Feasibility of Telerehabilitation-Monitored Functional Electrical Stimulation on Walking and Quality of Life in People With Multiple Sclerosis: A Case Series

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ABSTRACT

BACKGROUND: Foot drop in people with multiple sclerosis (MS) commonly leads to decreased mobility and quality of life (QOL). Functional electrical stimulation (FES) of the peroneal nerve can improve the gait of people with foot drop, yet various barriers restrict widespread use. The purpose of this case series was to examine the feasibility of a telerehabilitation-monitored FES device and report changes in functional mobility and QOL in people with moderate MS-related disability.

METHODS: FES use was progressed over 8 weeks via 3 telerehabilitation sessions. Feasibility of telerehabilitation was assessed by percentage of telerehabilitation visits completed and participant-reported satisfaction. At baseline and study completion, functional mobility with and without FES were assessed by the Timed 25-Foot Walk (T25FW), Timed Up and Go (TUG), and 2-Minute Walk Test (2MWT), Multiple Sclerosis Impact Scale (MSIS-29), and the 12-item Multiple Sclerosis Walking Scale (MSWS-12). Fatigue was assessed via the Modified Fatigue Impact Scale (MFIS) before and after the intervention.

RESULTS: Eleven participants (mean age = 50.4 years [SD 10.8]; 2 males) completed the study. All (33/33) telerehabilitation visits were completed and participants attained high levels of satisfaction with no adverse events. At 8 weeks, compared to baseline, there were clinically meaningful improvements on the T25FW, 2MWT, and TUG for 45%, 55%, and 82% of participants, respectively. Clinically meaningful improvements on the MSIS-29 and MSWS-12 were also recorded for 64% and 36% of participants, respectively.

CONCLUSIONS: Telerehabilitation was safe and feasible for FES intervention, and improvements in functional mobility and QOL were observed. Telerehabilitation to monitor FES may improve access and reduce patient burden; therefore, studying its efficacy is warranted.

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Multiple sclerosis (MS) is an autoimmune, neurodegenerative disorder characterized by demyelination of axons in the central nervous system (CNS) affecting approximately 3 million people worldwide.[1] Difficulty walking is highly prevalent in people with MS and is a defining feature of disease progression.[2,3] Improving walking ability is also one of the top priorities for people with MS.[4,5] One important cause of walking difficulty is foot drop, or the inability to sufficiently dorsiflex the ankle during the swing phase of gait. Individuals with foot drop report an increased incidence of falls, worse participation in mobility-related activities, and reduced quality of life.[6,7]

Functional electrical stimulation (FES) of the peroneal nerve is a common first-line treatment to address foot drop in people with MS.[8] Surface electrodes placed over the common peroneal nerve provide electrical stimulation to elicit ankle dorsiflexion as the swing limb advances.[9] FES can improve gait speed, decrease energy cost of walking, and reduce falls when used by people with MS who have foot drop.[10,11] In spite of the acknowledged advantages provided by FES for enhancing mobility, there are various barriers to extensive adoption of this assistive technology.[12] First, both in terms of the cost of the device itself and the multiple, in-person clinic visits required to optimize the device settings, high initial costs limit access to wearable FES.[13] Second, challenges with precise electrode placement[12] and time to set up the device[14] affect long-term adherence and contribute to high abandonment rates of the assistive technology.[15] Finally, a recent qualitative study[13] and clinical practice guideline[16] found that FES users value "access to professional help" when initially learning to use FES, and that physical therapy (PT) intervention is imperative to promote optimal results. However, to date, many of the studies investigating the use of FES in people with MS offer no or limited ongoing support and training for participants, ranging from 0 to 8 PT visits,[10] and

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thus, the optimal amount and type of PT intervention is not clearly defined.

Telerehabilitation may mitigate several of the aforementioned barriers to FES delivery and use. This virtual mode of health care has emerged as a viable rehabilitation option for people with MS,[17] reducing travel time for in-person appointments[18] and providing an ecologically valid environment for clinicians to evaluate and treat without the burden of an in-person visit. Recent evidence supports the use of telerehabilitation as a safe and effective method of delivering care for people with MS, which can lead to functional improvements in gait and balance outcomes.[19] However, to the best of our knowledge, no studies to date have investigated the use of telerehabilitation to facilitate delivery of FES intervention for people with MS.

Therefore, the primary aim of this case series was to examine the feasibility of telerehabilitation to remotely monitor and advance an FES intervention in people with MS. The secondary aim was to report changes in functional mobility and quality of life (QOL) after 8 weeks of FES and telerehabilitation.

METHODS

Design and Participants

This prospective case series enrolled adults (>18 years of age) with either progressive or relapsing MS from the departments of Physical Therapy and Neurology at the University of California San Francisco. Participants were included in the study if they met the following criteria: diagnosis of MS (by 2010 International Panel criteria)[20]; ability to walk with or without an assistive device (Expanded Disability Status Scale score of ≤ 6.5) for at least 10 meters; presence of unilateral foot drop as determined by a physical therapist; access to a smartphone and the internet; and adequate cognitive and communicative function to understand training instructions and use the FES device. Participants in this study had never used an FES device previously. Participants were excluded if they were unable to communicate in English (the software used in the study was only available in English); had comorbid neurologic, orthopedic, or cardiovascular diagnoses that would impact the participant's mobility or treatment response; had an active implanted device or cancer in proximity to the area of electrode placement; were pregnant; had a fixed plantarflexion contracture; or had anatomical contraindications (eg, swollen/infected skin, edema). All subjects provided signed informed consent approved by the University of California San Francisco Institutional Review Board.

Study Procedures

Participants received an initial in-person assessment from a licensed physical therapist. During the baseline assessment, each participant performed functional mobility testing first without FES then with FES following a 5-minute acclimation period with FES in which participants walked overground with the FES device turned on. Participants were provided a rest break between the acclimation period and the formal functional mobility testing. Initial device tolerability and changes in gait parameters were assessed with and without FES activated. If FES was well-tolerated, participants were instructed on how to don and doff the device and prescribed an individualized wear-time for the first week of use. Participants then completed a total of 3 telehealth visits at weeks 2, 4, and 6 with the same physical therapist during the 8-week intervention period (**FIGURE S1**). The 30-minute telehealth visits assessed participants' self-reported experience with the FES device, screened for adverse events, and allowed the physical therapist to assist remotely with electrode placement and FES progress on an individual basis in the participant's environment. All participants completed an in-person final assessment at study completion. The same acclimation period to FES was not required during the final study visit; however, participants were again provided a rest break prior to performing functional mobility testing.

FES Device

The EvoWalk FES device (Evolution Devices, Inc) was used to administer FES. The EvoWalk FES device uses an artificial intelligence–based algorithm and a single sensor to detect when the user initiates the swing phase of gait and appropriately delivers stimulation to the common peroneal nerve to elicit dorsiflexion. The EvoWalk is paired via Bluetooth to a smartphone-based application so participants and clinicians can adjust stimulation intensity as needed. During the initial study visit, the study physical therapist applied 2 surface electrodes over the common peroneal nerve as it passes over the head of the fibula, and the other over the tibialis anterior muscle belly. The level of stimulation was selected individually, based on the participants' motor response and tolerance.

Feasibility

Feasibility was measured by retention (ie, percentage of participants who completed the study), acceptability (ie, percentage of the telerehabilitation visits completed), adherence (ie, use of the FES device), participant-reported satisfaction with the telerehabilitation visits, and safety (via recording of adverse events). At the end of each telerehabilitation visit, participants completed the Telerehabilitation Satisfaction Survey, a 10-item self-report questionnaire (**TABLE S1**). Each item is scored on a 5-point Likert scale from 1 (not at all satisfied) to 5 (very satisfied). Scores range from 10 to 50, with a higher score indicating more satisfaction.[21]

Functional Mobility Tests

Functional mobility was assessed by the Timed 25-Foot Walk Test (T25FW), the 2-Minute Walk Test (2MWT), and the Timed Up and Go (TUG). For all functional mobility tests, participants were allowed to use their preferred assistive device, if needed. The T25FW test, the most common measure of walking speed in people with MS, was obtained. Participants were asked to walk 25 feet in a straight hallway as quickly as possible, safely. The time taken to walk 25 feet was recorded by

a stopwatch. This test was repeated 3 times and the average was taken and converted to meters per second for analysis. An improvement of 20% has been suggested as a minimal clinically important difference (MCID).[6] The 2MWT was used as a measure of walking endurance. Participants were asked to walk for 2 minutes at maximal effort around cones placed in a 50-foot hallway. The 2MWT has high intrarater reliability for people with MS and can detect meaningful changes in walking endurance.[22] An improvement of 11.4 meters has been suggested as a minimally important change (MIC).[23] The TUG was used as a measure of balance and mobility. Participants began while seated in a chair with armrests. Participants were instructed to stand up and walk around a cone placed 3 meters away and return to a seated position as quickly as possible, safely. The time taken to complete this task was recorded by a stopwatch. The TUG has good construct validity for people with MS[24] but lacks sensitivity in detecting clinically relevant changes.[25]

Step count was measured by the remote capture of steps during FES device use. The EvoWalk device collects step count through an accelerometer and gyroscope with a sampling frequency of 66.7 Hz. The step count feature has yet to be validated against accelerometry in people with MS.[26] Mean FES device wear-time (ie, wearing and using the FES device) and weekly step count (ie, a continuous 7-day period) were derived from the EvoWalk software and averaged for each participant for their first and last week of FES use.

Self-Reported Measures

The Multiple Sclerosis Impact Scale is a 29-item questionnaire (MSIS-29); it assesses the impact that MS has on a person's physical and psychological QOL. Items related to physical and psychological function are rated on a 1-to-5 response scale as being affected by MS or bothersome from "not at all" to "extremely." Scores range from 29 to 145, with a score of 29 indicating that physical and psychological functions have not been affected at all and a score of 145 indicating that these domains have been extremely affected by the individual's MS. The MSIS-29 is a highly recommended outcome measure with strong psychometrics.[27] An improvement of 8 points has been suggested as the MCID.[28]

The Multiple Sclerosis Walking Scale (MSWS-12) is a 12-item questionnaire; it assesses the impact that MS has on a person's walking function over the previous 2 weeks. Items related to physical and psychological function are rated on a 1-to-5 response scale as being affected by MS from "not at all" to "extremely." Individual item scores are summed, and the total score is standardized to a scale ranging from 0 to 100, with a lower score indicating that MS has not affected walking function and a higher score indicating that walking function has been extremely affected by MS. The MSWS-12 is a valid and reliable measure of walking ability in people with MS.[29] An improvement of 8.6 points has been suggested as a MIC.[25]

The Modified Fatigue Impact Scale (MFIS-5) is a 5-item questionnaire that quantifies fatigue symptoms in people with MS. This is a shortened version of the MFIS and includes questions pertaining to the physical, cognitive, and psychosocial subscales of the longer questionnaire. The MFIS-5 scores each item on a 0 (never) to 4 (almost always) rating scale. Scores range from 0 to 20, with a higher score indicating more fatigue.[30] An improvement of 4 points has been suggested as the MCID.[31]

TABLE 1. Baseline Demographics, Acceptability, and Device Wear-Time (N = 11)

Demographics	
EDSS (median, IQR)	4.5 ± 1.5
Age (mean, SD)	50.6 ± 10.8
Sex: female, n (%)	9 (81%)
MS type: relapsing, n (%)	9 (81%)
Acceptability of telerehabilitation	
Sessions completed, n (%)	33 (100%)
Satisfaction with telerehabilitation (%)	100%
FES device wear-time	
Week 1 average use (min)	219.9 ± 104.1
Week 8 average use (min)	349.3 ± 150.6
Change (min)	129.4 ± 124.3

EDSS, Expanded Disability Severity Scale; FES, functional electrical stimulation; min, minutes; MS, multiple sclerosis.

Data Analysis

Descriptive statistics for demographic data and feasibility (ie, retention, acceptability, adherence) are presented as mean plus or minus SD or medians, as appropriate. The impact of FES was measured by the initial and combined orthotic effect. The initial orthotic effect was defined as the difference in walking without FES and with FES at baseline; the combined orthotic effect was defined as the difference between walking without FES at baseline and with FES after the 8-week intervention period.[16] The initial and combined orthotic effects are presented using mean change and 95% CI. Due to the exploratory nature of this case series, only participants who completed both assessments were considered for analysis. All analyses were performed in SPSS Statistics 28 (IBM Corp).

RESULTS

Twelve individuals were enrolled, and 11 completed the study (9 women and 2 men); 1 participant withdrew after 4 weeks of the study because of an unrelated health problem. Participants ranged in age from 33 to 63 years and were 50.6 ± 10.8 years old. Baseline characteristics of the participants in this study are further outlined in **TABLE 1**.

Feasibility

The use of telerehabilitation to remotely monitor and progress FES intervention was feasible, acceptable, and safe: 92% of participants completed the study (11/12) and 91% (10/11) of participants who completed the 10-item Telerehabilitation

TABLE 2. Results of Walking Tests and Patient-Reported Outcomes

		Initial orthotic effect		Combined orthotic effect	
Test	Baseline	Baseline with FES	Change (range)	Post training with FES	Change (range)
T25FW (m/sec)	1.03 ± 0.30	1.00 ± 0.30	−0.03 + 95% CI (−0.09 to 0.04)	1.23 ± 0.41	0.20 + 95% CI (.003-0.38)
2MWT (m)	113.1 ± 43.4	116.6 ± 44.7	3.52 + 95% CI (−0.78 to 7.83)	131.8 ± 48.9	16.7 + 95% CI (7.07-26.4)
TUG (sec)	11.2 ± 5.0	11.2 ± 5.1	0.002 + 95% CI (−0.85 to 0.86)	9.4 ± 3.8	−1.79 + 95% CI (−3.26 to −0.31)
Avg weekly steps with FES	—	2131.1 ± 915.7	—	3668.8 ± 1878.1	1537.7 + 95% CI (741.6-2333.9)
MSWS-12	70.3 ± 23.4	—	—	56.1 ± 28.3	−14.2 + 95% CI (−29.0 to 0.59)
MFIS-5	10.6 ± 4.3	—	—	9.7 ± 4.9	−0.91 + 95% CI (−2.45 to 0.64)
MSIS-29	79.2 ± 24.2	—	—	69.2 ± 21.7	−10.0 + 95% CI (−17.97 to −2.03)

2MWT, 2-Minute Walk Test; avg, average; FES, functional electrical stimulation; m, meter; MFIS-5, Modified Fatigue Impact Scale; MSIS-29, Multiple Sclerosis Impact Scale; MSWS-12, Multiple Sclerosis Walking Scale; sec, second; T25FW, Timed 25-Foot Walk test; TUG, Timed Up and Go.

Satisfaction Survey[21] reported being "more than satisfied" with the telerehabilitation sessions (Table 1). Adherence to the biweekly telerehabilitation sessions during the study was 100% (33/33 telerehabilitation sessions) for the 11 participants who completed the study, and there was an average increase in FES device wear-time of 129.4 ± 124.3 minutes from week 1 to week 8 of FES use. There was 1 noninjurious fall reported and it was determined to be unrelated to any study activities. No other adverse events were reported.

Functional Mobility

There was no initial orthotic effect on the T25FW (**TABLE 2**). There was an initial orthotic effect on the 2MWT (Table 2) and TUG exceeding the MIC for 18% (2/11) and 55% (6/11) of participants, respectively. Five out of 11 (45%) participants demonstrated a combined orthotic effect with FES on the T25FW exceeding the MCID (Table 2). Fifty-five percent (6/11) and 82% (9/11) of participants demonstrated a combined orthotic effect with FES exceeding the MIC on the 2MWT (Table 2) and TUG, respectively. Eighteen percent (2/11) of participants required assistive devices (ie, 4-wheeled walker) during functional mobility testing and maintained the same level of assistive device use throughout the duration of the study. Individual participant data for the T25FW and 2MWT data can be found in **TABLE S2** and **TABLE S3**, respectively.

Step Count

Remote step count data were available for 10 participants during FES use (**TABLE S4**). There was an average increase in weekly step count of 1537.7 ± 1185.1 steps (Table 2) from week 1 to week 8 of FES use. A comparison to the MCID for daily step count was not possible given the limited amount of time that step data were recorded (ie, during FES device use).[32]

Self-Reported Measures

There were improvements at study completion exceeding the MCID for 64% (7/11) on the MSIS-29 and 36% (4/11) on the MSWS-12 (Table 2). There were no clinically meaningful improvements observed in fatigue (Table 2). Individual participant data for all self-reported measures can be found in **TABLE S5**.

DISCUSSION

Eight weeks of FES training monitored and advanced remotely through telerehabilitation was feasible, acceptable, and showed an overall positive impact on functional mobility and QOL in this case series of 11 participants with MS.

To our knowledge, this is the first study utilizing telerehabilitation-assisted delivery of FES. This novel use of telerehabilitation was feasible, safe, and practical as highlighted by high adherence and participant satisfaction. The majority of participants in the present study demonstrated a mean increase in wear-time of the FES device from week 1 to week 8, indicating the relative usability of the device. This is an important finding, as other researchers have highlighted several barriers to FES use in people with MS.[12,13] Squires et al[33] found that factors related to a supportive environment played a significant role in predicting long-term use of assistive technology. Building upon this, Miller Renfrew et al[13] identified that access to professional help and the support of caregivers were crucial in facilitating use of FES. Telerehabilitation offers physical therapists a means to address these barriers and promote a positive experience with FES, without requiring patients and caregivers to engage in additional in-person visits.[34] By mitigating some of the commonly encountered obstacles to FES, telerehabilitation may encourage increased usage and offset the higher cost of FES over a longer period of time.[35]

Due to the exploratory design of this case series, conclusions cannot be drawn regarding the efficacy of telerehabilitation-delivered FES on functional mobility and self-reported outcomes. Numerous studies[36,37] have found that the provision of behavioral interventions delivered remotely increased physical activity and reduced self-reported walking impairment in people with MS. Knowing this, it is possible that the improvements observed in the present study were attributable to the increased interaction between participants and the study

PRACTICE POINTS

The use of telerehabilitation to monitor a functional electrical stimulation (FES) intervention for people with foot drop due to multiple sclerosis (MS) was safe, feasible, and practical.

The results of this case series suggest that telerehabilitation-delivered FES may have a positive impact on walking and quality of life for people with MS and may mitigate commonly encountered obstacles to continuous FES use. ■

physical therapist, which may have been an impetus to be more physically active. Regardless of the mechanism, the growing body of evidence supporting the remote delivery of behavioral interventions to increase physical activity in people with MS may be translatable to FES delivery by providing patients with necessary skills to promote a specific behavior change (eg, FES use).

The current study did not demonstrate initial orthotic effects on the T25FW. While there are mixed results in the literature on the initial orthotic effects of FES in people with MS,[11,35,38] 9 of 15 studies included in a recent systematic review and meta-analysis found significant initial orthotic effects on short walking tests.[10] One explanation for the variability across these results could be the higher average baseline walking speed of the participants in this case series (1.03 ± 0.30 m/s) compared to those included (0.69 ± 0.03 m/s) in the aforementioned review.[10] It is possible that individuals who walk faster may take longer to see benefit from the use of FES, as these individuals may have less marked gait abnormalities and may not experience an immediate impact compared with those with more significant disability. Barr et al[39] found similar results in an MS cohort, where participants with an average gait speed of 1.18 m/s did not demonstrate initial orthotic effects, but demonstrated significant combined orthotic effects after 8 weeks of FES use. Our results extend these findings by demonstrating that individuals with a faster baseline gait speed (> 0.8 m/s) and mild disability can also benefit from FES and highlight the importance of a training period to facilitate improvements in gait performance. The improvements observed in the present study were comparable to those reported in previous literature supporting the positive effects of FES on short[10] and long walking tests[40] in people with MS.

An important finding in this case series was the changes on patient-reported outcomes. The scores on the MSIS-29 indicate the intervention may have had positive effects on QOL. Previous studies using FES in people with MS demonstrate conflicting results regarding the impact on QOL (using the MSIS-29).[40,41] Downing et al[41] studied a 2-week FES intervention which yielded significant improvements in QOL, whereas a 12-week FES intervention in a study by van der Linden et al[40] did not. Our findings show improved QOL over an 8-week period of FES use, contrasting previous results from longer FES intervention periods,[40] during which people with MS may be more likely to experience symptom fluctuations. There are a few possible explanations for our results. First, the use of FES may have provided a physical and psychological benefit, in which participants could walk faster with less concern about their foot drop. This may have led to increased motivation and confidence to participate in meaningful activities that center around ambulation. Indeed, we saw some preliminary evidence of this as participants modestly increased their weekly step count from week 1 to week 8 of FES use. It is also plausible that the telerehabilitation component of this study contributed to the positive QOL improvements. Self-management interventions are increasingly being used and have demonstrated a positive impact on managing MS-related symptoms.[42] The telerehabilitation sessions used in this study may have fostered the development of self-management strategies with the FES device, which could have led to a sense of empowerment and increased confidence in its usage. If participants feel competent in navigating the common challenges to FES use, they may be more likely to utilize the device and garner the benefits associated with a training period.

A small group of participants (36%) demonstrated clinically meaningful improvements on the MSWS-12, which suggests these individuals experienced a positive effect from the intervention on self-perceived effects of MS on walking ability. The lack of improvement in the other participants is in line with previous literature with FES intervention periods greater than 2 weeks, which failed to show improvements on the MSWS-12.[40] It is possible the MSWS-12 is not as responsive as other outcomes to detect changes in walking-related function across participants with a broad range of disability levels.[43]

While reductions in energy cost of walking and perceived exertion with FES use have been previously reported,[40,44] we observed no changes in self-reported fatigue. A limitation of the current study was the measurement of fatigue using solely the MFIS-5 before and after the intervention, which provided narrow insight into the multidimensional nature of fatigue and did not capture changes in performance fatigue or fatigability.[45] Future studies may consider increasing the frequency of self-reported fatigue measures and ecologically valid activity monitoring using wearable devices to further elucidate the impact of FES use on fatigue and fatigability.[46]

This study has several limitations. Due to the feasibility nature of this case series and small sample size, the results should be interpreted cautiously. There was no comparison

group and so it is not known if telerehabilitation-delivered FES intervention was the cause of the change or if it is superior to a traditional, in-person approach. Potential bias may have been introduced as no blinding was performed; the same member of the study team conducted the telerehabilitation sessions as well as the study outcome tests. Furthermore, the FES intervention period in this study was 8 weeks, which varies from other studies investigating FES in MS, and this may limit the ability to compare the effects of FES dosing needed to produce meaningful change in functional mobility and QOL measures. Lastly, while the virtual mode of FES delivery was feasible with high adherence, future studies with qualitative thematic analysis and a longer follow-up period are needed to determine which aspects of the telerehabilitation sessions are most useful, and if this can reduce the high levels of assistive device abandonment in people with MS.

CONCLUSIONS

The results of this study demonstrate the feasibility of using telerehabilitation to monitor and advance an FES intervention for people with MS. Eight weeks of FES training with 3 telerehabilitation visits had positive effects on functional mobility and QOL. Further research is needed to compare FES training delivered in-clinic versus remotely via telerehabilitation to determine which method is superior in improving mobility outcomes and adherence to FES use, and which is preferable to individuals with MS. Investigation of optimal dosing for FES training is also needed to guide clinicians in prescription of this intervention. ■

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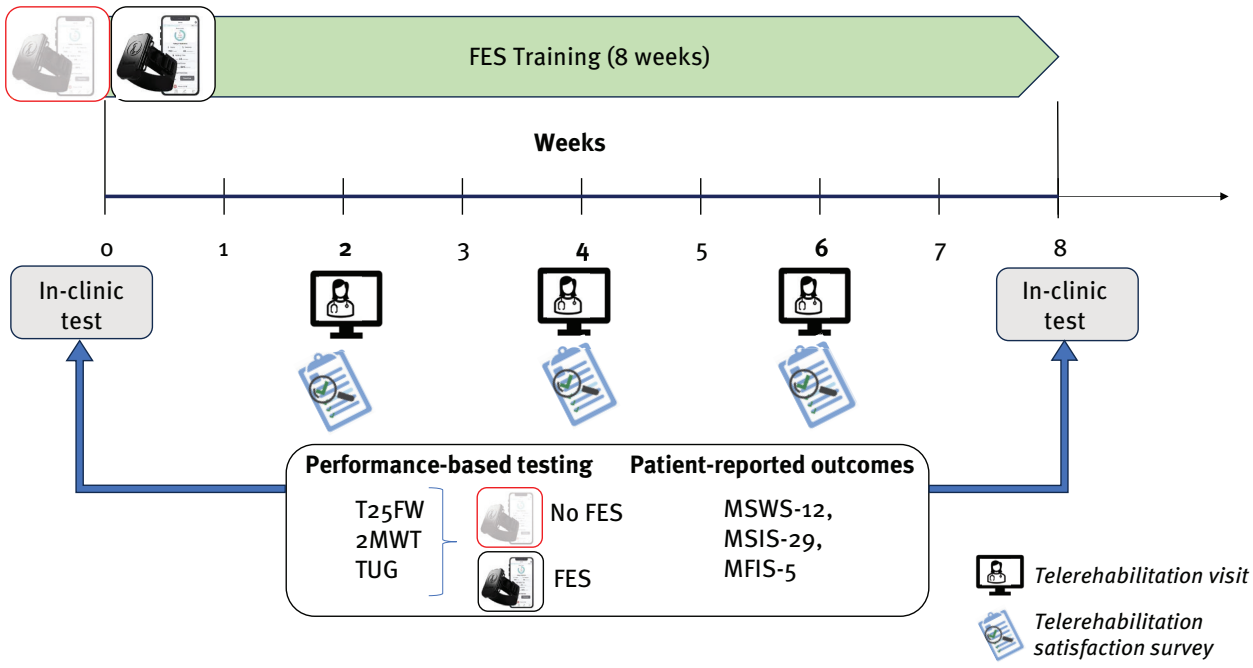
FIGURE S1. Overview of Study Activities



2MWT, 2-Minute Walk Test; FES, functional electrical stimulation; MFIS-5, Modified Fatigue Impact Scale; MSIS-29, Multiple Sclerosis Impact Scale; MSWS-12, Multiple Sclerosis Walking Scale; T25FW, Timed 25-Foot Walk; TUG, Timed Up and Go.

Note: Participants completed in-person testing at baseline and study completion, which consisted of performance (ie, T25FW, 2MWT, TUG) and self-reported measures (ie, MSWS-12, MSIS-29, MFIS-5). Three telerehabilitation visits were utilized to monitor and advance FES use over the 8-week intervention period.

TABLE S1. Participant Baseline Characteristics, Acceptability, Satisfaction

	EDSS	Age	Sex	MS type	Satisfaction with telerehabilitation[21]
1	5	35	F	RRMS	Very satisfied
2	5	58	F	RRMS	Very satisfied
3	6	60	M	SPMS	More than satisfied
4	6.5	57	F	RRMS	More than satisfied
5	4.5	52	F	RRMS	Satisfied
6	2.5	63	F	RRMS	Very satisfied
7	4.5	57	F	RRMS	Very satisfied
8	3.5	36	F	RRMS	Very satisfied
9	2	51	F	RRMS	More than satisfied
10	6	33	M	RRMS	More than satisfied
11	3.5	54	F	PPMS	Very satisfied

Note: All listed participants completed all 3 telerehabilitation sessions.

EDSS, Expanded Disability Status Scale; F, female; M, male; MS, multiple sclerosis; PPMS, primary progressive MS; RRMS, relapsing remitting MS; SPMS, secondary progressive MS.

TABLE S2. Participant Results of T25FW

		Initial orthotic effect		Combined orthotic effect		
	Baseline (m/s)	Baseline with FES (m/s)	Change (m/s)	After training with FES (m/s)	Change (m/s)	Exceeded MCID[6]
1	1.11	1.09	−0.02	1.26	0.15	
2	0.95	0.83	−0.12	0.94	−0.01	
3	0.61	0.48	−0.13	0.39	−0.22	
4	0.65	0.58	−0.07	0.91	0.26	✓
5	0.87	0.83	−0.04	1.11	0.24	✓
6	1.31	1.44	0.13	1.67	0.36	✓
7	1.02	1.05	0.03	1.11	0.09	
8	1.19	1.15	−0.04	1.30	0.11	
9	1.05	1.19	0.14	1.89	0.84	✓
10	1.15	1.03	−0.12	1.49	0.34	✓
11	1.39	1.34	−0.05	1.46	0.07	

FES, functional electrical stimulation; m, meter; MCID, minimal clinically important difference; s, second; T25FW, Timed 25-Foot Walk Test.

TABLE S3. Participant Results of the 2MWT

		Initial orthotic effect			Combined orthotic effect		
	Baseline (m)	Baseline with FES (m)	Change (m)	Exceeded MIC[23]	After training with FES (m)	Change (m)	Exceeded MIC[23]
1	122.6	123.8	1.2		142.6	20	✓
2	81.7	79	−2.7		87.47	5.77	
3	48.8	46.9	−1.83		43.28	−5.52	
4	67.4	71.93	4.5		104.8	37.4	✓
5	93.0	89.9	−3.1		N/A	N/A	
6	166	176.1	10.1		187.2	21.2	✓
7	105.5	117.6	12.1	✓	113.2	7.7	
8	109.8	124.4	14.6	✓	144.2	34.4	✓
9	197	193.6	−3.4		214.9	17.9	✓
10	105	107	2.0		128.3	23.3	✓
11	147.2	152.5	5.3		152.4	5.2	

2MWT, 2-Minute Walk Test; FES, functional electrical stimulation; m, meter; MIC, minimal important change.

TABLE S4. Participant FES Wear-Time and Step Count

	Week 1 avg FES use (min)	Week 8 avg FES use (min)	Change (min)	Week 1 avg steps with FES	Week 8 avg steps with FES	Change (steps)
1	183	239	56	1682	4350	2668
2	383	518	135	1811	3062	1251
3	229	170	−59	1775	2307	532
4	329	443	114	1456	2310	854
5	324	448	124	759	2064	1305
6	191	471	280	3445	6636	3191
7	N/A	N/A	N/A	1684	1165	−519
8	138	445	307	2147	4288	2141
9	N/A	N/A	N/A	3277	6477	3200
10	106	94	−12	3631	5391	1760
11	96	316	220	1775	2307	2668

Avg, average; FES, functional electrical stimulation; min, minutes; N/A, data not available.

TABLE S5. Participant PROM Results

	MSWS-12 baseline	MSWS-12 post intervention	Change	Exceeded MIC[25]	MFIS-5 baseline	MFIS-5 post intervention	Change	MSIS-29 baseline	MSIS-29 post intervention	Change	Exceeded MCID[28]
1	95.8	31.3	−64.6	✓	17	14	−3	126	102	−24	✓
2	70.8	79.2	8.3		10	10	0	63	66	3	
3	100	100	0		14	16	2	85	93	8	
4	85.4	81.3	−4.2		14	16	2	104	93	−11	✓
5	81.3	79.2	−2.1		6	9	3	83	75	−8	✓
6	41.7	37.5	−4.2		6	5	−1	61	54	−7	
7	52.1	29.2	−22.9	✓	4	1	−3	48	38	−10	✓
8	87.5	45.8	−41.7	✓	14	12	−2	94	62	−32	✓
9	39.6	16.7	−22.9	✓	7	4	−3	62	42	−20	✓
10	81.25	81.25	0		14	11	−3	93	83	−10	✓
11	37.5	35.4	−2.1		11	9	−2	52	53	1	

MCID, minimal clinically important difference; MFIS-5, Modified Fatigue Impact Scale; MIC, minimal important change; MSIS-29, Multiple Sclerosis Impact Scale; MSWS-12, Multiple Sclerosis Walking Scale; PROM, patient-reported outcome measure.