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ISSN

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Fast-velocity Resistance Training Improves Force Development and Mobility in Multiple Sclerosis

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Key words
neurodegenerative disorders, exercise, strength, neuromuscular

accepted 28.11.2021
published online 2021

Bibliography
Int J Sports Med
DOI 10.1055/a-1710-1492
ISSN 0172-4622

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Supplementary Material is available under https://doi.org/10.1055/a-1710-1492.

ABSTRACT

This study aimed to analyze the benefits of a lower-limb fast-velocity concentric resistance training on rate of force development, mobility, and quality of life in people with Multiple Sclerosis. A randomized controlled trial was conducted in 30 people with Multiple Sclerosis, who were randomly assigned to either an experimental (n = 18) or a control (n = 12) group. The experimental group carried out 10-weeks of fast-velocity concentric resistance training, while the control group did not perform any intervention. Early and late rate of force development during knee extension in both legs, sit-to-stand and Timed Up and Go tests and quality life questionnaire were evaluated before and after intervention. The training program evoked an increase in early rate of force development in experimental group (0–30; $Right_{leg}$: 63.9 %, $p < 0.001$; ES = -1.4; $Left_{leg}$: 52.7 %, $p < 0.001$; ES = -1.0) compared to control group (showed modest increases). Furthermore, experimental group improved mobility after training (Sit-to-stand: 22.2 %, $p < 0.001$; ES = 1.0; Timed Up and Go Test: 10.1 %, $p < 0.001$; ES = 1.1) and increased the perception of quality of life after training, while control showed no changes. The fast-velocity concentric resistance training has the potential to improve early rate of force development and mobility after 10-weeks of training. In addition, the increase in self-perceived quality of life following this training modality demonstrates promising results in the Multiple Sclerosis population.

Introduction

Multiple sclerosis (MS) is a progressive neurodegenerative disease that affects more than 2 million people worldwide and requires a multidisciplinary approach where physical exercise provides significant benefits [1]. Up until the end of the 20th century, exercise was discouraged in people with MS (pwMS), and its role in the rehabilitation process was controversial. Nowadays, it is clear that exercise is beneficial for pwMS, and the number of studies supporting this non-pharmacological strategy to improve the quality of life of MS patients is growing [2, 3].

It is known that the implementation of different training modalities, such as aerobic training, yoga, pilates or resistance training, have an impact on different physiological variables. Resistance training has a great capacity to improve the neuromuscular system without causing adverse effects, which makes it an appropriate type of exercise training for pwMS [4]. Moreover, resistance training has demonstrated moderate-to-high gains in muscle strength and mobility, two of the most common impaired abilities in MS patients [5]. Recently, it was suggested that resistance training that is specifically designed to exercise the concentric phase of movement at maximum voluntary speed (FVCRT) could improve neuromuscular performance, such as the rate of force development (RFD), in the general population [6]. In this context, a recent meta-analysis by Blazevich et al. [6] indicates that one of the most important factors in improving RFD during resistance training is performing the concentric phase of the exercises at maximum voluntary velocity. Following these recommendations, other authors have applied FVCRT in older people and have observed an enhancement in neural performance [7], although further research is necessary to confirm these findings [8]. In pwMS, the ability to produce force in short periods of time is weakened due to demyelination and lesions or plaques in the central nervous system that impede the transmission of high-speed nerve impulses [5]. Thus, FVCRT could play a beneficial role in increasing force development in the healthy nerves to help overcome the MS pathology.

Previous studies have shown a close relationship between RFD and different tasks of daily living [9, 10], such as getting up from a chair or maintaining balance while standing, which underlines the importance of applying a design-specific training for increasing RFD. Furthermore, physical exercise, and more specifically resistance training, improves the psychosocial profile (e. g. anxiety, depression or health-related quality of life) of patients with chronic progressive diseases, including MS [11, 12]. However, not all studies report such changes [13]. Thus, to our knowledge, no studies have examined the impact of a resistance training program based on RFD improvement in pwMS.

Therefore, we conducted a randomized clinical trial (RCT) with the following objectives: 1) to analyze the benefits of a 10-week lower-limb FVCRT on RFD in pwMS and 2) to examine the impact of FVCRT on mobility and quality of life. We hypothesized that FVCRT would increase RFD and mobility in pwMS and would have a favorable impact on their quality of life.

Materials and Methods

Study design and testing procedure

We conducted a single-blinded, RCT that consisted of a 10-week intervention. All evaluations were conducted at the same time of day to avoid different responses to circadian rhythm changes, and the temperature (21–22°C) and humidity (55–60 %) of the room were controlled. The study design adhered to Consort RCT guidelines (identifier: NCT04452760).

Participants

Thirty pwMS were recruited from the local MS association, and a board-certified neurologist diagnosed them with Relapsing-Remitting MS or Primary Progressive Multiple Sclerosis, based on the McDonald criteria. Using a 3:2 randomization table (3 participants to experimental group (EG), 2 participants to control group (CG)), pwMS were randomly assigned to either the EG or CG. PwMS had to be ambulatory (i. e., walk independently for more than 100 meters) and without exacerbations in the 12 months before study inclusion. The exclusion criteria were as follows: 1) an Expanded Disability Status Scale < 1 or > 6; 2) on corticosteroid treatment within the prior 2 months and 3) involved in a training program prior 4 months. In addition, volunteers were excluded if they had an exacerbation that affected the pyramidal functions during the study or if they attended less than 90 % of the programmed training sessions. All volunteers provided informed consent before their participation in the study.

Procedures

While the CG did not perform any intervention, the EG came to the UCAM Sport Center and underwent 10 weeks of lower-limb FVCRT (3x per week on alternating days; ≥ 48 h rest between sessions). Prior to each exercise session, participants performed a standardized warm-up protocol, consisting of 5-min cycling on a stationary bicycle, lower-limb mobility exercises and 5 repetitions at 40 % 1-RM (one-repetition maximum) for each exercise. The 4 lower-limb exercises that included unilateral leg press, unilateral leg extension, bilateral hip extension, and seated plantarflexion were performed on conventional weight machines (Technogym, Cesena, Italy). Intensity, sets, repetitions and rest between sets were determined according to published recommendations (intensity: 60–75 % 1-RM, sets: 2–4, repetitions: 8–15, rest between sets: 120 s) [6] **Supplementary Table 1**. The training load was individualized and based on the 1-RM for each exercise before study initiation. It was emphasized that the weight should be lowered in a controlled manner with a short pause at the end, followed by maximal force production in the concentric phase in order to maximize the neural component [6]. The 1-RM load was estimated by carrying out 4 sets of each exercise, as follows: 1 set of 10 repetitions at 50 % of the perceived 1-RM, 1 set of 5 repetitions at 75 % of the perceived 1-RM, and 1 set of 1 repetition at 100 % of 1-RM. Participants rested for 5 minutes between sets. The 1-RM was estimated using previous recommendations if the volunteer could perform more than one repetition in the fourth set [14]. During FVCRT, the investigator increased the load by 2–5 % if the volunteer could ≥ 2 more repetitions than the predetermined number, but always with the consideration of having 2 repetitions in reserve. The investigator recorded

a detailed diary at the end of each session, regarding each exercise, the weight lifted, the number of repetitions and the number of sets completed for each participant.

Outcomes measures

A separate investigator, not involved with the training program and blinded to group allocation, measured the participant's strength, mobility and quality of life. Participants, however, were not blinded to the intervention due to the design of the intervention (FVCRT vs. no exercise). CG participants were invited to undergo the 10-week lower-limb FVCRT after completing the post-measurements.

Strength

Rate of Force Development

We used the same previously described protocol to determine RFD [15]. The time intervals used to analyze RFD were 0–30 ms and 0–50 ms, which is considered as early RFD, and 0–100 ms and 0–200 ms, which is considered as late RFD.

Mobility

Sit-to-Stand Test

Participants were seated upright on an adjustable chair (for lower limb length; 90º knee flexion) with the arms crossed over the chest, and they were instructed to stand quickly as possible. A video recording was used to determine the end time when the participant's trunk and knees were fully extended. This test was repeated the test 2 times and the best trial was used for analysis.

Timed Up and Go Test (TUG)

As quickly as possible, participants stood up from the seated position, walked 3 meters in the forward direction, turned around, walked back and sat down again. This test was performed twice. A video recording was used to determine the fastest time of the 2 trials, which was used for analysis.

Quality of life

Multiple Sclerosis Quality of Life-54

Participants filled out the Multiple Sclerosis Quality of Life-54 (MSQoL-54) questionnaire. MSQoL-54 is a structured, self-report questionnaire that contains 14 sub-scales: physical function, physical role limitations, emotional role limitations, pain, emotional well-being, energy, health perceptions, social function, cognitive function, health distress, sexual function, satisfaction with sexual function, change in health and overall quality of life. From the MSQoL-54 questionnaire, 2 summary scores can be derived: the physical health and the mental health composite summaries. Higher scores in each subscale or summary score corresponded to better quality of life.

Statistical analysis

SPSS software (v.24.0) performed the statistical analyses. Descriptive analyses were calculated as mean and standard deviation. The Shapiro–Wilks's test verified the assumption of normality before using parametric tests, and Levene's test determined the homogeneity of variance. A two-way repeated measures analysis of variance (rmANOVA) analyzed the effects of FVCRT (general linear model; 2 time points (pre- and post-intervention) × 2 groups (EG and CG). Post-hoc Bonferroni test was applied when significant main effects were observed. In addition, the effect size (ES) was determined via eta squared partial (η^2_p) for variance analysis and Cohen's d to calculate the standardized difference between two means. A $\eta 2_p$ of 0.1–0.24, 0.25–0.36 and ≥ 0.37 represents a small, medium, and large effect, respectively. The Cohen's d of 0.2, 0.5 and 0.8 mark a small, moderate, and large effect, respectively. Statistical significance was established at $p < 0.05$.

Results

Participant's characteristics and flowchart are presented in ▶ **Table 1** and **Supplementary Figure 1**. All participants completed the intervention and were included in the data analysis. No participant showed adverse effects related to FVCRT. In addition, no difference was observed between groups at baseline.

Rate of force development

▶ **Table 2** shows the neuromuscular results. A group x time interaction was observed in RFD 0–30 and in RFD 0–50 in both legs (RFD 0–30 Right: F = 22.8; Left: F = 4.9; RFD 0–50 Right: F = 29.0; Left: F = 6.3) with a significant improvement from pre- to post-training in EG (RFD 0–30 Right: ES = 1.43; Left: ES = 0.98; RFD 0–50 Right ES = 1.68; Left: ES = 1.08) and significant differences between EG and CG at the end of the program in RFD 0–30 of the left lower limb (ES = 0.98). No main group x time effect was observed in other RFD variables.

▶ **Table 1** Participant characteristics.

Characteristics	All (n = 30)	Resistance training group (n = 18)	Control group (n = 12)	P
Sex (men:women)	15:15	10:8	5:7	
MS phenotype (RR:SP)	27:3	16:2	11:1	
Age (years)	46.21 ± 10.43	44.89 ± 10.62	48.36 ± 10.23	0.394
EDSS	3.21 ± 1.51	3.17 ± 1.65	3.27 ± 1.33	0.858
Weight (kg)	68.51 ± 11.55	67.19 ± 10.63	70.67 ± 13.17	0.442
Height (cm)	166.86 ± 6.95	166.44 ± 7.32	167.54 ± 6.58	0.687
BMI ($kg \cdot m^{-2}$)	24.56 ± 3.29	24.26 ± 3.12	25.06 ± 3.64	0.534
Fat mass (%)	26.47 ± 8.72	25.92 ± 8.28	27.34 ± 9.69	0.680

Data are presented as mean ± SD. Significance was set at P = 0.05. BMI: Body Mass Index; EDSS: Expanded Disability Status Scale; MS: Multiple Sclerosis; RR: Relapsing-Remitting; SP: Secondary-Progressive.

▶ **Table 2** Neuromuscular performance and mobility tests.

						ANOVA (F, p, η^2_p)									Post Hoc				
		PRE-training		POST-training		Time effect			Group effect			Time x Group effect			Intra			Inter	
Outcome	*Group*	*Mean*	*SD*	*Mean*	*SD*	*F*	*p*	*η2p*	*F*	*p*	*η2p*	*F*	*p*	*η2p*	*p*	*ES*	*M*	*p*	*ES*
Neuromuscular performance in right and left leg																			
Right: $RFD_{0\text{-}30}$ (N/s)	CG	53.9	28.5	54.4	31.1	24.7	<0.001	0.50	0.1	0.995	0.01	22.8	<0.001	0.48	0.903	−0.1	Pre	0.192	0.620
	EG	41.0	21.5	67.2	24.9										<0.001	−1.4	Post	0.247	−0.291
Right: $RFD_{0\text{-}50}$ (N/s)	CG	88.6	38.9	90.1	42.0	34.4	<0.001	0.58	0.2	0.652	0.01	29.0	<0.001	0.54	0.769	−0.1	Pre	0.435	0.414
	EG	77.6	32.9	113.8	34.3										<0.001	−1.7	Post	0.120	−0.441
Right: $RFD_{0\text{-}100}$ (N/s)	CG	119.3	48.0	130.4	52.5	12.1	0.002	0.33	2.2	0.153	0.08	1.3	0.259	0.05	0.335	−0.5	Pre	0.254	−0.309
	EG	140.0	43.7	162.2	46.3										<0.001	−0.8	Post	0.109	−0.446
Right: $RFD_{0\text{-}200}$ (N/s)	CG	188.4	85.0	208.9	94.5	13.3	0.001	0.35	2.1	0.161	0.08	1.5	0.233	0.06	0.39	−0.5	Pre	0.265	−0.302
	EG	225.9	83.5	267.2	87.8										<0.001	−0.8	Post	0.113	−0.448
Left: $RFD_{0\text{-}30}$ (N/s)	CG	29.6	30.0	34.2	28.2	11.5	0.002	0.31	4.9	0.036	0.16	4.9	0.036	0.16	0.445	−0.3	Pre	0.217	−0.442
	EG	42.5	23.3	64.9	28.1										<0.001	−1.0	Post	0.010	−0.983
Left: $RFD_{0\text{-}50}$ (N/s)	CG	79.9	40.5	86.8	44.2	17.0	<0.001	0.40	0.5	0.469	0.02	6.3	0.019	0.20	0.294	−0.5	Pre	0.981	0.063
	EG	80.2	38.5	108.7	38.9										<0.001	−1.1	Post	0.186	−0.427
Left: $RFD_{0\text{-}100}$ (N/s)	CG	114.5	51.8	119.0	57.6	7.0	0.014	0.22	2.1	0.157	0.08	2.7	0.115	0.10	0.381	−0.3	Pre	0.283	−0.324
	EG	137.7	55.3	156.6	53.0										<0.001	−0.7	Post	0.093	−0.537
Left: $RFD_{0\text{-}200}$ (N/s)	CG	181.3	99.2	184.3	110.7	2.4	0.132	0.09	2.2	0.151	0.08	1.4	0.247	0.05	0.458	−0.1	Pre	0.232	−0.369
	EG	228.2	96.9	250.4	94.4										0.003	−0.4	Post	0.108	−0.510
Mobility tests																			
Sit to stand (s)	CG	1.2	0.7	1.3	0.7	6.6	0.019	0.19	6.3	0.018	0.19	11.2	0.002	0.29	1.000	0.3	Pre	0.367	0.723
	EG	0.9	0.3	0.7	0.2										<0.001	1.0	Post	0.028	1.187
TUG (s)	CG	15.0	10.4	15.3	10.7	6.4	0.018	0.19	12.3	0.002	0.32	17.4	<0.001	0.40	1.000	0.6	Pre	0.019	0.910
	EG	7.9	3.7	7.1	3.6										<0 .001	1.1	Post	0.005	1.102

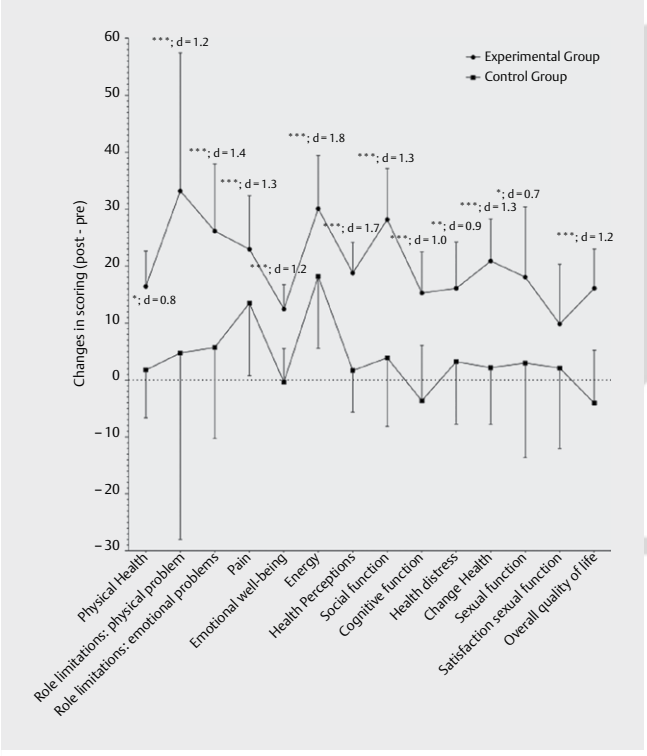
Data are presented as mean ± SD. Significance was set at $P=0.05$. CG: Control Group; EG: Experimental Group; ES: effect size; N/s: Newtons per second; RFD: Rate of Force Development; TUG: Timed Up and Go Test.

Concerning mobility (▶ **Table 2** and **Supplementary Figure 2**), group x time interaction were observed in sit-to-stand (F = 11.23) and TUG (F = 17.39). Furthermore, there was a main time effect in sit-to-stand (F = 6.25) and TUG (F = 6.37) and a main group effect in sit-to-stand (F = 6.37) and TUG (F = 12.27). In addition, the pairwise comparison showed a significant improvement in EG from pre- to post-training program (sit-to-stand: ES = 1.0; TUG: ES = 1.0). Furthermore, significant differences were observed at the end of the program in sit-to-stand (ES = 01.1) and TUG (ES = 01.1).

▶ **Fig. 1** provides results for the perception of quality of life measured with the MSQoL-54. There was a group x time interaction in physical health (F = 9.349, p = 0.005), role limitations due to emotional problems (F = 5.07, p = 0.033), emotional well-being (F = 14.63, p < .001), health perceptions (F = 16.95, p < .001), social function (F = 12.48,p = 0.002), cognitive function (F = 11.62, p = 0.002), health distress (F = 4.216, p = 0.050) and change in health (F = 10.812, p = 0.003). In addition, a main time effect was observed in pain, energy, health perceptions and overall quality of life. Thus, participants who completed the resistance training showed an improvement in the perception of quality of life for all dimensions of the MSQoL-54, except for satisfaction with sexual function (▶ **Fig. 1**). However, no differences were observed between groups in any dimension of the MSQoL-54.

Discussion

The present RCT aimed to investigate the effects of FVCRT on RFD, mobility and quality of life in pwMS. We found that 10 weeks of FVCRT could be effective in improving early RFD and mobility in pwMS. In addition, quality of life increased after completing this training program.



▶ **Fig. 1** Changes (post vs. pre training; ± SD) after of fast-velocity concentric resistance training on Multiple Sclerosis Quality of Life-54. * = p < 0.05 pre-post training; *** = p < 0.001 pre-post training.

Rate of force development

Early RFD showed significant improvements after the intervention in the EG compared to CG. As for late RFD, although pre-post differences were found in the EG, no group differences were observed. Recently, it has been suggested that RFD may have a greater impact on gait, functional capacity and fall risk [16, 17] than maximum strength values. To the best of our knowledge, to date, only one study investigated RFD in pwMS after a resistance training program and showed significant improvements [4] in this variable. A tendency towards an increase in late RFD was found after the FVCRT program. One possible explanation for the absence of significant changes could be due to the short duration of the training program. Future studies should examine whether this type of training with a longer duration could lead to changes in late RFD.

According to a previous study, an increase in early RFD is more related to neural mechanisms, while late RFD is more affected by structural mechanisms [18]. In our study, early RFD improved in EG, so it can be expected that gains in neuromuscular performance are due to neural mechanisms, which could include increased synchronization and recruitment of motor units, changes in motor neuron excitability, altered co-activation of antagonist muscles or higher firing rate [19, 20]. Future studies should explore the neuromuscular mechanisms leading to RFD improvement after FVCRT.

Traditional studies have established that when the central nervous system requires maximal speed and force, it achieves maximal motor unit recruitment rates compared to sustained contractions [21], thus chronic neuromuscular stress during FVCRT could lead to an increased ability to recruit motor units during maximal and submaximal efforts. It has been speculated that the firing rate of motoneurons during a maximal velocity movement is higher than during a controlled and moderated movement [22]. Therefore, these adaptations could be the mechanism that explains the improvements in RFD found in our sample population. However, the time course of the firing rate of motoneurons during maximal velocity contractions was not measured and remains unknown. Improving RFD in pwMS is crucial because of the benefits obtained in some of the most recurrent symptoms in this disease, such as balance [10], fall risk [23], mobility [9], gait [16], and spasticity [24].

Mobility

Mobility, measured by the sit-to-stand and TUG, improved after 10 weeks of FVCRT in the EG compared to CG, which showed no change. Regarding the TUG test, studies have shown benefits after the implementation of resistance training programs [25–28]. The changes reported by the authors vary from 9 % [27, 28] to 26 % [25]. Those studies in which the improvements were greater, as in the study by Aidar et al. [25] effect may have been due to lower baseline values (12.9 s) with which the sample had started with prior to the intervention compared to other studies, such as those by de Oliveira et al. [27] and Sabapathy et al. [28] (9.3 s and 7.5 s, respectively). In our study, we found a change of 11 % in EG, with a baseline values of 7.9 s. Improved TUG performance in pwMS suggests better gait and ability to perform daily living tasks, such as getting out of a chair, which are goals in the patients' daily rehabilitation process. To our knowl-

▶ **Table 3** Training program characteristics.

Week	1	2	3	4	5	6	7	8	9	10
Intensity (% 1-RM)	60	65	70	75	60	65	70	75	75	60
Sets per exercise	2	3	3	4	2	3	3	3	4	2
Repetitions	15	13	9	8	15	13	9	8	8	15
Rest between set (s)	120	120	120	120	120	120	120	120	120	120

1-RM = one-repetition maximum.

edge, only one RCT [4] has analyzed the effect of resistance training on sit-to-stand performance and found improvements of 21 % in the intervention group (24 weeks of progressive full-body resistance training at 65–85 % 1-RM). Similarly, the sit-to-stand performance in our study improved by 22 %, which can be considered clinically relevant [29]. The effectiveness of strength training on mobility variables is promising and underlines the importance of implementing this type of physical exercise in the MS population.

Quality of life

Self-perceived quality of life for pwMS (MSQoL-54) improved significantly in all domains in EG but not in CG. As poor quality of life is one of the main problems in MS, these results are promising and indicate that FVCRT can reverse the quality status of life. The improvements in the physical components of the MSQoL-54 in our sample population can be explained by the increases observed in the mobility tests in EG [30]. In addition, improvements were found in the cognitive component of the questionnaire. A recent meta-analysis by Ruiz-Gonzalez et al. [31] suggested that physical exercise has a positive effect on plasma brain-derived neurotrophic factor in neurodegenerative diseases, such as MS, and can partially explain the improvements in cognition in our study.

To date, only 6 studies have investigated the effects of resistance training on quality of life in pwMS [11, 12, 32–35]. The baseline values of these studies are similar to our data. However, the results of these studies are controversial. Some authors found improvements [11, 12, 32, 34] while other studies found no change [33, 35] after the training programs. This discrepancy may be due to the wide variety of training variables (i. e., intensity, load, frequency, sets, etc.) used in the interventions. In line with our results, the studies that found improvements in quality of life used intensity of resistance training similar to ours (moderate-to-high; 60–85 % 1-RM) [11, 12, 32, 34]. However, the two studies that did not observe a change in quality of life when using lower intensities. For example, Romberg et al. [35] used elastic bands and Frevel et al.'s [33] study consisted of an internet-based home training in which exercises were performed only with body weight (squats, lunges…) or with small overloads (elastic bands). Therefore, more resistance training programs with moderate and high intensities in the MS population are necessary to confirm our results.

Limitations

The present study contains some limitations. There was heterogeneity in the sample population with MS (sex, disease phenotype and age range). In addition, although an analysis of covariance was performed, the level of the EDSS scale did not change the direction and power of the results. The pwMS in this study had an EDSS range between 1 to 6, so caution should be taken when interpreting the data for patients with an EDSS > 6. Finally, participants were not blinded to the intervention. However, due to the characteristics of the study (exercise vs non-exercise), it was impossible to blind the participants. As for future lines of research, we propose the use of surface electromyography decomposition to analyze possible changes in motor unit recruitment and firing rates during maximal actions after a resistance-training program in pwMS. Albeit the limitations, the study has some strengths that we would like to highlight. First, the study design (RCT) adds further value to the results found. Second, the sample size was considerably high, considering the recruitment difficulty in this population. Finally, the measurement of RFD in such small time periods (0–30 ms, 0–50 ms, 0–100 ms, and 0–200 ms) allows us to know more precisely the direction of the adaptations.

Conclusion

The 10-week FVCRT has the potential to improve early RFD and mobility. In addition, FVCRT provides benefits to self-perceived quality of life in pwMS. Therefore, FVCRT could be a novel way of conducting resistance trainings to optimize results in pwMS. Finding modes of exercise, such as the FVCRT, that have the capacity to improve those neuromuscular and functional variables that are most impaired in people with MS is a major challenge for research in this field. Therefore, more studies are needed to provide us with a better understanding of the neuromuscular effects of different types of training on people with MS, with the aim of finding the modality that provides the greatest benefits to this population.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding

This work has been supported partially by the Spanish Ministry of Education, Culture and Science through the National Program FPU.

Conflicts of Interest

The authors have no conflicts of interest to disclose between any outside institution, company, or manufacturer. The results of this study are presented clearly, honestly, and without fabrication, or inappropriate data manipulation.

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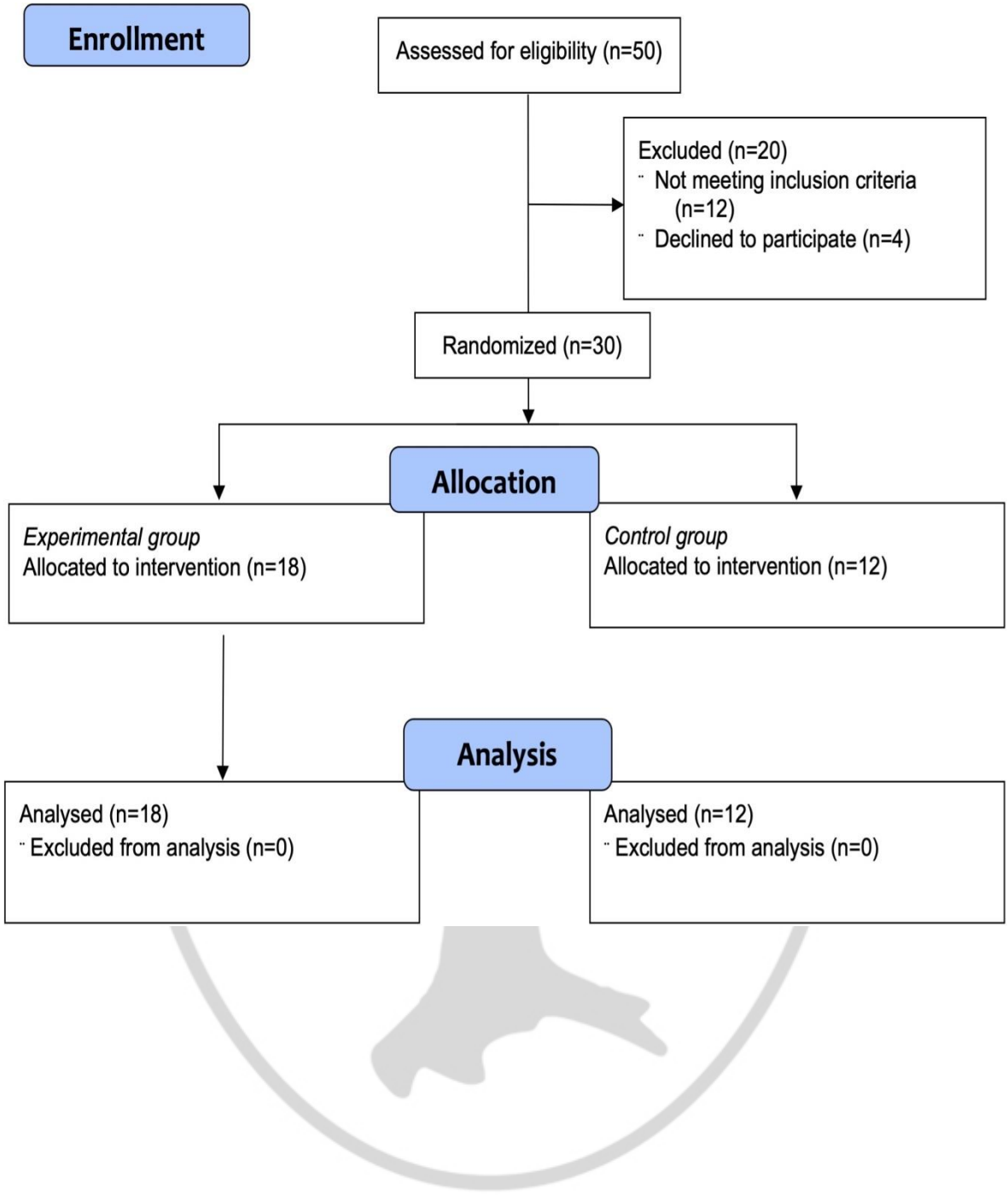
Supplementary material

Supplementary Table 1. Training program characteristics.

Week	1	2	3	4	5	6	7	8	9	10
Intensity (% 1-RM)	60	65	70	75	60	65	70	75	75	60
Sets per exercise	2	3	3	4	2	3	3	3	4	2
Repetitions	15	13	9	8	15	13	9	8	8	15
Rest between set (s)	120	120	120	120	120	120	120	120	120	120

1-RM = one-repetition maximum.

Supplementary Figure 1. Flowchart showing patient inclusion.



Supplementary Figure 2. Effects of fast-velocity concentric resistance training on mobility. * = p<0.05 pre-post training; *** = p<0.001 pre-post training; # = p<0.05 differences between group at end of training; ## = p<0.01 differences between group at end of