Continuous In-Home Symptom and Mobility Measures for Individuals With Multiple Sclerosis: A Case Presentation

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CASE STUDY

ABSTRACT

Gait impairment represents one of the most common and disabling symptoms of multiple sclerosis (MS). To identify which temporal or spatial parameters of gait could be used as outcome measures in interventional studies of individuals with MS with different levels of disability, we evaluated characteristics of these parameters in a case study of 3 participants with MS, using 1 case as an exemplar and the other participants as validation. A case study of an exemplar participant was conducted with a 67-year-old woman with secondary progressive MS served as exemplar, with 2 other participants (52 and 55 years old) as validation. The primary outcome measures we used were stride time, stride length, gait velocity, and daily symptoms. Stride length and velocity of gait decreased with increasing pain and fatigue. The step time was significantly longer later in the day, whereas the step length remained the same. Stride length and velocity are associated with the level of fatigue and pain, as well as the time of day. These characteristics and parameters of gait need to be considered in future studies of gait in MS, with particular attention to temporality of occurrence in persons with MS.

Keywords: case study, gait, multiple sclerosis, step length, stride time, stride velocity, symptoms

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Multiple sclerosis (MS) is an abnormal response of the immune system in which the body attacks its own central nervous system. Specifically, the T-cell–mediated component of the immune response targets the myelin that surrounds nerve fibers, causing inflammation and damaged or sclerosed nervous tissue.[1] This damage leads to a variety of physical and cognitive symptoms among persons with MS.

Because of the progressive nature of the disease, individuals with MS experience worsening symptoms and gait instability, which place them at a high risk for falls. Studies have shown that gait characteristics may be analyzed to assess fall risk in addition to being a diagnostic marker of progression. Cameron and Wagner[2] identified walking endurance, gait speed, and gait quality as indicators of MS-related disability and progression of the disease. In addition, Learmonth et al[3] examined cognitive motor interference for the upper and lower extremities in individuals with MS and found that there was significant impairment during walking across all disability levels.[4]

None of the studies on gait to date have addressed real-time assessment of gait and symptoms by time of day using continuous monitoring systems in the home

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environment.[5–8] The use of a continuous monitoring system in the homes of individuals with MS may allow for targeted symptom management and fall prevention strategies. The detailed information such systems provide can lead to more a nuanced understanding of changes in gait characteristics, which may translate to better clinical management. This may be particularly important in this population because the pathophysiological processes in MS are modulated by a complex array of inflammatory and demyelinating processes, which may show marked circadian variation (predictable change for a 24-hour period).[4] We describe data from monitoring 3 people with MS, using one as an exemplar case, to explore the relationship between the type of distress experienced (MS symptoms) and time of day.

Methods

The gait measurement device, a 3-dimensional infrared depth imaging system (SensorForesite Patient care; SensorForesite Healthcare System), was developed to measure gait and falls in the home environment objectively in real time. This system has been validated in the geriatric population.[5,9] The details of the system are described elsewhere.[6,10] Briefly, 3-dimensional infrared depth cameras are used to sense a room environment. The floor plan is detected, and people are segmented as they move through the environment, effectively creating 3-dimensional silhouettes while maintaining the privacy of the person being monitored. A tracking algorithm is used to identify walks. The system calculates stride length, stride time, and walking speed by analyzing the motion of these 3-dimensional silhouettes.

The gait parameter definitions commonly used in clinical gait analysis are described hereinafter for reference purposes. These definitions are used by the GAITRite system (CIR Systems Inc), one of the "ground truth" systems, which are based on mathematical algorithms originally developed for identifying gait parameters using privacy-protecting images constructed from Web cams.[7,11] Walking speed/velocity is defined as distance traveled divided by the ambulation time, step time is defined as time elapsed from the first contact of 1 foot to the first contact of the opposite foot, and step length is defined as the distance between the center of the left foot to the center of the right foot along the line of progression.

Procedure

Participants were recruited from an MS clinic in the midwest and a database of previous research participants (Dr Wagner). The inclusion criteria were as follows: Internet access, age of 18 or older, diagnosis of any subtype of MS, no relapse in the previous 30 days, Self-Report Expanded Disability Status Scale (EDSS) score of 0 to 6.5, and self-report of 2 or more falls in the last 6 months. Persons with MS unable to give consent were excluded. Informed written consent was obtained from eligible participants. The research study was approved by the institutional review board at Saint Louis University.

Each participant was asked to complete a daily log (developed by the primary author)[12] for 30 days after their baseline and 3- and 6-month visits. Participants logged their pain and fatigue on a scale of 0 to 10, on an hourly basis each day of the month. In addition, they could log falls and their position when they fell.

Data Analysis

Data were analyzed using SPSS 22 and SAS 9.4 (SAS Institute, Cary, North Carolina). Sensor measures (continuous variables) were described using means (SDs), whereas the symptom data used medians and the 25th and 75th percentiles. Symptom data were summarized using the average reported levels for each of the 24-hour periods for the days reported in the log, and then, plots were created of the average symptom level for each day in the 30-day period. Calculations of hourly means and standard deviations for 24 hours summarized gait parameters. For example, all 9-AM measurements during the 30 days were averaged, and then, the average gait measurements were plotted against each hour, in 24 hours, to show variation of gait parameters throughout the average day. The gait data were based on the first 30 days closest to the baseline and 3 and 6 months after the first measurement.

Case Reports

Exemplar Participant With MS

The exemplar participant (participant 1) was a 67-year-old white woman (73 kg, 163 cm; body mass index, 27.5) with MS for 20 years. The participant reported being treated with Copaxone and vitamin D. She used a wheeled walker as an assistive device and exhibited no evidence of foot or lower-extremity abnormalities. This particular participant was chosen for the exemplar case based on the consistency and completeness of gait data obtained during the study period and because the pattern of the data was more similar to the other 2 participants than any other single participant (see Supplemental Digital Content 1, available at http://links.lww.com/JNN/A92).

Validation Participants With MS

The 2 validation participants included a 52-year-old white man (77 kg, 176 cm; body mass index, 24.9) diagnosed 20 years ago (participant 2). This participant reported being treated with amantadine and Tysabri. He reported using no assistive device.

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The second validation participant was a 55-year-old white woman (63 kg, 164 cm; body mass index, 23.4) given a diagnosis of MS 20 years ago (participant 3). The participant reported being treated with Gilenya, vitamin D, and gabapentin. She reported using a wheeled walker.

Results

The exemplar participant completed (100%) the daily log for each of the baseline and 3- and 6-month periods, whereas participant 2 (the first validation participant) completed 90% of the daily log entries, and participant 3 (the second validation participant) completed 98% of the daily logs.

The gait parameters and symptom distress (fatigue, pain) during the course of the day for each of the three of the 30-day study periods for the exemplar participant are depicted in Figure 1. As the day went on, fatigue and pain distress seemed to increase (Fig 2). Likewise, a similar pattern was described for stride length and stride time, with decreases in these parameters occurring later in the afternoon than the reported increases in pain and fatigue. Specifically, the frequent oscillation in data can be interpreted as walks between the hours of midnight and 6:00 AM, which coincide with the daily logs. Data for the other 2 participants were largely similar but less complete (available on request).

Discussion

We provide preliminary evidence that gait parameters change after variations in pain and fatigue. These case presentations are unique because they document the cases of 3 participants with MS with symptom change throughout the course of the day during a 30-day period. Whereas our data set is focused on assessment of gait parameters and symptom distress, the results are in general agreement with previous studies of gait abnormalities in MS. For example, Socie et al[13] studied a group of 81 independently walking patients with MS (mean EDSS, 2.8; range, 0–5.5). Data indicated that patients walked slower, used shorter steps, and had longer step time than healthy controls. Similarly, Kim and colleagues[14] found that a digital watch measuring fatigue significantly correlated with the fatigue severity scale scores (r = 0.55, $P < .001$) and modified fatigue severity index scale (r = 0.55, $P < .001$), with variations in fatigue increasing from a mean of 3.4 at 9 AM to 4.0 at 1 PM, 4.5 at 5 PM, and 5.0 at 9 PM. According to Learmonth et al,[3] based on data collected from observing 86 individuals with MS, a strong association was found between reported fatigue and a walking self-reported questionnaire (Spearman's ρ = 0.763, $P < .001$). Longer step time than healthy controls and gait parameters correlated strongly with EDSS scores. In contrast, Kalron[15] found that modifications in spatiotemporal parameters of gait (eg, step and stride length) were not closely related to symptomatic fatigue in individuals with MS. However, the previous studies did not examine the relationship of time of day with symptoms and gait.

Research and Nursing Implications

Given the importance of translating nursing care to the home environment, these findings offer important preliminary data. Individuals with MS in the community setting may not participate in structured exercise activities or have individualized instruction, which includes frequent rest periods, designed to avoid overexertion. Nurses and other healthcare professionals such as physical therapists and occupational therapists should be involved in providing personalized instruction based on the overall responses of the participants' symptom experience related to gait. For example, depending on the task, some individuals with MS overexert themselves by doing a cluster of activities. Moreover, because other variables can be in play (eg, poorly fitted shoes, distractors, lack of sleep, depression), individuals in their home environment require ongoing self-care options. On the basis of the descriptive data collected for medications, it is important for individuals with MS to discuss with nurses and other healthcare providers pharmacological and nonpharmacological measures that can improve symptoms and gait. Nurses and other healthcare providers need to conduct regular follow-ups of the population with MS in the community before, during, and after any clinical contact.

Although the information presented here is preliminary, more research is needed to tease out the contributing factors that can lead to an increase in fatigue and pain later in the day. For example, correlation studies using the MS Functional Composite Scale, which collects confounders such as medications, relapse rate, and other clinical data, might be beneficial. Future studies should elucidate in-depth mechanisms by which symptoms such as pain and fatigue are associated with changes in specific gait parameters. Ultimately, using depth sensors to analyze gait and events leading up to falls will lead to better fall prediction/detection and better analysis of falls that can aid in developing future strategies[10]

Limitations

There are limitations to this case presentation. Foremost, as a study of 2 cases with 1 exemplar extracted from a pilot study, these results should not be generalized beyond what were these participants. Through this ongoing pilot study, we are optimistic that, despite the possible privacy issue, individuals with MS

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FIGURE 1 Symptoms and Gait Sensor for Participants With Multiple Sclerosis

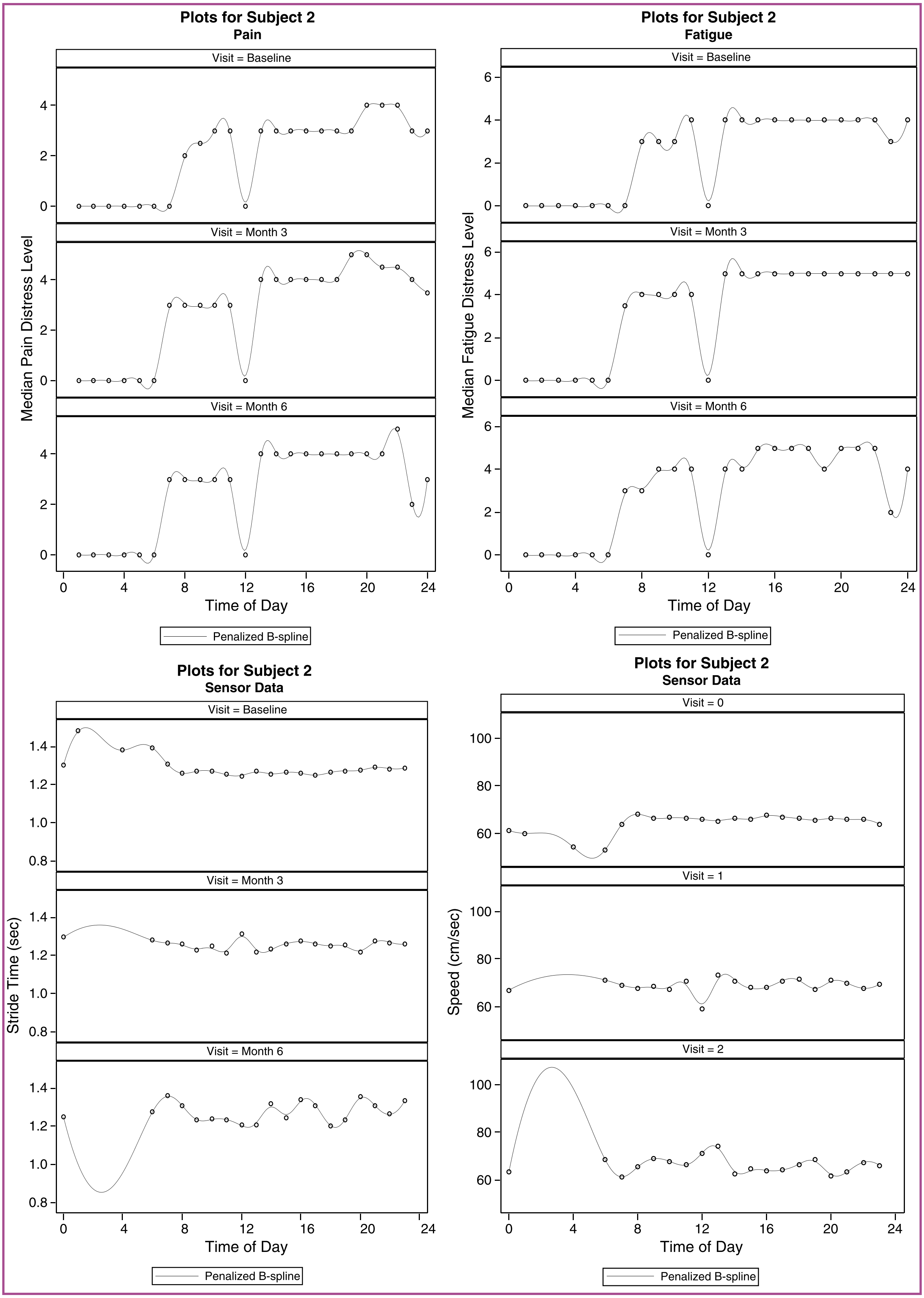

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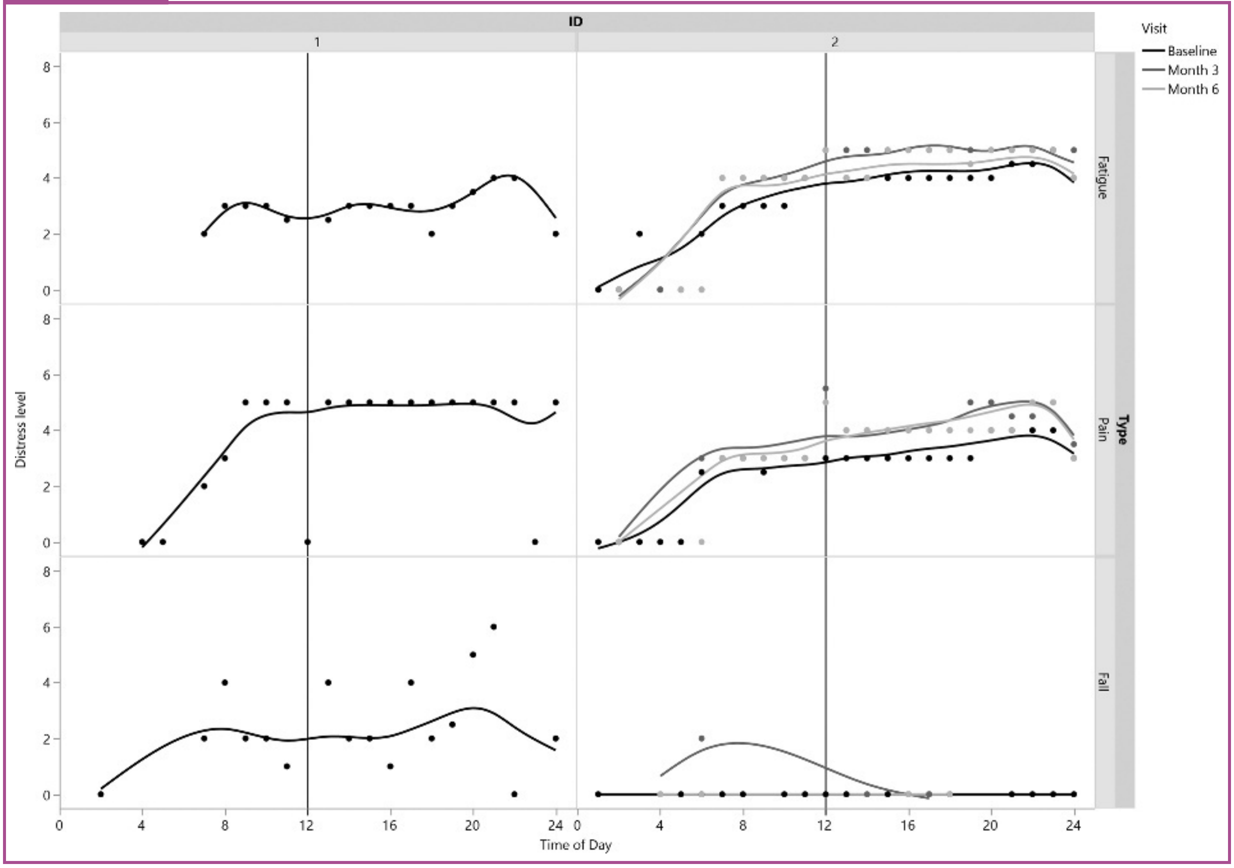
FIGURE 2 Median Distress Level by Type Versus Time of Day



are usually willing to take part in in-home monitoring to allow for discovery of improvements in care.[16] In addition, although the gaps in participants' documentation of symptom distress were minimal, we did not collect data on naps or other rest periods that may impact their gait pattern during the day. In addition, our data do not allow determining causal relationships between characteristics and parameters, such as medications, vision, other illnesses, and so forth, with effects on gait and symptom. Each participant is receiving a different therapy; therefore, we cannot make generalizations. Additional research is needed to account for these factors. For example, does fatigue or pain alter the walking pattern or vice versa, or do impaired walking abilities cause elevated fatigue or pain? Specific medication and sleep patterns and overall lifestyle influences may also affect reports of fatigue and pain. However, this was not the purpose of this article.

Conclusion

This study elucidated how the temporal and spatial parameters of gait change in 3 individuals across the time of day, in relation to associated symptoms. The step length shortens significantly at around 3 PM and occurs with higher degrees of pain and fatigue. However, the beneficial effects of having patients use self-knowledge of the usual effects of time of day on their function and symptoms as prompts for early self-management of pain and fatigue need to be explored and may be highly effective.

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References

1. National MS Society. *What is MS?* Retrieved from http://www.nationalmssociety.org/What-is-MS
2. Cameron MH, Wagner JM. Gait abnormalities in multiple sclerosis: pathogenesis, evaluation and advances in treatment. *Curr Neurol Neurosci Rep*. 2011;11(5):507–515.
3. Learmonth YC, Pilutti LA, Motl RW. Generalized cognitive motor impairment in multiple sclerosis. *Gait Posture*. 2015;42(1):96–100.
4. Nogueira LA, Teixeira L, Sabino P, Filho HA, Alvarenga RM, Thuler LC. Gait characteristics of multiple sclerosis patients in the absence of clinical disability. *Disabil Rehabil*. 2013;35(17):1472–1478.
5. Socie MJ, Motl RW, Sosnoff JJ. Examination of spatiotemporal gait parameters during the 6-min walk in individuals with multiple sclerosis. *Int J Rehabil Res*. 2014;37(4):311–316. doi:10.1097/MRR.0000000000000074

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6. Monticone M, Ambrosini E, Fiorentini R, et al. Reliability of spatial-temporal gait parameters during dual-task interference in people with multiple sclerosis. A cross-sectional study. *GaitPosture*. 2014;40(4):715–718. doi:10.1016/j.gaitpost.2014.06.015
7. Lizrova Preiningerova J, Novotna K, Rusz J, et al. Spatial and temporal characteristics of gait as outcome measures in multiple sclerosis (EDSS 0 to6.5). *J Neuroeng Rehabil*. 2015;12:14.
8. Feys P, Severijns D, Vantenderloo S, et al. Spatio-temporal gait parameters change differently according to speed instructions and walking history in MS patients with different ambulatory dysfunction. *Mult Scler Relat Disord*. 2013; 2(3):238–246. doi:10.1016/j.msard.2013.01.004
9. Stone EE, Skubic M. Unobtrusive, continuous, in-home gait measurement using the Microsoft Kinect. *IEEE Trans Biomed Eng*. 2013;60(10):2925–2932.
10. Rantz M, Skubic M, Abbott C, et al. Automated in-home fall risk assessment and detection sensor system for elders. *Gerontologist*. 2015;55(suppl 1):S78–S87. doi:10.1093/geront/gnv044
11. Sosnoff JJ, Weikert M, Dlugonski D, Smith DC, Motl RW. Quantifying gait impairment in multiple sclerosis using GAITRite technology. *Gait Posture*. 2011;34(1):145–147. doi:10.1016/j.gaitpost.2011.03.020
12. Newland P, Wagner JM, Salter A, Thomas FP, Skubic M, Rantz M. Exploring the feasibility and acceptability of sensor monitoring of gait and falls in the homes of persons with multiple sclerosis. *Gait Posture*. 2016;49:277–282. doi:10.1016/j.gaitpost.2016.07.005.
13. Socie MJ, Motl RW, Pula JH, Sandroff BM, Sosnoff JJ. Gait variability and disability in multiple sclerosis. *Gait Posture*. 2013;38(1):51–55. doi:10.1016/j.gaitpost.2012.10.012
14. Kim E, Lovera J, Schaben L, Melara J, Bourdette D, Whitham R. Novel method for measurement of fatigue in multiple sclerosis: Real-Time Digital Fatigue Score. *J Rehabil Res Dev*. 2010;47(5):477–484.
15. Kalron A. Association between perceived fatigue and gait parameters measured by an instrumented treadmill in people with multiple sclerosis: a cross-sectional study. *J Neuroeng Rehabil*. 2015;12:34. doi:10.1186/s12984-015-0028-2
16. Wang F, Skubic M, Rantz M, Cuddihy PE. Quantitative gait measurement with pulse-Doppler radar for passive in-home gait assessment. *IEEE Trans Biomed Eng*. 2014;61(9): 2434–2443. doi:10.1109/TBME.2014.2319333

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