

Feasibility, Reliability, and Convergent Validity of the Five Times Sit-to-Stand Test via Telehealth in Multiple Sclerosis

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ABSTRACT

BACKGROUND: Physical therapy via telehealth for people with multiple sclerosis (MS) may be a feasible mode of delivery to improve accessibility and continuity of care. However, little evidence exists to guide the selection of tests and measures in telerehabilitation. This study aimed to confirm the reliability and examine the feasibility, safety, and convergent validity of the remote Five Times Sit-to-Stand (rFTSTS) test among people with MS.

METHODS: Demographics, disease characteristics, in-person Five Times Sit-to-Stand (FTSTS) and rFTSTS, and hip and knee isometric strength were collected on people with MS (N=32) at a one-time visit. The rFTSTS and FTSTS were administered concurrently. Inter-rater reliability between rFTSTS and FTSTS was assessed using a 2-way random effect, single measurement intraclass coefficient (ICC). Spearman rank correlations (ρ) were used to determine the association between rFTSTS and knee and hip strength.

RESULTS: The rFTSTS and FTSTS had excellent inter-rater reliability (ICC=1.00, $P < .001$), and were easy to administer without adverse events. The rFTSTS exhibited moderate to large associations ($P < .05$) with the strongest and weakest limb's hip flexion (strongest: $\rho = 0.449$; weakest: $\rho = 0.474$) and extension (strongest: $\rho = 0.378$; weakest: $\rho = 0.362$) and the weakest limb's knee flexion ($\rho = 0.552$) and extension ($\rho = 0.427$).

CONCLUSIONS: The rFTSTS is feasible, safe, and reliable, and exhibits convergent validity with hip and knee strength. While further validation is needed, the rFTSTS may be a useful measure for telerehabilitation in people with MS with mild to moderate impairment.

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Multiple sclerosis (MS) is a neurodegenerative disease affecting approximately 2.9 million people worldwide as of 2023.¹ Common MS symptoms include muscle weakness, impaired coordination and balance, spasticity, and fatigue, which may significantly impact functional independence and quality of life.^{2,3} Evidence suggests that physical therapy (PT) may be beneficial for people with MS⁴ by addressing impairments such as fatigue,⁴ spasticity,⁵ and decreased balance.⁶ Furthermore, participation in PT is associated with reductions in MS-related disability⁶ and fall risk,⁷ and improvements in physical function,⁶ gait,⁸ quality of life, and overall well-being.⁹

Given the impairments and decreased functional mobility that is associated with MS, traveling to PT appointments may be a hardship.¹⁰ Delivering PT services via telehealth is a feasible strategy that can improve accessibility, maximize resources, eliminate travel challenges, allow for direct social support, and improve continuity of care.^{11,12} Additionally, telehealth-based rehabilitation services (telerehabilitation) may yield similar benefits compared with traditional therapy in neurological populations.¹²⁻¹⁴ Specifically, telerehabilitation was comparable to in-person rehabilitation for improving motor status and increasing patient knowledge for individuals who have had a stroke,¹⁵ and produced similar outcomes in balance and gait, quality of life, and patient satisfaction in individuals with Parkinson disease.¹⁶ Among people with MS, telehealth emerged as a viable option for a wide range of health care services, including rehabilitation.¹⁷ Telehealth is well-received by people with MS¹⁸ and is feasible and effective in addressing balance deficits, increasing levels of physical activity, and improving overall function.^{13,19}

Increased utilization of telehealth in health care²⁰ means more physical therapists may provide telerehabilitation services to people with MS, and these professionals need appropriate measures to use. The recently published *Telerehabilitation in Physical Therapist Practice: A Clinical Practice Guideline From the American Physical Therapy Association* supports the implementation of remote PT examinations; however, it emphasizes

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the need to evaluate the effectiveness of the examination process, including the validity of specific outcome measures.¹¹ As changing the administration of an outcome measure can affect its reliability (ability to consistently measure the specific outcome with similar results) and validity (the ability to accurately measure what it intends to measure),²¹ establishing these metrics is crucial for physical therapists to have confidence in remote assessments. Furthermore, as the physical therapist will not be in the same location as the patient, determining the ease and safety of remote administration in people with MS is necessary.

One of the core outcome measures recommended by the Academy of Neurologic Physical Therapy (ANPT) is the Five Times Sit-to-Stand (FTSTS) test, a valid and reliable assessment of sit-to-stand performance and functional lower limb (LL) strength in adults.^{22,23} In people with MS, the FTSTS (ie, in-person assessment) has high inter-rater and test-retest reliability²⁴ and is a valid measure for evaluating dynamic balance, transfer ability, and knee extensor and hip flexor strength in the weakest leg.²⁴⁻²⁷ The FTSTS test can potentially be used in telerehabilitation for people with MS, with 1 study to date showing high inter-rater and intra-rater reliability when conducted remotely.²⁸ However, data on the reliability of the remote FTSTS (rFTSTS) is limited for people with progressive MS or more extensive disability. Further, the convergent validity of the rFTSTS test to measure functional LL strength in people with MS has yet to be established.

This study aimed to confirm the reliability and examine the feasibility, safety, and convergent validity of the rFTSTS test among people with MS. It was hypothesized that the rFTSTS would have good reliability, be feasible and safe, and have good convergent validity to support its use in telerehabilitation settings as a functional LL strength measure.

METHODS

Participants

All participants signed informed consents approved by the Trinity Health Of New England and the Quinnipiac University institutional review boards (IRB) for the current study (IRB#: MSH-22-01) in accordance with the World Medical Association Declaration of Helsinki. This cross-sectional study used a convenience sample recruited through flyers, word of mouth, and the recruitment pool at the Joyce D. and Andrew J. Mandell Center for Comprehensive Multiple Sclerosis Care and Neuroscience Research (Mandell Center) at Mount Sinai Rehabilitation Hospital in Hartford, CT, (Recruitment Pool IRB#: MSH-19-48). Eligible individuals met the following criteria: diagnosed with MS using the 2017 revised McDonald criteria,²⁹ between the ages of 18 and 99, willing to complete and adhere to study protocol, able to understand directions given in English, and able to complete a sit-to-stand transfer and ambulate at least 10 meters without physical assistance from another individual. Exclusion criteria included a recent injury or surgery affecting the LL, absolute contraindications to exercise,³⁰ and abnormal response to physical activity or unsafe to participate (ie, uncontrolled medical conditions, cannot safely perform the FTSTS). A sample size of 24 was sufficient for establishing the reliability between the rFTS-

PRACTICE POINTS



The remote Five Times Sit-to-Stand (rFTSTS) test is feasible and safe for ambulatory people with multiple sclerosis (MS), and the reliability of the measure was confirmed by our study.

The rFTSTS demonstrated convergent validity with hip flexor and extensor strength and weakest limb's knee flexor and extensor strength, which provides clinicians an objective way to measure functional strength through telerehabilitation.

Our findings suggest that the in-person FTSTS showed convergent validity with the hip flexor and the weakest limb's knee flexor and extensor strength in people with MS. ■

TS and FTSTS with 2 raters and 90% power, using a null hypothesis of 0.90 and a target level of agreement of 0.97.³¹ Increasing the sample size to 29 allowed for the detection of a correlation coefficient of 0.5 for convergent validity with a P value of .05 and 80% power.^{32,33}

Procedures

Data were collected at a one-time visit that lasted approximately 1 hour. Study visits were conducted at the Mandell Center with a research therapist present with the participant during all procedures. Demographics (age, gender, ethnicity, and race), disease characteristics (disease duration and subtype), and anthropometric measures (body mass index) were collected. Disability was measured using the self-reported Patient-Determined Disease Steps (PDDS), in which participants used a 9-point rating scale to identify the score (0-8) that best reflected their perceived ambulation level; 0 signifies normal, 4 signifies early cane use, and 8 signifies being bedridden.^{34,35}

The rFTSTS and FTSTS were administered concurrently by an in-person and a remote therapist, who interacted with the participant through a video-based, Health Insurance Portability and Accountability Act-compliant version of QliqSOFT (QliqSOFT, Inc.) on an iPad (sixth generation; Apple), with an iPhone 12 as a backup for the remote therapist only. The remote therapist provided the participant with instructions for the assessment. Using the ANPT protocol for the FTSTS,²³ participants were instructed to sit on a chair with their arms crossed and feet comfortably underneath them, and then to fully stand up and sit back down for a

total of 5 repetitions as quickly and safely as they could. A standard-sized chair (18 inches high and without armrests) was used.

Due to the lag in audio delivery that was noted during training for the study assessments, the protocol for starting the stopwatch was slightly adapted. Each therapist started the stopwatch when the participant first moved and stopped the stopwatch when the participant's body touched the chair after the fifth stand. Two trials were completed, and the fastest time was included for data analysis.²⁵ A 1- to 2-minute rest break was given to participants between trials. If participants were unable to complete a sit-to-stand without the use of their arms, they were asked to use the least amount of upper extremity (UE) support necessary (eg, pushing off the seat of the chair with their hands). The assessing therapists documented whether no UE, 1 UE, or both UEs were used for at least 1 repetition.

Additionally, the feasibility (eg, ease of administration) and safety of the rFTSTS were documented by the therapists. Ease of administration (yes or no) encompassed the use of equipment (chair, electronic devices [phone, tablet, or laptop], and timer) and the number of technological complications. Patient safety was measured by recording if there was any physical intervention by the in-person therapist, any need for supervision of participants (ie, spotting or verbal cueing), and technological complications that could impede safety (eg, a lag or lack of audio).

Bilateral LL isometric muscular peak torque of the hip flexors, hip extensors, knee flexors, and knee extensors was measured to establish convergent validity with the rFTSTS, using the Biodex 4 Pro Dynamometer (Biodex Medical Systems). Participants were asked to push as hard as they could for 3 seconds against the arm of the dynamometer 3 times, with 20 seconds of rest in between, beginning with the dominant limb for each measure. The muscles were tested in the same order on all participants, starting with hip flexion and extension (measured in the supine position with the hip at 50 degrees of flexion), followed by knee flexion and extension (measured in a seated position with the knee at 70 degrees of flexion). Positioning was based on previous studies and the Biodex manual.^{36,37} Isometric strength was presented as peak torque in Newton meters for the strongest and weakest limbs.

Statistical Analysis

SPSS Version 26 (IBM) software was used to analyze the data. Descriptive statistics were conducted, with participant's demographics and performances reported using either frequencies or median and IQR due to the non-normal distribution. Inter-rater

TABLE 1. Descriptive Characteristics of Participants (N=32)

Demographics ^a	
Age, years	55.0 (49.3; 62.5)
BMI, kg/m ²	29.7 (25.1; 33.6)
Sex, n (%)	Male: 10 (31.25) Female: 22 (68.75)
Ethnicity, %	Hispanic or Latino: 9.40 Not Hispanic or Latino: 90.6
Race, %	Black or African American: 9.40 White: 90.6
Disease characteristics	
MS subtype, %	PPMS: 3.1 RMS: 84.4 SPMS: 12.5
PDDS	2.5 (1.0; 4.0)
PDDS score frequency, %	0: 21.9 1: 15.6 2: 12.5 3: 18.8 4: 18.8 5: 3.1 6: 9.4
Disease duration, years	14.4 (9.6; 24.8)
Outcome measures	
rFTSTS (s), median (Q1; Q3) and mean (SD)	10.06 (8.2; 12.4) and 13.23 (11.5)
FTSTS (s), median (Q1; Q3) and mean (SD)	10.05 (8.2; 12.3) and 13.25 (11.5)
Hip flexion strongest (Nm)	59.0 (44.9; 81.0)
Hip flexion weakest (Nm)	48.1 (35.9; 67.0)
Hip extension strongest (Nm)	52.2 (37.1; 61.9)
Hip extension weakest (Nm)	41.6 (29.5; 52.1)
Knee flexion strongest (Nm)	43.3 (26.6; 59.5)
Knee flexion weakest (Nm)	27.5 (19.8; 47.1)
Knee extension strongest (Nm)	82.0 (67.4; 124.2)
Knee extension weakest (Nm)	70.9 (51.1; 106.1)

BMI, body mass index; FTSTS, in-person Five Time Sit-to-Stand; MS, multiple sclerosis; Nm, Newton meters; PDDS, Patient Determined Disease Steps score; PPMS, primary progressive multiple sclerosis; Q, quarter; rFTSTS: remote Five Times Sit-to-Stand; RMS, relapsing multiple sclerosis; s, second; SPMS, secondary progressive multiple sclerosis.

^aData presented as median (Q1; Q3) unless otherwise stated.

reliability between rFTSTS and FTSTS was assessed using a 2-way random effect, single measurement intraclass coefficient (ICC). Based on the ICC, the reliability could be described as poor (<0.50), moderate (0.50-0.75), good (>0.75-0.90), or excellent (>0.90).³⁸ Convergent validity of the rFTSTS was assessed using the nonparametric Spearman rank correlation (ρ) to determine whether there was an association between rFTSTS and knee and hip strength. For comparison, correlations were also conducted with the FTSTS and strength measurements. The effect sizes of the correlations were defined as small ($\rho < 0.30$), moderate ($\rho 0.30$ to <0.50), or large ($\rho \geq 0.50$).³⁹

TABLE 2. Correlations (ρ) Between the rFTSTS and FTSTS and Lower Limb Isometric Strength

	Limb	rFTSTS	P value	FTSTS	P value
Hip flexion	Strongest	0.449	.010*	0.427	.015*
	Weakest	0.474	.006*	0.435	.013*
Hip extension	Strongest	0.362	.042*	0.343	.055
	Weakest	0.363	.041*	0.338	.058
Knee flexion	Strongest	0.335	.061	0.311	.083
	Weakest	0.552	.001*	0.543	.001*
Knee extension	Strongest	0.324	.071	0.312	.083
	Weakest	0.427	.015*	0.427	.015*

FTSTS, in-person Five Times Sit-to-Stand; rFTSTS remote Five Times Sit-to-Stand.

* $P < .05$.

RESULTS

Participants ($N=32$) had a median age of 55.0 years and had a median disease duration of 14.4 years. The sample population was primarily White (90.6%), non-Hispanic (90.6%), and female (68.8%). Over 84% had relapsing MS, with a median PDDS score of 2.5 (TABLE 1). The rFTSTS and FTSTS had excellent inter-rater reliability ($ICC=1.00$, $P < .001$). The median rFTSTS score was 10.06 seconds, which was 0.01 second slower than the median FTSTS score.

The time to complete the testing, including the rest period, was approximately 5 minutes. There was only 1 technological complication during the rFTSTS, in which the QliqSOFT remote visit request would not send through email. The issue was remedied by the remote therapist sending the request via a text message. The assessing therapists all endorsed that the equipment was easy to use, and no adverse events occurred during testing. While the in-person therapist did provide close supervision for both participants with a PDDS of 6.0, who required bilateral UE support to complete the FTSTS, no participants required any physical assistance.

The rFTSTS had moderate to large associations with the strongest and weakest limb's hip flexion and extension and the weakest limb's knee flexion and extension (TABLE 2 and FIGURES S1 and S2; supplemental figures are available in a PDF at the end of the online article). In comparison, the FTSTS had similar relationships, although its correlation with both the strongest ($\rho=0.343$, $P=.055$) and weakest hip extension ($\rho=0.338$, $P=.058$) was not significant. While nonsignificant, the strongest knee flexion had a moderate association with the rFTSTS ($\rho=0.335$, $P=.061$) and FTSTS ($\rho=0.311$, $P=.083$), as did the strongest knee extension (rFTSTS: $\rho=0.324$, $P=.071$; FTSTS: $\rho=0.312$, $P=.083$).

DISCUSSION

The current study demonstrated that in people with MS, the rFTSTS has excellent inter-rater reliability compared with the FTSTS, with minimal differences in timing. Additionally, no safety issues emerged during remote testing, and the assessing therapists endorsed high ease of administration. Consistent with Dos Santos et al,²⁸ these results suggest that the rFTSTS is a reliable, feasible, and safe outcome measure in a telehealth setting

for people with MS with a PDDS score between 0 and 6. Further, the rFTSTS showed convergent validity with bilateral hip flexion and extension and the weakest limb's knee flexion and extension. Although nonsignificant, likely due to the study only being powered to detect a large effect, the rFTSTS had a moderate association with the strongest knee extension and flexion. The magnitude of these relationships was comparable to the FTSTS in the current study. The magnitude of associations for both the FTSTS and rFTSTS was slightly lower than in previous studies using in-person administrations, which were large associations (.600 to .871).^{24,25}

Recent studies have reported the reliability of the rFTSTS in other populations, including persons with gastrointestinal cancer⁴⁰ and older veterans.⁴¹ In people with MS, only one other study to date has evaluated the reliability of the rFTSTS.²⁸ Although Dos Santos et al reported findings similar to the current study, there are some critical differences in methodology and participant demographics. Dos Santos and colleagues²⁸ had both investigators measure the rFTSTS simultaneously on the same video call, similar to the methodology used by Ogawa et al⁴¹ when assessing the reliability of the rFTSTS in older veterans. However, in the current study, one research therapist was present in the room with the participant, collecting data in real time for the FTSTS, while the second therapist simultaneously measured the FTSTS through a telehealth platform. Previous studies have examined FTSTS through review and real-time assessment of only video footage. To the best of our knowledge, this study is the first to compare the rFTSTS with the previously validated in-person FTSTS in real time, on the same test.

Participants in this study included an older population of individuals with MS and people with greater levels of disability than those included in Dos Santos et al,²⁸ which included participants with an Expanded Disability Status Scale score (EDSS) of up to 6, indicating occasional or constant unilateral assistance (eg, cane, crutch, brace) required to walk 100 meters with or without resting. Only 1 participant with that level of disability was included in their study, while the rest did not require any aid to walk 100 meters.²⁸ In our study, 10 people with MS with PDDS scores of 4 to 6 were included; a score of 4 indicates that a unilateral aid (eg, cane, crutch brace, wall support) is necessary to walk at least 3 blocks and a score of 6 indicates that a bilateral aid (eg, walker,

rollator, bilateral crutches) is needed to walk 25 feet. In addition, the current study included participants with relapsing-remitting and progressive MS, while the previous study did not include individuals with progressive MS.²⁸ Despite including participants with higher levels of disability, our results show lower median FTSTS scores than those reported by Dos Santos et al,²⁸ possibly due to the investigators adjusting the start of the timing to coincide with participants first moving, rather than at the word *go*, to account for any lag in the video.

The rFTSTS test was easy to instruct, required little physical space, and did not require specialized equipment. Although other researchers have reported connectivity issues in telehealth studies,²⁸ minimal technology-based barriers were encountered during the testing and were easy to remedy, further supporting the feasibility and ease of FTSTS test administration via telehealth. Although no physical intervention was required during test administration, 2 participants with a PDDS of 6.0 required close supervision from the in-person therapist, as well as the use of bilateral UL support. Based on the need for close supervision to improve the safety of this outcome measure for these 2 participants, physical therapists may choose not to implement rFTSTS for people with MS who have a PDDS score of 6.0, or they may request in-person supervision from a caregiver. Finally, the test administration was quick, with both trials of the FTSTS lasting approximately 5 minutes altogether, including rest periods.

Validity of the FTSTS as a measure of functional LL strength has been established in people with MS for knee extension. To date, this study is the first to explore the convergent validity of the rFTSTS for functional LL strength. Considering that the FTSTS test involves the evaluation of sit-to-stand transfers, muscle recruitment patterns associated with the performance of a sit-to-stand transition were expected. This study's results support previous findings,²⁵ in which the FTSTS was correlated with isometric knee extension, knee flexion, and hip flexion strength in the most affected leg among mildly to moderately impaired people with MS. Kjølhede et al²⁷ also found correlations between the weakest limb's knee extension and FTSTS performance for people with MS with mild to moderate impairment (EDSS 2 to 4), while Özüdoğru et al²⁴ noted a significant effect of bilateral knee extensor strength on test performance. The current findings concur with studies in other populations that demonstrated a correlation between knee extension⁴² strength with the FTSTS. These muscle groups are key factors in standing,⁴³ with LL strength positively associated with FTSTS times.⁴² These results are also consistent with evidence in other populations associating the weakest limb's hip flexion⁴⁴ and extension⁴⁵ with the FTSTS. Since hip extensor muscle strength is a contributor to the sit-to-stand transition,⁴³ the current findings may indicate an important role for hip extensor strength in FTSTS performance, warranting further exploration in individuals with mild to moderate MS.

To the best of our knowledge, this is the first study to have found that the rFTSTS test demonstrates convergent validity with bilateral hip flexion and extension and weakest limb's knee flexion and extension, and that the in-person FTSTS has convergent validity with bilateral hip flexion strength and weakest knee flexion in people with MS, which have previously been

nonsignificant in other samples.^{25,27} While the in-person FTSTS did not have a significant association with hip extensors as the rFTSTS did, this is likely a reflection of the study's sample size not being powered to detect effect sizes less than 0.5, rather than a difference in the measures. Closer examination shows that the hip extensor's correlation coefficients with the FTSTS (S: $\rho = .343$, W: $\rho = .338$) were very similar to the rFTSTS (S: $\rho = .362$, W: $\rho = .363$); however, their *P* values were just slightly over the threshold for significance. Therefore, these findings should be interpreted with caution, with the lack of significance likely attributable to the study being underpowered, rather than the association between the FTSTS and functional strength differing by administration method.

While telerehabilitation has several benefits and the current study found the rFTSTS to be feasible and safe, digital practice may also present challenges, such as limitations in access and familiarity with technology, legality, privacy, and insurance coverage, which all must be considered.^{10,18,46,47} The findings from this study can help physical therapists make more informed decisions when selecting outcome measures for use in telerehabilitation with people with MS. Establishing that the rFTSTS is reliable, feasible, safe, and has convergent validity with hip and knee strength for people with MS with mild to moderate impairment (PDDS scores 0-6) is particularly important, as these individuals have a high likelihood of experiencing functional limitations and increased barriers in accessing health care, which may impact their ability to attend in-person physical therapy.⁴⁸ In people with MS, decreased LL strength and function, as well as sit-to-stand ability, have been linked to decreased walking capacity, transfers, stair climbing,²⁷ and dynamic balance.²⁶ The ability to accurately assess functional LL strength through telehealth visits may improve the ability to monitor disease progression and promote a more informed plan of care.²⁶ Through identifying and addressing LL strength deficits, clinicians may achieve better functional outcomes and improve quality of life when caring for people with MS.⁴⁹

One limitation is that although the sample size was sufficiently powered for the detection of a correlation coefficient of 0.5, it was underpowered (41.9%) for detecting significance with the lowest correlation coefficient (0.311).³² Results from this study are limited to people with MS who could walk 25 feet and had a PDDS of 6 or less. However, there is a possibility that individuals who use a wheelchair as their primary form of mobility may be able to perform a sit-to-stand transfer and be able to complete an FTSTS assessment, warranting future research with individuals who score a 7 on the PDDS while exploring methods to ensure safe test administration. This study also did not measure other factors that may affect a person's ability to complete the FTSTS and rFTSTS (eg, endurance, flexibility, and balance); however, future studies should include these factors to demonstrate convergent validity with other aspects of functional mobility.

In addition, all testing was performed in a research setting, allowing for equipment and technology-based setup to be carried out by investigators on site. This may have eliminated potential barriers encountered in a real-life telehealth visit, such as difficulty with the camera or video setup, internet access and

connectivity, and other technology-based barriers, including variability in user knowledge of remote conferencing systems. A research therapist was also present in the room during testing, which may have led to altered performance on the test when compared with a remote-only therapist. Further, access to a chair meeting the standardized testing requirements may not be available in the telehealth setting, requiring test administrators to use a modified protocol. Only isometric testing was utilized in this study, and while isometric and isokinetic strength tend to be strongly correlated,^{50,51} isokinetic testing may have been more comparable to the FTSTS. As isokinetic testing measures force production through the range of motion at a fixed speed, it may be more closely associated with functional strength. Finally, the current sample was very homogenous—predominantly women, White, and non-Hispanic. However, these demographics are broadly similar to the larger MS population.⁵² Future research should evaluate the rFTSTS with larger sample sizes and include more diverse participant pools, while determining existing barriers and sensitivity to change.

CONCLUSIONS

The study's results indicate that the rFTSTS is a feasible, safe, and reliable measure via telehealth and exhibits convergent validity with hip and knee strength for people with MS. In addition, these results confirm previous findings indicating the FTSTS has convergent validity with knee extension, while providing evidence that it also exhibits convergent validity with bilateral hip flexion and the weakest limb's knee flexion. These findings may allow physical therapists to make more informed decisions when selecting tests and measures for telerehabilitation for people with MS with mild to moderate impairment (PDDS scores 0-6). ■

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