane coordination relative to segmental control and fall risk in people with MS is warranted.

(3) CONNECTIONS BETWEEN POSTERIOR PARIETAL AND SENSORIMOTOR CORTICES PREDICT POSTURAL ADAPTATION IN PEOPLE WITH MULTIPLE SCLEROSIS

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Background and Purpose: People with multiple sclerosis (MS) have increasingly well-characterized deficits in gait and balance. As yet, rehabilitation strategies to improve these deficits have limited effectiveness. This study aimed to assess short- and long-term postural motor adaptation in people with MS and to identify neuroanatomic networks underlying short- and long-term adaptation of postural responses within people with MS. **Methods:** Twenty-four people with relapsing-remitting MS and 14 age-matched healthy controls (HCs) stood on a platform that translated anteriorly and posteriorly in an oscillating pattern. Testing consisted of five blocks of trials on day 1; participants also returned on a second day to assess long-term adaptation. Diffusion-weighted images (DTIs) were also acquired, and whole-brain tract-based spatial statistics (TBSS) were used to identify associations between white matter microstructural integrity and postural adaptation. **Results:** Despite significant deficits in postural motor performance at baseline ($P < .01$), people with MS demonstrated a similar ability to improve postural control with training. TBSS analysis revealed a widespread network of decreased white-matter microstructure in people with MS compared to HCs. Further, TBSS correlation analysis revealed strong associations between short-term adaptation and fiber tract quality within the corpus callosum (genu, body, and splenium) as well as white-matter tracts connecting the posterior parietal cortices with the primary somatosensory and motor cortices ($P \leq .05$; corrected

for age, brain volume, and EDSS) in people with MS. **Conclusion:** People with MS have the capacity to improve the use of a feed-forward postural strategy with practice and retain the learned behavior despite their significant postural response impairments. Further, we show that interhemispheric callosal connections and those connecting the posterior parietal cortices with the sensorimotor cortices are strongly related to a given individual's ability to adapt their behavior. These results suggest that people with MS who are able to engage this circuitry to a greater extent may benefit more from gait and balance training.

(4) SUPRA-SPINAL CONTROL OF AUTOMATIC POSTURAL REACTIONS IN PEOPLE WITH MS

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Background: People with multiple sclerosis (MS) exhibit delayed automatic postural responses that are related to decreased function. While we have previously shown that reduced structural integrity of the corticoproprioceptive pathways is strongly related to deficits in quiescent stance in people with MS, it remains unclear how supra-spinal structures are related to automatic postural responses. Our goal was to assess whether white-matter pathways of two supra-spinal regions known to be related to postural dysfunction in people with MS (Brodmann's Area-3 and pedunculopontine nucleus; PPN) were associated with postural muscle response latency.

Methods: Nineteen individuals with MS (48.84 ± 11.4 years; EDSS = 3.5 [range: 2–4]) and 13 healthy adults (49 ± 13.3 years) underwent 20 discrete, backward translations of a support

surface (velocity: 15 cm/s). Electromyography was captured from agonist (medial-gastrocnemius) and antagonist (tibialis anterior) muscles. On a separate day, diffusion tensor imaging was performed to assess white-matter integrity of corticoproprioceptive and balance/locomotor-related fiber tracts emanating from the PPN. **Results:** Muscle latencies were not different between groups. White-matter fiber tract integrity of corticoproprioceptive tracts was not different between groups, but was poorer in PPN tracts of people with MS compared to controls ($P = .02$). In people with MS, white-matter integrity of PPN tracts was significantly correlated to agonist ($\rho = 0.534$, $P = .027$) muscle-onset latencies, and this relationship was much stronger in antagonist muscles ($\rho = 0.74$, $P < .001$). Corticoproprioceptive tracts were not correlated to agonist or antagonist muscle onset in either group, suggesting that this pathway is not related to muscle onset following perturbations. **Conclusions:** These data suggest that supra-spinal structures, particularly the PPN balance/locomotor network and its connections, contribute to delayed onset of muscle activity after external perturbations in people with MS. This indicates that PPN balance/locomotor pathways may have a specific and important role in postural response delays in people with MS. More work is necessary to determine whether other brainstem regions also contribute to delayed muscle onset in people with MS.

(5) GREATER ROLE FOR LESS AFFECTED LIMB IN STANDING BALANCE WITH MS

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Background: Most patients with MS (people with MS) have impaired balance abilities. While there are notable side-to-side differences in strength/power, it is not clear how impairments of each limb contribute to bilateral stance. The purpose of this investigation was to measure weight distribution and individual limb corrections in people with MS during quiet standing with eyes open and closed. **Methods:** Twenty-eight people with MS (19 female; age range, 22–69 years; height range, 1.43–1.93 m; PDDS, median 2, range 0–6) performed four trials of quiet standing for 60 s, two with eyes open (EO) followed by two with eyes closed (EC), while standing on adjacent force platforms. Individual limbs were categorized into self-reported less-affected (LA) and more-affected (MA) sides. Individual limb and net center of pressure (COP) movements of sway and path length, each normalized to standing height (%ht), were calculated in anterior-posterior (AP) and medial-lateral (ML) directions. Vertical ground reaction forces were also recorded on each side, normalized to body weight (%wt). **Results:** With EO, AP sway was greater on the LA side (1.38 [0.60] vs. 1.12 [0.45] %ht, $P = .016$). With EC, borderline significance was found in AP path length, greater on the LA side ($P = .076$). As expected, balance was worse with EC, indicated by greater COP sway and path length in all net and individual limb COP movements ($P \leq .013$) except LA and MA ML path length ($P \geq .127$). EC also resulted in a weight distribution shift from MA to LA side (0.9 %wt shift, $P = .038$). **Conclusion:** The LA lower limb appears to play a greater role in AP maintenance of quiet standing balance in people with MS. Targeting the MA over the LA limb with therapeutic interventions, specifically AP control, may improve overall balance in people with MS. However, it is unclear how a weight distribution change between EO and EC affects standing balance ability.

(6) CHARACTERISTICS OF GAIT DURING LONG-DURATION WALKING IN PEOPLE WITH MULTIPLE SCLEROSIS

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Background: Multiple sclerosis (MS) is a progressive degenerative neurologic disease resulting in sensory and motor dysfunction. Gait impairments are one of the most frequent complaints in MS, increasing the risk of falls. We hypothesized that gait characteristics in people with MS (MS) will change over the course of a long walk. **Methods:** Twenty-six people with MS (age 49.2 ± 12.9 years; 18 female; EDSS 2.5–4) and 14 age-matched healthy control participants (age 45.6 ± 13.6 years; 10 female) were included in the study. Subjects performed a 6-minute walk test at a comfortable walking speed in a 20-m hallway. The subjects wore four inertial sensors (Opals, APDM) at the ankles, sternum, and lumbar region. Gait and turning metrics were directly computed through Mobility Lab (APDM). Mean and coefficient of variation of each of the metrics were determined for the complete 6-minute walking trial, as well as for the first and last 2 minutes. Nonparametric statistics were applied to test between group differences (Mann-Whitney test) and changes over time (Wilcoxon signed rank test). **Results:** We found marked differences in spatiotemporal measures of gait as well as turning between people with MS and control groups. Furthermore, people with MS appeared to be more variable in their walking. People with MS showed gait adjustments over time in some, but not all, measures of gait. **Conclusions:** Although they did not significantly slow down their comfortable walking speed over time, double-support time increased, along with a decrease in cadence and increase in trunk

horizontal rotation. In addition, turns in people with MS became slower and number of steps per turn increased over time.

(7) INSTRUMENTED GAIT AND BALANCE MEASURES ARE RELATED TO
COGNITIVE SCORES AND SELF-REPORTS OF FUNCTION IN PERSONS WITH
MULTIPLE SCLEROSIS

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Background and Purpose: Outcome measures to assess disease status in people with multiple sclerosis (MS) may focus on several different areas of disease impact, including gait and balance problems and cognitive status. These measures may be self-report format or use more quantitative outcome methods. The present study examined the relationship between these different outcome measures in people with MS starting an exercise program. Of particular interest was whether relationships exist between quantitative measures of gait and balance and the self-report functional status and cognitive performance, all of which could change as a result of an exercise program. **Methods:** Thirteen people with MS (age 48.2 ± 12.8 ; 10 RRMS and 3 SPMS) underwent baseline walking, balance, and cognitive testing and completed self-report measures of functional status before beginning their exercise program. **Results:** There were several significant relationships between gait and balance measures and cognitive and functional status scores, but peak leg swing velocity during gait showed the most relationships, including with the MS Functional Composite score ($r = 0.698$), MS Fatigue Impact Scale psychosocial subscale ($r = -0.559$), MS quality of life physical component ($r = 0.566$), and functional status

questionnaire ($r = 0.881$). Sway range during quiet standing was the balance measure that showed the most relationships, including PASAT2 ($r = 0.867$), MS Fatigue Impact Scale physical ($r = 0.906$), cognitive ($r = 0.788$), and psychosocial subscale ($r = 0.779$), and MS quality of life cognitive component ($r = -0.570$). The Functional Status questionnaire and the MS Functional Composite scale showed a relationship with several gait measures but no balance measures. **Conclusions:** The results indicate that the gait outcomes are more closely related to cognitive and functional status than the balance variables, which could be important when selecting outcome measures for future studies. Moving forward, it will be of interest to evaluate the relationships between these variables after subjects have completed their exercise program, as it is possible that the relationships may change to reflect more healthy movement and behavior patterns.

(8) EFFECT OF FATIGUE ON SENSORY IMPAIRMENT IN MS: PARTIAL RESULTS OF AN ONGOING STUDY

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Introduction: Fatigue and sensory impairment are common findings in people with multiple sclerosis (MS). MS fatigue is known to worsen with exertion, and previous studies have shown that both worsening fatigue and sensory loss can worsen walking endurance. Anecdotally, MS patients have noted that symptoms of sensory impairment worsen with fatigue as well, but this has not been examined. The purpose of this ongoing study is to examine whether worsening MS fatigue affects sensory impairment in people with MS. **Methods:** A randomized crossover design

was used. Ambulatory subjects with a definitive diagnosis of MS were recruited from local MS practices. Following obtaining consent and subject characteristics, subjects were randomized into walking (W) and resting (R) groups. All subjects received sensory testing using a biothesiometer on 5 key (B) lower-extremity points. Subjects in the (W) group then performed a 6-minute walk (6MW) to induce fatigue, while subjects in the (R) group lay supine for 6 minutes to minimize fatigue. Fatigue was assessed using the Visual Analogue Fatigue Scale. Immediately following either 6-minute condition, biothesiometer testing was repeated. This was repeated for three trials in 1 week, followed by a 2-week detraining period. Subjects then crossed over, performing whatever type of testing they did not participate in initially. **Results:** Thirteen subjects (mean EDSS = 3.45) have so far completed the study. Paired *t* tests revealed a significant difference in pretest (\bar{x} = 22.0 microns, SD = 12.9) to posttest (\bar{x} = 25.6 microns, SD = 13.7) mean biothesiometer readings in the fatigued condition, P = .001. There was no significant pre- to post difference in sensation for the unfatigued state. **Discussion:** Preliminary results indicate that increasing fatigue in people with MS can result in worsening of sensation. This may in part explain the worsening of balance seen in fatigued MS patients.

(9) FALL PREVALENCE IN NONAMBULATORY PERSONS WITH MULTIPLE SCLEROSIS

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Background: Falls are a serious health concern for individuals with multiple sclerosis (MS).

However, the vast majority of research focusing on falls and falls prevention in MS has focused

on individuals who are ambulatory. This focus has seemingly ignored the 25% of the MS community who are nonambulatory. The purpose of this investigation was to determine the prevalence and circumstances of falls in people with MS who are nonambulatory. **Methods:** Individuals with MS who utilized a wheelchair for mobility were recruited from various research centers (Sheba Medical Center, Tel-Hashomer, Israel; University of Illinois at Urbana-Champaign; Shepherd Center, Atlanta, GA) and through online advertisements. Participants completed a survey focusing on prevalence of falls in the last 6 months, injurious falls, and circumstances of the fall. **Results:** A total of 37 individuals (27 females/10 males) completed the survey. The sample had a mean age of 58 (range 27–82 years). Over half (59%; $n = 26$) reported falling at least once in the last 6 months, and 25% ($n = 7$) of those who fell sustained an injury. Only one individual reported their fall-related injury to a health-care professional. The majority (78%) of the falls occurred inside the home, while 10% occurred outside. Most individuals (73%; $n = 28$) reported concerns about falling, and 65% ($n = 25$) limited their activities because of their concern about falling. **Discussion:** Falls are prevalent in individuals with MS who are nonambulatory. The observations highlight the need for interventions targeting this segment of the MS community.

(10) HOW ASSISTIVE DEVICES ARE ASSOCIATED WITH FALLS IN PEOPLE WITH MS: CONCEPTUAL MODELS

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Background: Over 50% of people with MS (MS) fall in a 3- to 6-month period. Cross-sectional studies suggest that over 60% of people with MS use assistive devices. Assistive devices are intended to improve functional walking and to prevent falls. However, studies consistently find that assistive device use is associated with increased risk of falls in people with MS. This report presents conceptual models of potential mechanisms underlying the relationship between falls and assistive device use in people with MS. **Methods:** We reviewed published literature on assistive devices, falls, and gait in people with MS. Studies on dual tasking in people with MS were included because walking with an assistive device requires both walking and managing the device. Studies on assistive device use in older adults were also included because there is limited MS-specific literature. **Results:** The literature supports two conceptual models to explain the association between falls and assistive device use: 1) People with MS who have fallen use assistive devices but continue to fall. Cross-sectional studies indicate that people with MS with greater disability, lower income, and progressive or deteriorating disease status are at increased risk for falls and are more likely to own assistive devices. 2) Alternatively, assistive devices may directly contribute to fall risk. They increase the attentional and metabolic demands of walking and alter gait mechanics, affecting walking speed and variability. Devices are also often fitted and used incorrectly. **Conclusions:** For people with MS who use assistive devices, we recommend considering 1) dual task training to improve attention allocation to gait control; 2) using the least metabolically demanding devices to minimize fatigue; 3) strengthening and balance exercises to improve strength and functional balance; and 4) professional advice for device selection, fitting, and training to optimize device use. People with MS use assistive devices to prevent falls, but many continue to fall. More research is needed to optimize fall prevention strategies in people with MS.

(11) BLADDER DYSFUNCTION IS A RISK FACTOR FOR FALLS IN PEOPLE WITH
RELAPSING-REMITTING MULTIPLE SCLEROSIS

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Background: Falls are common and have serious adverse consequences in people with multiple sclerosis (MS), and there is a need to clarify the role of bladder dysfunction in predicting falls in this population. **Methods:** This investigation was a secondary analysis of data from a prospective cohort study that included 51 people (14 males, 37 females) aged 22 to 50 years with mild to moderate relapsing-remitting MS (RRMS) (Expanded Disability Status Scale [EDSS] score ≤ 6.0). At baseline, participants self-reported if they had urinary incontinence, urgency, and/or frequency and then prospectively recorded their falls for the following 3 months using fall calendars. Participants were classified as fallers (≥ 1 fall; $n = 32$) or nonfallers (0 falls; $n = 19$), and then reclassified as recurrent fallers (≥ 2 falls; $n = 15$) or nonrecurrent fallers (< 2 falls; $n = 36$). **Results:** Unadjusted analyses (Fisher exact tests) indicated that there were significant associations between falls and urinary incontinence ($P = .019$) or urgency ($P = .028$) as well as between recurrent falls and urinary incontinence, urgency, or frequency ($P < .001$; $P = .005$; and $P = .037$, respectively). After adjusting for EDSS, age, and gender, using logistic regression, a significant association was found only between recurrent falls and having urinary incontinence with urgency (log [OR] = 4.053; 95% CI = 1.233-6.873; $P = .005$). **Conclusions:** This study establishes that urinary incontinence with urgency is associated with recurrent falls in the following 3 months in people with RRMS aged 50 or less with mild to moderate disability.

Further studies are needed to determine whether treating bladder dysfunction in people with RRMS helps prevent falls and their sequelae.

(12) THE CONTEXT, CAUSES, AND CONSEQUENCES OF FALLS IN PEOPLE WITH MULTIPLE SCLEROSIS: PRELIMINARY RESULTS FROM AN IRISH CROSS-SECTIONAL STUDY

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Background: It is estimated that over 50% of people with MS (MS) will fall in any 3-month period, often resulting in significant morbidity. Few studies have investigated the context, causes, and consequences of falls in people with MS. The purpose of this study is to explore these aspects in an Irish cohort of community-dwelling people with MS. **Objectives:** 1) to investigate the context, causes, and consequences of falls; 2) to assess the level of concern about falling in this population; 3) to investigate the level of reporting of falls and participation in falls prevention programs. **Design:** Cross-sectional self-report survey. **Methods:** A sample of community-dwelling adults with a definite diagnosis of MS who had experienced a fall in the previous 3 months completed a questionnaire-based phone survey relating to their most recent falls. **Results:** Thirty-three participants with a mean age of 53.18 years (SD = 10.82) completed the survey. Ninety-one percent of the respondents were female (n = 30), with a mean disease duration of 17.14 years (SD = 10.55). Seventeen (51.5%) participants attributed their falls to general mobility, with 45.5% (n = 15) of falls occurring inside the home. Poor balance (24.2%, n = 8) and leg weakness (21.2%, n = 7) were the most frequently reported causes of falls. A total

of 79.7% of participants reported being “somewhat worried” (n = 12) or “very worried” (n = 11) about falling. Seventeen (51.5%) participants had reported their fall to a health-care professional, and one had taken part in a falls prevention program. **Conclusion:** Preliminary results from this study suggest that the majority of falls for Irish people with MS occur inside the home during general mobility. A considerable degree of worry exists, and previous participation in falls prevention programs is minimal. Data collection is ongoing.

(13) FALL ASSESSMENT IN PEOPLE WITH MULTIPLE SCLEROSIS: WHAT DO PM&R RESIDENTS NEED TO LEARN?

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Background: People with multiple sclerosis (MS) commonly report falls to physicians. Since the cause of falls is typically multifactorial, physicians must gather and integrate numerous clinical factors into their assessments and plans to help prevent falls in this population. While it is clearly important for residents in physical medicine and rehabilitation (PM&R) to develop the ability to assess falls in people with MS, there is limited information regarding their ability to do so. **Methods:** We obtained a convenience sample of 6 documented patient encounters in a large urban teaching hospital. In each case, a PM&R resident documented their evaluation of an ambulatory patient with MS who reported a fall. We obtained rates of how frequently these notes included each of the following eight clinical factors in the history and physical examination: 1) detailed description of a fall, 2) impaired vision, 3) impaired cognition, 4) fatigue, 5) strength, 6) sensation, 7) coordination, and 8) spasticity. We also obtained the rate of documented use of at

least one of these clinical factors in the assessment and plan for fall prevention. **Results:** Clinical factors were documented in the history and physical examination at variable rates. Detailed descriptions of falls were never provided (0 out of 6). Vision, fatigue, and cognition were each described in 4 out of 6 charts. Physical examination findings were reported at the following rates: strength (6 out of 6), sensation (4 out of 6), coordination/ataxia (5 out of 6), and spasticity (3 out of 6). In the assessment and plan, fall prevention was included as a problem in 3 out of 6 cases. Of the 3 assessments and plans for fall prevention, integration of clinical features was documented 2 out of 3 times. **Discussion:** Though not necessarily unexpected, these preliminary data suggest that residents in PM&R may not be optimally assessing falls in people with MS. Based on this information, we would like to perform a larger chart review to better describe these initial findings. Our ultimate goal is to identify targeted educational interventions to improve the ability of PM&R residents to perform fall assessments in people with MS.

(14) MEASURES OF FALLS RISK IN PERSONS WITH MULTIPLE SCLEROSIS: A COMPARATIVE STUDY OF THE TIMED UP AND GO AND TIMED UP AND GO COGNITIVE TESTS

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Background: The Timed Up and Go (TUG) was developed to assess functional mobility in older adults and identifies those at risk for falls. Some TUG versions have an added cognitive task (TUG-cog), such as saying the alphabet backwards (TUG-Alpha) or subtracting numbers by 3 (TUG-3s). The TUG and TUG-cog have not been studied specifically in people with multiple

sclerosis (MS). **Objectives:** 1) To compare performance (in seconds) in the TUG and TUG-cog between people with MS and a similarly aged control group, and 2) within each group, compare TUG and TUG-cog for people with and without reported falls in the previous 3 months. **Design:** Comparative study. **Methods:** One hundred ten community-dwelling participants (53 with MS; 57 controls). TUG measures between MS and control groups were compared via repeated-measures ANOVA. Measures between fallers and nonfallers were compared via nonparametric test for medians. **Results:** Control participants had lower mean time than people with MS ($P = .009$) in all three TUG tests. Both groups had increased mean time from TUG to TUG-Alpha to TUG-3s ($P < .001$), with no interaction effect. Eleven individuals in the control and 28 in the MS groups reported falls in the previous 3 months. When comparing fallers to nonfallers, there was no difference in TUG times among controls ($P = .54$ to $.95$). For people with MS, fallers had slower average times than nonfallers for TUG ($P = .005$) and TUG-3s ($P = .03$) but no difference in TUG-Alpha ($P = .26$). **Conclusions:** People with MS had slower performance on the TUG, TUG-Alpha, and TUG-3s than controls. All participants slowed down with the addition of a cognitive task. These results suggest that all three versions of the TUG can be used in people with MS and should be considered as part of a fall risk assessment.

(15) INSTRUMENTED TIMED UP AND GO IDENTIFIES MOBILITY IMPAIRMENTS
RELATED TO FALL RISK IN PERSONS WITH MULTIPLE SCLEROSIS

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Purpose: To determine if specific gait and postural transition parameters during a Timed Up and Go (TUG) test differ between people with multiple sclerosis (MS) based on predicted fall risk. We hypothesized that people with MS with increased fall risk would have slower walking speed, slower cadence, increased base of support, decreased stride length, and decreased speed during turning, turn-to-sit, and sit-to-stand. **Methods:** Ninety-eight people with MS completed 3 trials of a 7-m Timed Up and Go (TUG) test while wearing body-worn motion sensors that measured spatiotemporal gait parameters and postural transition parameters. Based on previous literature, an Activities-specific Balance Confidence Scale (ABC) cut-off score of <63.92% was used to identify those with increased fall risk. Independent *t* tests were used to compare gait parameters and postural transitions of people with MS with increased fall risk to those of people with MS without increased fall risk. **Results:** People with MS with increased fall risk walked more slowly (1.20 m/s \pm 0.25 vs. 1.43 m/s \pm 0.23, $P < .001$, $d = |0.85|$), had increased % double support (24.5% \pm 6.5 vs. 20.1% \pm 5.6, $P = .002$, $d = |0.66|$), shorter stride length (1.24 m \pm 0.19 vs. 1.39 m \pm 0.17, $P < .001$, $d = |0.77|$), slower turning peak velocity (120.5 $^{\circ}$ /s \pm 19.1 vs. 150.1 $^{\circ}$ /s \pm 35.2, $P < .001$, $d = |1.20|$) and slower turn to sit peak velocity (146.9 $^{\circ}$ /s \pm 31.9 vs. 192.0 $^{\circ}$ /s \pm 51.4, $P < .001$, $d = |0.84|$) compared to people with MS without increased fall risk. There were no significant differences in cadence (115.1 steps/min \pm 16.2 vs. 122.7 steps/min \pm 14.0, $P = .027$, $d = |0.46|$) or sit to stand velocity (89.4 $^{\circ}$ /s \pm 31.2 vs. 117.3 $^{\circ}$ /s \pm 56.4, $P = .021$, $d = |0.48|$). **Conclusions:** Instrumentation of the TUG identified specific mobility impairments of turning, gait velocity, % double support, and stride length related to increased fall risk in people with MS. Interventions for people with MS aimed at improving gait and balance should incorporate speed with walking and turning in order to minimize fall risk.

(16) TIMED 25-FOOT WALK TEST PERFORMANCE IS DECREASED WITH INCREASED PERCEPTION OF FALL RISK IN PATIENTS WITH MS

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Background: Patients with multiple sclerosis (MS) have an increased risk of falls. Our objective was to determine if one's perception of fall risk, based on the Falls Efficacy Scale–International (FES-I), affected motor performance. **Methods:** Twenty-seven patients with MS (mean [SD] age, 56 [13] years; 9 men; PDDS, median 2, range 0–6) completed the FES-I, MS Functional Composite (MSFC), isometric upper- and lower-body strength testing, and a static balance test. Upper-body strength testing was performed using a hand dynamometer. Lower-body strength was assessed via isometric knee extension and flexion with the knee at a 90° angle. The peak force of the knee extensors and flexors was added together and averaged between the legs to estimate total lower-body strength. Participants stood quietly, eyes open, with their feet on a force platform for 60 sec to measure static balance. Three groups were created by stratifying participants by their reported FES-I scores, and a 1-way ANOVA was used to compare the variables from the MSFC, strength testing, and balance. **Results:** High fall patients needed more time to complete the Timed 25-Foot Walk test than those in the low group (high 9.0 [4.6] sec, low 4.7 [1.5] sec, Bonferroni adjusted $P = .013$). All other variables were not different between the groups ($P > .070$), although performance on the Nine-Hole Peg Test ($P = .090$) and the strength of the individual's less affected knee extensors ($P = .070$) were borderline significant.

Conclusions: In some patients with MS, walking performance may be influenced by perceived fall risk, rather than actual physical ability. These findings suggest that confidence may be just as important during rehabilitation as muscular strength and coordination.

(17) CORRELATION BETWEEN FALLS AND NEAR FALLS IN PEOPLE WITH MODERATE TO ADVANCED MULTIPLE SCLEROSIS

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Background: It is well known that people with multiple sclerosis (MS) often have impaired balance and fall frequently. A previous study reported a proportion of fallers at 63% during 3 months, 2352 near fall incidents, and 270 falls, with a correlation between falls and near falls at $r = 0.57$ in a sample with EDSS 3.5 to 6.0; median 4.5. This implies that many near-fall incidents were managed successfully and did not result in a fall. The correlation between falls and near falls in those with more advanced MS is not known. The aim was therefore to analyze this correlation in people with moderate to advanced MS. **Methods:** Twenty-four people (EDSS 4.0–7.0; median 6.0) reported falls and near falls on a daily basis by using a diary during a 7-week period. Reminders were given weekly using text messages. **Definitions:** Fall: “an unexpected contact with the any part of the body on the ground”; near fall: “an occasion on which an individual felt that they were about to fall but did not actually fall.” Spearman’s rho was used for analysis. **Results:** A higher proportion (18 out of 24; 75%) reported falls in this sample (EDSS median 6.0) compared to a previous study (63%) (EDSS median 4.5) despite the shorter study period. In total, 91 falls and 502 near falls were reported during 7 weeks. The correlation

between falls and near falls was similar to that reported for people with milder to moderate MS ($r = 0.58$). **Conclusion:** Three out of four people with moderate to advanced MS fell within a 7-week period. Previously reported moderate to strong correlation between falls and near falls is valid also in people with moderate to advanced MS (EDSS 4.0–7.0; median 6.0).

(18) EFFECT OF AN ACUTE BOUT OF EXERCISE ON BALANCE, MOBILITY, MOOD, AND EXECUTIVE FUNCTION IN ADULTS WITH MULTIPLE SCLEROSIS

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Background and Objective: Individuals with multiple sclerosis (MS) face daily challenges with balance, mobility, cognition, and mood. Participating in regular physical activity alleviates some of these challenges, but exercise might acutely enhance impairment due to fatigue. The objective of this study was to examine the effects of an acute bout of exercise on balance, gait, mood, fatigue, and executive function in adults with MS. **Methods:** Eight people with MS were assessed on two sessions separated by 1 week. In randomized order, during one session, subjects exercised at a moderate intensity for 15 minutes on a stationary bicycle, and in the other session, subjects rested for the 15-minute period. At baseline on both days, subjects were assessed on mood, executive function, fatigue, 25-Foot Timed Walk, and clinical and instrumented measures of balance and gait. Subjects then completed the balance and gait measures immediately after and 2 hours after the exercise or rest period. Subjects also completed the executive-function and mood assessments immediately, 1 hour, and 2 hours after the exercise or rest period. The mood assessment was further completed at home, 4 and 6 hours after the exercise or rest period.

Results: The results showed significantly higher fatigue immediately and 1 hour after exercise compared to rest, as well as increased stride length immediately and 2 hours after exercise compared to rest. There were no significant detriments to gait, balance, executive function, or other constructs of mood. **Conclusions:** Although an acute 15-minute bout of moderate cycling exercise briefly enhances fatigue, the fatigue normalizes and the exercise also generates small increases in stride length without eliciting detriments to gait, balance, executive function, or mood. Thus, daily activities could potentially safely include 15 minutes of moderate exercise.

(19) BETTER REPORTING OF COMORBIDITIES IS NEEDED IN MS EXERCISE STUDIES

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Background: Exercise rehabilitation has demonstrated positive effects on mobility and symptom management in people with multiple sclerosis (MS). As the evidence of exercise interventions is multiplying and the awareness of the burden of comorbidities in MS is increasing, it is important to determine if comorbidities moderate exercise outcomes in MS rehabilitation. **Aim:** To identify to what extent exercise intervention studies in MS rehabilitation are addressing comorbidities.

Methods: Five major databases (EMBASE, Medline through OVID, PMC, CINAHL, and Web of Science) were searched for exercise interventions (exercise, physical activity, motor activity, or fitness) and multiple sclerosis. Studies were screened and limited to RCTs, full-text articles, and English language. We assessed how comorbidities were excluded or included, reported and described, and if they were examined as possible moderators on exercise outcomes. **Results:** We reviewed 74 MS rehabilitation RCTs that included any type of exercise intervention. Exercise

interventions found were general multifacet exercise program (n = 27), progressive and resistance training (n = 10), cardiovascular training (n = 15), balance and gait training (n = 4), respiratory training (n = 6), pelvic floor exercises (n = 3), yoga and flexibility exercises (n = 2), technology-enhanced training (n = 6), and coaching-enhanced training (n = 1). Most studies do not clearly report exclusion or inclusion criteria regarding comorbidities. The most common excluded comorbidities were cardiovascular disease or having a pacemaker, cognitive impairment or dementia, “any condition that precludes safe exercise,” and psychiatric illness. Across studies that reported participant comorbidities (n = 13), none examined comorbidities as a possible moderator on exercise outcomes. **Conclusion:** Although a variety of exercise interventions have positive outcomes, information about comorbidities is limited. Participation criteria and lack of moderator analyses means that there is limited evidence that these interventions are suitable for people with MS with comorbidities.

(20) ADAPTATIONS IN GAZE, POSTURAL SWAY, BALANCE, AND PARTICIPATION AFTER HOME-BASED TRAINING IN PERSONS WITH MULTIPLE SCLEROSIS

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Background and Purpose: Demyelination of vestibulo-ocular and vestibulo-spinal pathways in the brainstem and cerebellum may adversely affect gaze, posture, and balance in multiple sclerosis (MS); however, the effect of gaze and postural stabilization (GPS) training on these measures remains unexplored. We aimed to determine the effect of 2-week, home-based GPS training on gaze stability, postural sway, dynamic balance, and self-reported participation

measures in people with MS. **Methods:** Nineteen ambulatory people with MS, with no concurrent relapses but at fall risk, were recruited. Outcomes included gaze stability (vestibulo-ocular gain, number of compensatory saccades per head rotation [CS/HR], latency of CS onset and gaze position error [GPE]); postural stability (sway amplitude [mediolateral (ML) and anteroposterior (AP)] and total sway path); dynamic balance (Functional Gait Assessment [FGA] and Four Square Step Test [FSST]); and self-reported participation (Activities-specific Balance Confidence [ABC] and Dizziness Handicap Inventory [DHI]). Home-based GPS training comprised two sitting horizontal gaze stability and two standing postural stability exercises performed 4 times per day for a total of 20 minutes per day for 2 weeks. Pre- and post-training differences were determined by separate Wilcoxon signed rank tests. **Results:** Participants demonstrated significant ($P < .05$) changes in vestibulo-ocular gain, CS/HR, ML sway amplitude, FGA, FSST, ABC, and DHI. No significant differences were observed in CS latency, GPE, AP sway amplitude, and total sway path. **Conclusions:** The GPS training resulted in improvements across the entire spectrum of outcome measures, highlighting its efficacy in people with MS. Gaze stability was achieved by recruiting substitutive oculomotor strategies (CS/HR) while postural stability was achieved by ML sway adaptations. Consistent improvements in the dynamic balance performance and self-report participation measures following the GPS training suggest a clinically meaningful effect. Future research should examine the efficacy of training using a randomized clinical trial design, examine skill transfer (passive versus active head rotations), and test for long-term retention of improvements in people with MS.