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REVIEW ARTICLE

Is Functional Electrical Stimulation Effective in improving Gait in People with Multiple Sclerosis? A Systematic Review

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ABSTRACT

Introduction: One of the reasons for difficulty with walking in people with multiple sclerosis (PwMS) is foot drop; the inability to dorsiflex the ankle during the swing phase of the gait. One approach to correct foot drop is to passively support the ankle joint with an ankle foot orthosis (AFO) or a foot up splint. Another approach is to use functional electrical stimulation (FES).

Objective: Is FES effective in improving gait in people with foot drop due to multiple sclerosis (MS)?

Materials and methods: AMED, EMBASE, BNI, MEDLINE, and CINAHL were searched. Meta-analysis, randomized control trials (RCTs) and non-RCTs, and case series involving investigating FES for foot drop in PwMS were reviewed. Conference abstracts, non-English articles, expert opinions, and FES for other indications were excluded. Full texts of the articles were reviewed by two authors independently using the Physiotherapy Evidence Database (PEDro) scale. The strength of evidence was graded from 1 to 5.

Results: Among the 172 results, we excluded 130 after reading the titles (duplicates, articles not in English, and articles on use of FES for indications other than foot drop). After reviewing the abstracts, we excluded further 27 (conference presentations, opinions, and reviews). The PEDro scores of the articles varied between 3 and 7. None of the studies blinded the participants and only one study used blinded assessors. Two RCTs and one meta-analysis found an orthotic effect of FES causing improvement in speed of walking by 0.05 to 0.08 m/s. Two RCTs reported 73 to 83% reduction in number of falls. There were no RCTs comparing effect of FES with AFO in this cohort.

Conclusion: There is level-1 evidence that the FES increases speed of walking through an orthotic effect. There is level-2 evidence that it reduces number of falls in PwMS. Further appropriately powered multicenter studies are required to assess the comparison of FES with AFO in this cohort.

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INTRODUCTION

Multiple sclerosis is an inflammatory disease causing demyelination of the central nervous system. It is the most common progressive neurological condition affecting young adults with a prevalence of 100 to 120 in every 100,000 adults in the United Kingdom. Only 18% of the PwMS were able to walk for 10 m without limping.[1] In a survey on perceptions of body functions, PwMS gave highest priority to lower limb functions.[2]

One of the reasons for difficulty with walking in PwMS is foot drop; the inability to dorsiflex the ankle during the swing phase of the gait. One approach to correct foot drop is to passively support the ankle joint with an AFO or a foot up splint. Another approach is to use FES. The FES has a heel-switch worn in the patient's shoe, positioned under the heel. This switch activates electrodes placed over the common peroneal nerve at the head of the fibula during the swing phase. Stimulation will cause dorsiflexion of the ankle and foot clearance. This device enables patients with foot drop due to MS to walk without tripping. The FES is approved by NICE for correcting foot drop in upper motor neuron conditions like MS. A meta-analysis of trials in patients with stroke showed that FES improved walking speed by 38%.[3] Patient compliance with FES is 86%.[4] The effects of FES on gait are: the orthotic effects (change in walking with and without FES) and therapeutic effects (the effect of regular use of FES on walking performance without FES).

Given the potential for FES to improve mobility for PwMS and provide a cost-effective alternative to the current standard care, there is need for a comprehensive review of evidence of this intervention. This systematic review evaluated the evidence on use of FES to correct foot drop in PwMS. The question for the systematic review was: "How effective is FES in improving gait in PwMS?"

MATERIALS AND METHODS

We aimed to include all published RCT, non-RCTs, and case series exploring the effectiveness of FES on gait of PwMS. We included the studies with participants more than 18 years of age with foot drop due to MS and used FES as one of the interventions. We included the studies using walking-related outcome measures, such as speed of walking, falls, gait analysis, and energy expenditure for walking. Only studies published in English were included as we did not have funding for obtaining translations from other languages.

Search Strategy

Databases searched were AMED, EMBASE, BNI, MEDLINE, and CINAHL from 2005 till June 2015. The keywords used were shown in Table 1.

Screening for Inclusion

We initially screened the titles of all search results and excluded repeated results, articles dealing with use of FES for indications other than foot drop, conference abstracts, and articles in languages other than English. Abstracts of the relevant articles were obtained and read. We further excluded nonsystematic reviews, expert opinions, editorials, and technical reviews. We obtained the full text of all the articles dealing with FES for foot drop.

Evaluation of the Evidence

Two reviewers read all the full-text articles independently and assessed the quality of the studies using the Physiotherapy Evidence Database (PEDro) scale.[5] Two reviewers then met and discussed the scores. The final scores were obtained in this meeting through consensus

Table 1: Keywords used in searching the databases

Multiple sclerosis
Foot drop
Gait
Walking
Functional electrical stimulation
Exercises
Physiotherapy
Ankle foot orthosis
Foot up splint
Speed of walking
Energy expenditure for walking
Physiological cost index
Falls

Table 2: Hierarchy of evidence

1	Systematic review of multiple well-designed systematic randomized controlled trials (the "gold standard")
2	A properly designed RCT
3	Well-designed trials without randomization
4	Well-designed non-experimental studies
5	Opinion of respected authorities, descriptive studies or reports of expert committees

between the two reviewers. Studies with PEDro score of <4 were classified as poor in quality and were excluded.[6] The strength of the evidence was classified from 1 to 5 based on the Muir's hierarchy of the evidences shown in Table 2.[7]

RESULTS

From the search 172 articles were identified (Flow Chart 1). We excluded 130 results after reading the titles (duplicate results, not in English, on FES cycling, FES for improving muscle bulk, and FES for swallowing). Forty-two abstracts were reviewed and a further 27 were excluded (conference abstracts, nonsystematic reviews, opinions). Full texts of 15 articles were obtained and 13 were analyzed using the PEDro scale. The scores could not be done for a study using focused interviews.[8] There were three RCTs, eight non-RCTs, one large retrospective case series, two case series, and one meta-analysis.

The PEDro scores of the 13 articles varied from 3 to 11 (Table 3).[9-21] The reasons for the low scores on PEDro scale were a lack of randomization-12, absence of concealed

Flow Chart 1: Process for selection of articles for the review

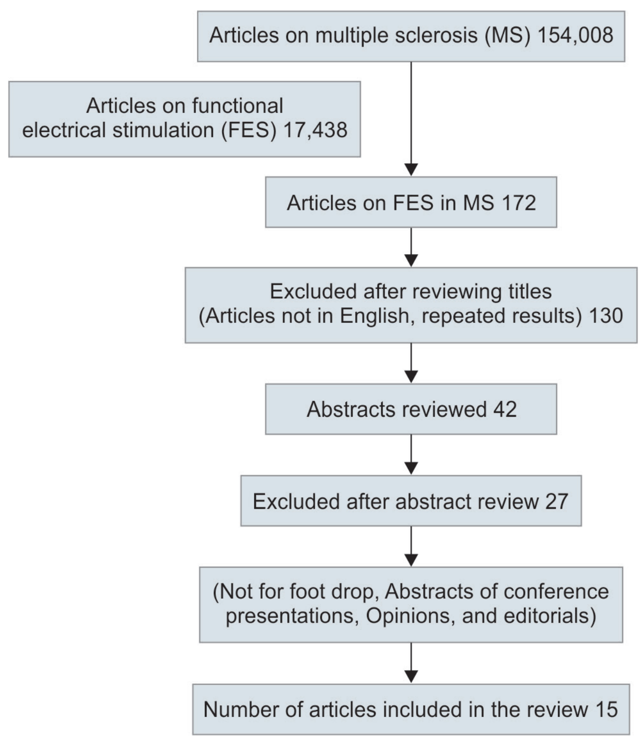

Table 3: PEDro scores of the articles reviewed

Authors	*Eligibility*	*Randomization*	*Concealed allocation*	*Similar groups*	*Blind subjects*	*Blind therapist*	*Blind assessors*	*Drop out <15%*	*Intention to treat*	*Between-group comparisons*	*Treatment effect*	*PEDro score 0–11*
Paul et al[9]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Barrett et al[10]	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	6
Esnouf et al[11]	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	7
Sheffler et al[12]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Sheffler et al[13]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Wahl et al[14]	Yes	No	No	No	No	No	No	Yes	No	No	Yes	3
Scott et al[15]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Taylor et al[16]	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	7
van der Linden et al[17]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Downing et al[18]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
van der Linden[19]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Street et al[20]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Mayer et al[21]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Miller et al[22]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	5

allocation-12, not blinding subjects-13, not blinding therapist-13, not blinding assessors-12, and not performing intention-to-treat analysis-13 (Table 3). One article with PEDro score of <4 was excluded from further analysis.[14]

The outcome measures used in these studies were speed of walking,[9,10,13,15-19,21-23] activities of daily living,[11] energy expenditure for walking,[9,22] qualitative interviews,[8] gait analysis-4,[12,15,17,19] and patient reported outcome measure-1.[18]

Speed of Walking

The search revealed two RCTs on FES for foot drop in PwMS with an orthotic effect on speed of walking.[10,15] Barrett et al[10] compared the therapeutic effects of FES and a home exercise program on walking speed of PwMS. They noted a 0.05 m/s improvement in gait speed on walking with FES. While walking without FES, the exercise group showed a statistically significant increase in walking speed relative to the FES group.[10] There is no evidence that the FES has a therapeutic effect on speed of walking. Taylor et al reported a 0.07 m/s improvement in walking speed with FES. A meta-analysis of 20 studies (RCTs, non-RCTs, and case series) involving 490 patients noted that use of FES improved speed of walking by 0.05 to 0.08 m/s through an orthotic effect.[23] There is level-1 evidence on effectiveness of FES as an orthotic device in improving speed of walking.

Energy Expenditure of Walking

Two non-RCTs investigated the physiological cost of walking in PwMS.[9,22] The use of FES led to a significant reduction in the physiological cost of gait. These studies provided level-3 evidence that FES improves energy expenditure for walking in PwMS. A qualitative study by Bulley et al[8] also found that patients reported reduced fatigue and falls with FES.

Gait Analysis

Scott et al[15] found that FES increased dorsiflexion at ankle, knee flexion, and reduced risk of knee hyperextension at initial contact (level-3). van der Linden et al[17,19] showed longer stride length and better dorsiflexion of ankle during swing with FES (level-3). There is level-3 evidence that FES improves kinematics of gait, especially ankle dorsiflexion (Table 4).[15,17,19]

Falls

Barrett et al[10] in an RCT found that participants in the FES group experienced 72% fewer falls than in the control group (level-2). Esnouf et al[11] also reported that the median number of falls was significantly lower (p = 0.036) in FES

Table 4: Summary of the evidence

Study	*Sample size*	*Design*	*Intervention/Comparator*	*Duration*	*Outcome measures and results*
Bulley et al[8]	10	Non-RCT qualitative study	FES/AFO n = 4	Variable	Focused interviews on fatigue, satisfaction with gait trips and falls
Paul et al[9]	12	Non-RCT	FES/No intervention	Immediate	Speed of walking improved by 0.06 m/s
					Physiological cost of walking improved by -0.05 mL $min^{-1}kg^{-1}m^{-1}$
Barrett et al[10]	44	RCT	FES/Physiotherapy	18 weeks	Speed of walking FES improved by 0.07 m/s
					Distance walked in 3 min improved by 13 m
Esnouf et al[11]	53	RCT	FES/Physiotherapy	18 weeks	Canadian Occupational Performance Measure improved by 1.1
					Mean number of falls reduced by 13
Sheffler et al[12]	4	Non-RCT	FES/AFO	Immediate	Number of subjects with significant ankle of dorsiflexion = 3
Sheffler et al[13]	11	Non-RCT	FES/No intervention	Immediate	Timed 25 feet walk: No change
					Stair component of modified Emory Functional ambulation profile improved by 1.04
Scott et al[15]	12	Non-RCT Before/After	FES/No intervention	Immediate	Ankle dorsiflexion improved by 5.3°
					Time to walk 10 m improved by 0.6 s
Taylor et al[16]	28	RCT	FES/Physiotherapy	6 weeks	Walking speed improved by 0.07 m/s
					Rivermead Observational Gait Analysis (ROGA) score improved by –1
van der Linden et al[17]	9	Non-RCT Before/After	FES/No intervention	12 weeks	Speed of walking improved by 0.06 m/s
					Dorsiflexion at ankle improved by +3.4°

group compared to the exercise only group (level-2). In a cross-over trial, Taylor et al[16] noted that 83% of falls experienced over the study period occurred at times when FES was not being used (level-2). Bulley et al[8] did a qualitative study to explore the impact of FES (n = 6) and AFO (n = 4) on PwMS. Participants of the focus groups described fewer falls for both FES and AFO (level-4). There is level-2 evidence that FES reduced falls in PwMS (Table 4).

Activities of Daily Living

Esnouf et al[11] studied the impact of FES on activities of daily living in 53 PwMS. Authors noted greater "improvements" in performance and satisfaction scores in the FES group than the exercise group. They concluded that the "use of the FES improved performance in activities of daily living PwMS (level-2)."

Quality of Life

Two non-RCTs reported that FES reduced the impact of MS and improved quality of life of PwMS (Table 3).[18,21]

Comparison of FES with AFO

There are three studies comparing AFO and FES for PwMS. Sheffler et al found that in three out of four subjects, FES resulted in more dorsiflexion at ankle compared to AFO. There were no differences in the speed of walking (level-3).[12] Street et al[20] noted that among 67 PwMS who were using FES, 27 had tried and rejected AFOs. Bulley et al[8] did a qualitative study to explore the impact of FES (n = 6) and AFO (n = 4) on PwMS. Participants of the focus groups described similar positive effects for both FES and AFO.

Cost-effectiveness of FES

One study with a sample of 39 PwMS demonstrated cost effectiveness, but has applied the same quality-adjusted life-year (QALY) gain from stroke for MS. The authors assumed that the QALY gain for MS is the same as in stroke. There are no other studies on the cost effectiveness of AFO.[24]

DISCUSSION

The PEDro scores of the studies included were low. Only three studies randomized the participants.[10,11,16] All three were from the same center, making it difficult to generalize the results to other centers. None of the studies blinded the participants. Only one study used partly blinded assessors.[16] None of the studies used intention-to-treat analysis. More than 15% of the recruited patients dropped out in two of the three RCTs.[10,11]

Two RCTs provided level-2 evidence that speed of walking with FES was significantly better than the speed of walking without FES in PwMS.[10,16] The speed of walking with and without FES was a secondary outcome measure in one trial.[10] The other one was a feasibility trial and was not designed to calculate the effect of the interventions. The trial also used multiple interventions which may have had a carry-over effect.[16] Five non-RCTs also reported that FES increased speed of walking in PwMS in a clinical setting.[9,12,18,19,21] A large pragmatic study reflecting the routine clinical use of FES in PwMS also reported significant. The two major limitations of this study are the lack of randomization and absence of a control group.[20] There is level-2 and level-3 evidences that FES work as an orthotic device in clinical settings (Table 4). There is level-2 evidence that it does not have a therapeutic effect (without switching on the stimulation) on speed of walking (Table 4). Most of these studies did the assessments in a clinical setting and may not reflect the effect of FES in daily life.

In PwMS walking is more effortful and has a higher energy cost. There was evidence from one non-RCT that FES reduces energy expenditure. This was also supported by a qualitative study on effect of FES and AFO on gait. However, there was no significant differences between the patient reported fatigue between FES and AFO.[8]

Gait analysis involves recording different aspects of gait like the force of movement, range of movements, and pattern of muscle activation using force plates, video cameras, and ambulatory electromyography. This offers advantages in assessing therapies which aim to improve gait function. There is level-3 evidence from four non-RCTs that FES improves kinematics of gait, especially ankle dorsiflexion (Table 4).

Three RCTs used number of falls as a secondary outcome measure[10,11,16] and noted significant reduction in falls with FES. A qualitative study also reported the patient perception of safety and less trips and falls with FES. A large case series also noted similar effect.[20] There were no studies using falls as a primary outcome measure. Overall, there was level-2 and level-3 evidences that FES reduce number of falls and improve safety of walking in PwMS. There is evidence from a single RCT that FES improved activities of daily living in PwMS.[11] The study did not use blind participants or assessors.

A key question for any intervention concerns comparison with other available technologies. Is FES better than standard orthotic devices, such as AFO and foot up splint for correcting foot drop in PwMS? There were no RCTs comparing FES with current standard orthotic interventions for foot drop in PwMS. There were only two small non-RCTs which are gait lab based and a qualitative study on patient perceptions comparing FES and AFO; none of which did not find any significant difference between FES and AFO.[8,12,15] There were no RCTs comparing AFO and FES in PwMS.

There is one study on cost effectiveness of FES on PwMS. This study has applied the same QALY gain from stroke for MS and demonstrated cost effectiveness.[23] However, this makes the assumption that the QALY gain for MS is the same as in stroke. There were no studies on the cost effectiveness of AFO.

CONCLUSION

This review found level-1 evidence that FES has an orthotic effect on speed of walking and level-2 evidence that it reduces falls in people with foot drop due to MS. Most of the studies on FES were done in gait laboratories and used laboratory-based outcome measures like speed of walking and energy expenditure which do not reflect the patients' experience with the use of FES in the community. There is no evidence that FES is better than AFO. Given the potential for FES to improve mobility for PwMS and provide a cost-effective alternative to current standard care, there is an urgent need for a comprehensive trial for this intervention. An adequately powered multicenter RCT in order to evaluate this technology and compare FES with current standard care (AFO/foot up splint) is required. The trial should use a mixed method design incorporating a comprehensive range of measures, including patient reported outcome measures, physical activity monitoring, and cost effectiveness.

Key Practice Points

In PwMS and foot drop:
- FES has an orthotic effect on speed of walking.
- FES has no therapeutic effect on speed of walking
- FES reduces number of trips and falls and improves activities of daily living

There is only weak evidence on cost effectiveness of FES.

There is no evidence that FES is better than AFO

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