EFFECTS OF FUNCTIONAL ELECTRICAL STIMULATION IN MYOTONIC DYSTROPHY TYPE I

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INTRODUCTION

Foot drop due to the progressive force decline of tibialis anterior muscle is one of the most significant factor for the increased risk of falls in Myotonic Dystrophy type I (DM1).[1] Tibialis anterior is the most affectected muscle with a 12% mean force decrease in 5 years vs 5-8% in the other muscle groups.[2] So far, DM1 is missing restorative interventions able to counteract ankle dorsiflexors weakness, especially in cases of severe involvement.[3] Functional Electrical Stimulation (FES) is a new rehabilitative approach and refers to the process of pairing the electrical stimulation with a functional task in persons unable to perform movements actively. [4]

AIM OF THE STUDY

To assess the efficacy of FES in improving tibialis anterior muscle strength, endurance and gait speed in DM1.

PATIENTS AND METHODS

DM1 inpatients were divided in two groups according to the rehabilitation training carried out.
Inclusion criteria: Age>18 ys; MIRS>2

Patient	*Sex*	Age (ys)	Disease Onset (ys)	MIRS	CTG Expansion Class	PM/Cancer/ Acute medical conditions
1	M	42	40	3	E2	-
2	M	67	53	4	E1-E2	-
3	M	40	23	3	E2	-
4	M	63	25	4	E2	
5	M	58	23	4	E2	PM
6	M	39	23	4	E2	Recent surgery for orbito-zygomatic fracture (accidental fall)
7	M	58	38	4	E1-E2	PM
8	F	40	19	4	E2-E3	Ovarian Cancer

Mean age 51±12 ys

FES Training Group (patients 1–4)

FES induced cycling training was performed for 30 minutes each day, for 3 weeks.

Resistance and Aerobic Training Group (patients 5–8)

Moderate isometric strength (30 minutes each day for six weeks) associated with aerobic training on a cycle ergometer (30 minutes daily session; speed 60% of the maximum heart rate)

Patients with Pacemaker (PM), suspected cancer, epilepsy and acute medical conditions did not receive FES training.

FES Training

Patients were seated on a chair in front of a motorized cycle ergometer (MOTOmed® viva2). Pedals were synchronized with a current-controlled 8 channels stimulator (Hasomed RehaStim2) in order to stimulate the extensors and flexors muscles of the knee as well as ankle dorsiflexors and plantarflexors muscles, bilaterally. The electrical stimulation was based on a rectangular waveform with the frequency of 30 Hz (pulse width of 200 μsec) with an intensity modulated as the minimum to elicit muscle contraction.

Outcome measures

The modified Medical Research Council (MRC) scale, the Six Minutes Walk test (6MWT), the time to cover 10 meters (10mWT) were used for the assessment at the baseline (T0) and at the end of the treatment (T1).

Muscle MRI

Muscle MRI was performed in the lower limbs at the baseline (T0) and at the end of the treatment (T1), using a 1.5T MR scanner (1.5T Philips Achieva). T1-weighted sequences and T2w images with fat saturation (SPIR) were acquired with the following parameters: field of view = 220x220 mm; voxel= 0.84x 1.31x5 mm; slices=40; thickness = 5 mm; reconstruction matrix= 528x528 voxels. The extent of fatty replacement was scored on T1w images using the scale published by Mercuri et al.[5]

ROI based MRI volume quantification of tibialis anterior percentage of fatty infiltration. Same baseline and post treatment sections of acquired axial T2-SPIR on tibialis anterior were visually-based selected. In both sections only left leg was then included in quantification process by cropping images using MRIcron tool. ROI were drown outlining a) the cross sectional area of the whole leg section b) the cross-sectional area of whole the tibialis anterior muscle. In order to avoid bias of section field disomogeneity on fat suppression quantification, the tibialis anterior muscle ROI was masked, thresholding low gray values at the minimum level that preserve leg section inclusion from foreground air noise. In order to avoid Field of View change and voxels partial volume effect bias between assessment on volume quantification, post-treatment volumes expressed in cc were normalized using cross sectional area of the whole leg section rate between post-treatment and baseline. Percentage of change between post-treatment and baseline was then calculated.

RESULTS

Muscle strength

	Patient	MRC Quadriceps (R/L)		MRC Hamstrings (R/L)		MRC Tibialis Anterior (R/L)		MRC Gastrocnemius (R/L)	
		T0	T1	T0	T1	T0	T1	T0	T1
FES training group	1	5/5	5/5	5/5	5/5	3-/3-	3/3	5/5	5/5
	2	5/5	5/5	4/4	4+/4+	3+/3+	4/4	3+/4	4+/4+
	3	5/5	5/5	5/5	5/5	3-/3-	3+/3+	5/5	5/5
	4	5/5	5/5	4-/4-	4/4	2/2	3-/3-	4/4	4/4
		T0 mean±SD	T1 mean (SD)	T1 vs T0#	ES(Cohen's d) *				
	Total MRC	4.13±1.02	4.34±0.78	p<0.01	0.23				
	Tibialis anterior MRC	2.67±0.50	3.25±0.32	p=0.01	1.38				
Resistance Aerobic Group	5	5/5	5/5	3/3	3/3	3/3	3/3	4/4	4/4
	6	5/5	5/5	4+/4	5/4	3+/4	3+/4	5/5	5/5
	7	4+/4+	4+/4+	4/4	4/4	2-/2-	2-/2-	4/4	4/4
	8	5/5	5/5	4-/4-	4-/4-	3+/3+	4/4	5/5	5/5
		T0 mean±SD	T1 mean (SD)	T1 vs T0#	ES(Cohen's d)				
	Total MRC	3.98±0.92	4.07±0.92	p=0.05	0.09				
	Tibialis anterior MRC	2.75±1.12	2.92±1.25	p=0.34	0.14				

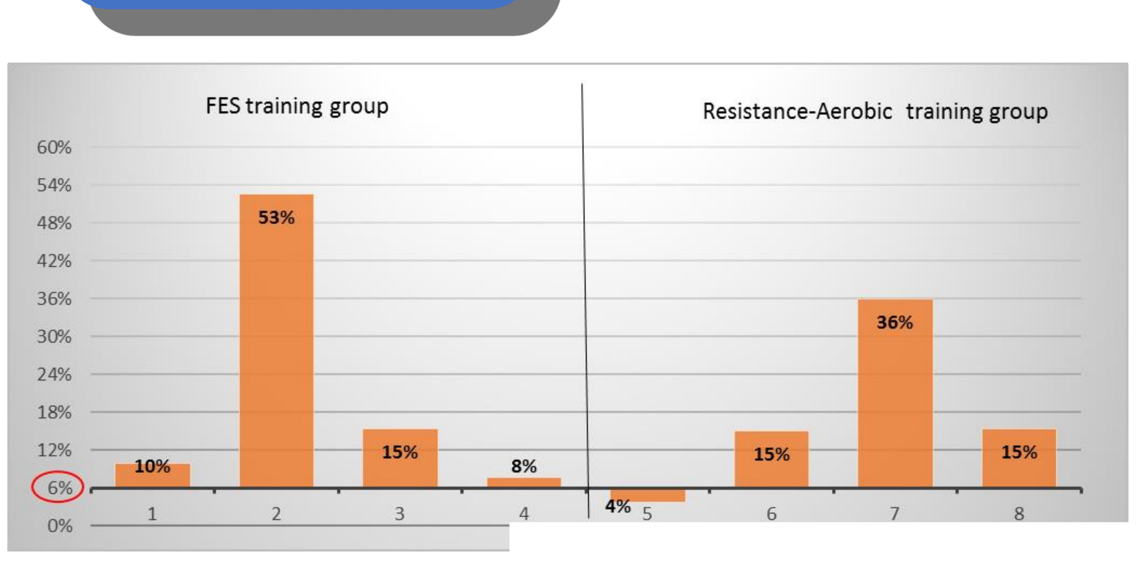
Note: # Wilcoxon non parametric paired sample test; * Cohen effect size; MRC: Medical Research Council Scale,

Table shows MRC scores at baseline (T0) and at the end of rehabilitation (T1).
A significant improvement of global muscle strength as well as tibialis anterior muscle strength was found only in the FES training group.

Between groups analysis

We detected a significant difference between the two training modalities in ameliorating tibialis anterior muscle weakness (p=0.005) with a mean percentage increase of 23% after FES and 5% after Resistance-Aerobic training.

6MWT

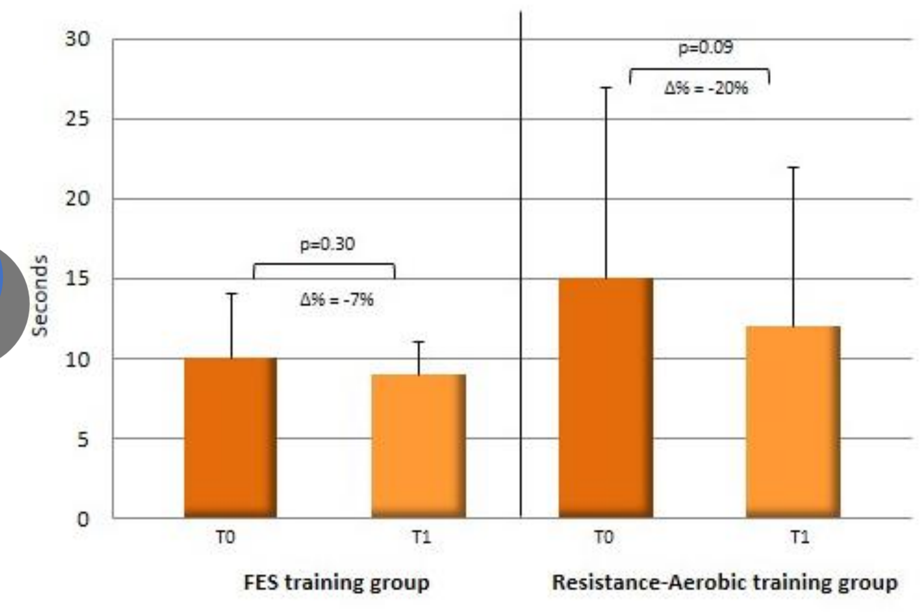


Histogram showing percent variation of the distance covered in six minutes by DM1 patients.

In the FES group we observed a 21% mean percent increase of the distance covered in 6 minutes, indicating a real efficacy of training. This result is indeed greater than 6%, the value under which a variation is considered expression of test-retest variability.

No significant difference has been found in the 6MWT between participants who performed FES and those who carried out aerobic training.

10 mWT



Histogram showing the mean time (seconds) required to cover 10 meters which did not changed significantly at the end of training.

Muscle MRI

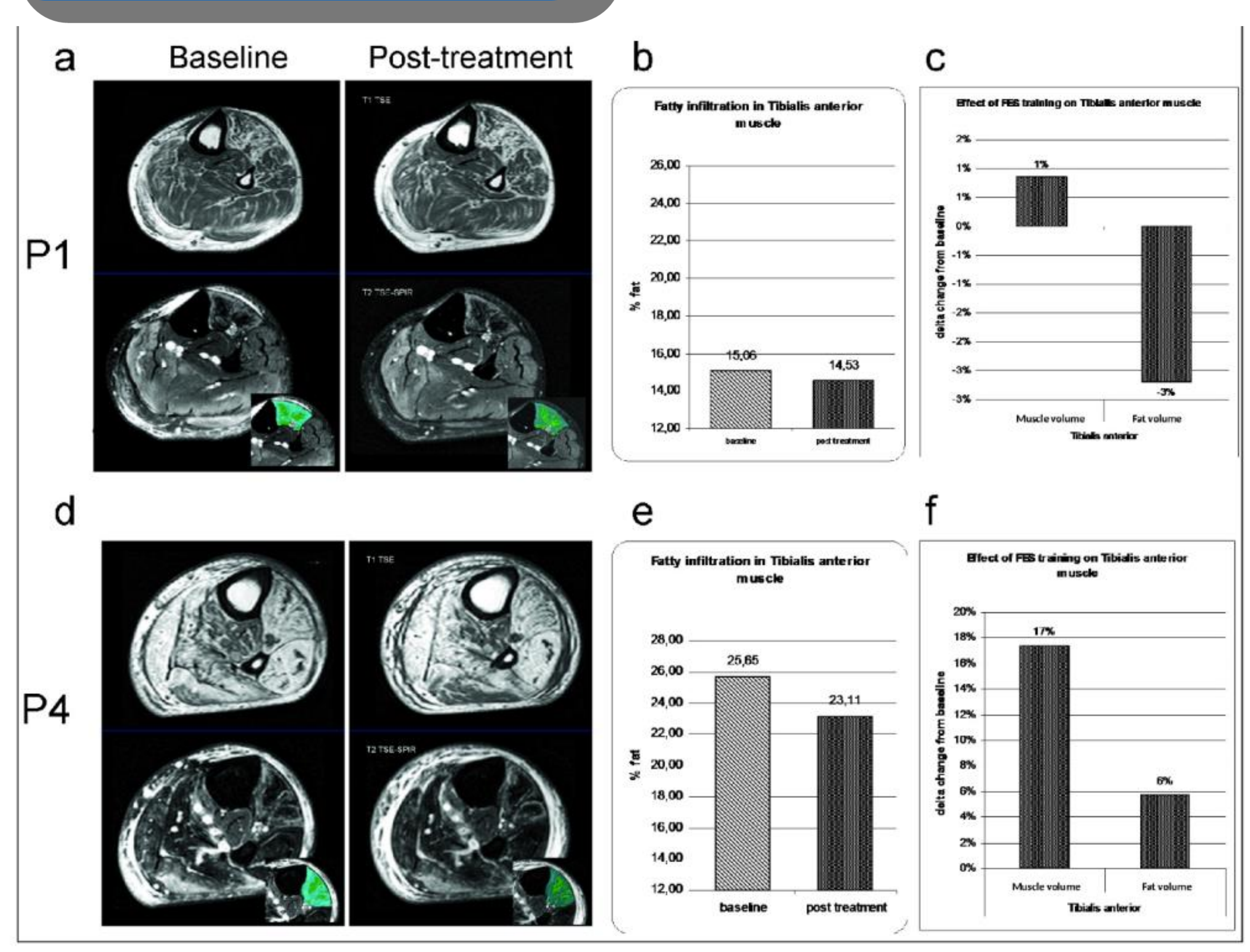


Fig. a-d *show T1 weighted - TSE and T2-TSE-SPIR images of the left leg of subjects 1 and 4, acquired at baseline and after 3 weeks of FES training.*
On T1-w sequences, the tibialis anterior muscle presented, before and after training, multiple areas of increased density, expression of stage 2b intramuscular fatty degeneration in patient 1 and stage 3 in patient 4, according to the Mercuri scale.

After 3 weeks of FES training, quantitative MRI analysis of the tibialis anterior showed a 1% and 17% muscle volume increase in patient 1 and in patient 4, respectively. The tibialis anterior fatty volume decreased by 3% in patient 1 and increased by 6% in patient 4 **(Fig. c-f)**. In summary, after 3 weeks of FES training, quantitative MRI study evidenced a reduction of intramuscular fatty infiltration (fat to muscle area ratio) of 0.53% in patient 1 and 2.54% patient 4 **(Fig. b-e)**.

CONCLUSIONS

FES can be considered a valid tool to improve endurance and muscle weakness in DM1, also in muscles more severely compromised in which no other restorative options are otherwise available.

The increment of the distance walked in six minutes without significant changes in the 10mWT might suggest a predominant effect of FES on type I-slow twitch muscle fibers, which are known to be selectively atrophic in DM1.

FES is safe and well tolerated. DM1 patients could maintain a good muscle function for longer time reducing therefore the risk of serious adverse events.

More extensive controlled trials are needed.

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