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Improvement in the Multiple Sclerosis Functional Composite Score by Multi-Function Swing Suspension Training Program

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ABSTRACT

Background: Physical activity has been considered as a promising approach to slow down the disease process in Multiple Sclerosis (MS) patients. While the functional impairments of MS have been studied in detail, but there is limited evidence of the efficacy of exercise training interventions on the Multiple Sclerosis functional composite (MSFC) score in these patients.

Aim: The aim of this study was to investigate the improvement in MSFC score by multi-function swing suspension training program (MFSST) in the women with MS.

Design: A randomized controlled trial.

Setting: The Department of Sports Injuries and Corrective Exercise at the Shahid Bahonar University of Kerman.

Population: Forty-seven MS women.

Methods: The patients were divided into two groups as the intervention and control groups. A total of 47 MS patients completed the MSFC components at baseline and after the intervention: the timed 25-foot walk (T25FW); the 9-hole peg test (9HPT); and paced auditory serial addition test (PASAT). Z scores were created for each test based on control means.

Results: The MSFC score, 9HPT, T25FW, and PASAT showed a significant increment in comparison with the baseline levels in the four, six, and eight weeks following the first exercise session (all $p<0.05$). These differences in the control group were not significant. The improvement in the MSFC score and the component Z-scores in the intervention groups was found from the fourth week onwards.

Conclusions: The study findings highlight that the progression of MS disability can be compensated by physical exercise. Overall, these results indicate that MFSST can be used as an effective treatment method in patients suffering from MS due to its positive effects on physical parameters, such as muscles strength, functional impairments, and cognitive problems. Longer (years) exercise studies are needed to evaluate the effect of other types of exercise interventions on the MSFC score in MS patients with different disabilities.

Clinical rehabilitation impact: The MFSST Program could be performed as an efficient clinical intervention for improving MSFC in patients suffering from MS due to the improvement of muscles strength, functional impairments, and cognitive problems.

Key words: Multiple sclerosis, Multiple Sclerosis Functional Composite Score, Multi-Function Swing Suspension Training,

Introduction

Multiple sclerosis (MS) is a chronic inflammatory demyelinating disease of the central nervous system manifested morphologically by demyelination and neurodegeneration [1]. Due to the diffuse character of the formation of the demyelinating plaques, the symptoms and presentations are determined by the location of the lesions [2]. The high variability of the symptoms has been reported that their persisting during the disease course leads to clinically significant symptoms such as changes in muscle tone, muscle weakness, motor incoordination, and postural errors [3]. These changes may limit MS patients in the performance of their daily activities, as well as has a negative influence on social life [2, 3]. Nowadays, the majority of clinicians and researchers agree that combining both pharmacologic and nonpharmacological treatments can manage the disease adequately [4].

Exercise rehabilitation is an important non-pharmacological approach that is effective in reducing the disease symptoms, improving and maximizing functional abilities, as well as helping to prevent the onset of disability resulting in improving the social life of MS patients [2]. The rehabilitation world is rapidly changing, and better and new treatment techniques are constantly being introduced. The new rehabilitation approach places emphasis on suspension training (ST) that is more challenging for neuromuscular control. Suspension exercises use the force of gravity as a challenge to the neuromuscular system, take advantage of body position changes and their mechanical properties, and with their unstable nature involve both movement and sense [5]. For example, Byrne et al. investigated the effect of suspension exercises on muscle activation during the performance of variations of the plank exercise [6]. They demonstrated that ST can considerably enhance the electromyographic activity of the abdominal muscles and have a positive effect on their functional stability. The swing suspension exercise program is among the most promising due to various advantages such as safety, low equipment cost, easiness, and efficiency of application [7], which can possess many advantages for MS patients over the other approaches due to its considerable effect on muscles and nerves. Our study protocol was included the workouts of neuromuscular re-education, core stability, sensorimotor, balance, and range of motion, within a single device.

Since the device is multi-purpose and the exercises are performed on the whole body, in our study, we decided to use a multidimensional criterion to evaluate the effect of the exercise program on the symptoms of the disease. The Multiple Sclerosis Functional Composite (MSFC) is a multidimensional tool used to assess disability [8]. This scale has been considered superior to others, due to its ease of application, the reliability of the results obtained and sensitivity to change as well as being cost-effective [9]. MSFC is considered as an instrument that has been suggested in recent years in MS clinical trials and includes two trials of Timed 25-Foot Walk (T25W) for leg function and ambulation, two timed trials of the 9-hole peg test (9HPT) for arm and hand function (dominant and non-dominant), and a single trial of Paced Auditory Serial Addition Test (PASAT-3) for cognitive function [10]. Up to now, no previous study has investigated the effect of the MSST program in MS Patients. Hence, we investigated the effect of the MSST program on MSFC in MS patients as a new method in the rehabilitation of these patients.

Materials and methods

Study design and Subjects

In this single-blind randomized control trial study, patients with the diagnosis of relapsing-remitting MS with an EDSS score of 2 – 6.5 which was confirmed by the MS committee of Kerman University of Medical Sciences were considered eligible. A simple random sampling method was used in recruiting the subjects. The sample calculation was estimated for 45 subjects using the G* Power 3.1.9.2 (G* Power 3 for Mac) software15,16 using a RM ANOVA between factors, 90% test power, probabilistic error: 0.05, and f = 0.5. Being F = 3.35413. It is necessary to mention, 57 patients were selected to prevent probable attrition from affecting the power of the research. Prior to entering the study, written informed consent was obtained from all participants according to the Helsinki Declaration (2004). This study was approved by the Ethics Committee of University of Medical sciences Kerman, Iran, under reference number: IR.UK.VETMED.REC.1399.002. The exclusion criteria were as follows. (I) History of

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musculoskeletal injury within the last six weeks. (II) History of orthopedic or rheumatic disorders within the last six months. (III) Relapse during the study period or two months before that. (IV) Changes to medication during the study or two months before that. (V) Pregnancy [11].

Familiarization and Measurement Procedure

All assessments, pre-test, fourth week and sixth week follow-up, and post-test, were performed by the same test leader at the same time of day. The study was done at the Department of Sports Injuries and Corrective exercise at the Shahid Bahonar University of Kerman. Each participant took part in two phases of the experiment: the familiarization session and the data collection trial. During the familiarization session (about 1 to 2 hours before data collection), the participants received an explanation of the project, and how to correctly perform the tests and the exercises. Before starting the exercise protocol, the participants completed a baseline questionnaire including demographic characteristics. Body height in meters was obtained from a single stadiometer and body weight was recorded in kilograms using a calibrated digital scale (SECA 769; SECA, Chino, CA, USA).

Participants performed the MSFC test according to standardized instructions. In the first trial, the 9-HPT was done. The 9HPT (nine-hole peg test) asks participants to repeatedly place the 9 pegs into the 9 holes of the pegboard and then remove, them as quickly as possible. The test was done in the sitting position, twice with the dominant hand, and immediately followed by twice with the non-dominant hand. The time was measured, in seconds by the chronometer, from the moment the dominant hand touched the first peg until the last peg hit the board. The final scores for each hand were evaluated using the average times of the two trials [9]. In the next trial, the walking speed of participants has measured in a short distance, 25 feet (~8 meters) using the T25FW. The gait speed value (m/s) in this test equaled travel the walking distance, divided by the total time of the test [9]. In the final trial, the Paced Auditory Serial Addition Test (3-second version, PASAT3; cognition) was done once; During this test, the patient was asked to listen to single-digit numbers which are presented at a rate of 3 seconds and then add each number to the one immediately preceding it and to say the answer out loud. The score was the number of correct answers given (out of 60 possible) [9]. To calculate the MSFC, the scores on each component were converted to a Z-score using the following formulas:

$$Z_{leg} = (\text{Mean T25W} - 9.5353)/11.4058$$
$$Z_{arm} = (\text{Mean}(1/9\text{HPT}) - 0.0439)/0.0101$$
$$Z_{cog} = (\text{PASAT3} - 45.0311)/12.0771$$

And then the composite score was calculated according to the standardized formula, as recommended by the Administration and Scoring Manual for the MSFC Measure [9].

$$Z_{MSFC} = (Z_{arm} - Z_{leg} + Z_{cog})/3$$

Intervention program

The MFSST intervention was held thrice weekly for 8 weeks at the university gym (from April to June 2020). The intervention sessions consisted of a 10 to 15 min warm-up (static stretching and dynamic warm-up), 40 min MFSST exercises, and 5 minutes cool-down (breathing and the muscles loosening exercises). The intervention program was designed and performed by the MFSST instructor based on a focused literature review on ST programs [12, 13]. The program was included workouts of neuromuscular re-education, core stability, sensorimotor, balance, and range of motion, within a single device, with 4 levels of difficulty for every exercise. All those randomized to the control group received no such training and continued to receive usual routine care (e.g., individualized drug treatment) and daily activities.

Statistical analysis

All data are presented as mean ± Standard Error of the Mean (x ± SEM). The Kolmogorov-Smirnov test was applied to determine the normal distribution of the findings. Levene’s test was performed to assess the homogeneity of variances. The tests were repeated several times during this observation, and the results were analyzed by the mixed model of one-way-ANOVA test (MANOVA) for repeated measures where the within-subject factor was time and MFSST intervention was the between-subject factor. The main effects of time, MFSST intervention and interaction between time x MFSST intervention were examined. The assumption of sphericity was assessed with Mauchly's test. A pairwise comparison using the Bonferroni correction followed by a paired t-test was used to analyze the inter-group differences of the within-subject factor. A p-value of < 0.05 was considered statistically significant”. The IBM SPSS statistical software version 26.0 was used.

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Results

The following diagram provides an overview of the current study (Figure 1). In this study, during the recruitment period, 102 eligible patients with MS remained. To examine the effect of the intervention program, 57 patients were randomly selected from the remaining 102 patients. The selected participants were randomly assigned into two groups as the intervention group, and the control group (no intervention). Overall, ten patients were excluded from this study as they did not attend the allocated intervention mostly due to the COVID-19 situation, relapse of MS symptoms, and lack of participation in post-test sessions. Finally, 34 patients in the intervention group, and 13 patients in the control group have been analyzed for the following training effects. Table I shows the demographic and clinical characteristics of the patients were not significantly different between groups ($P \geq 0.05$). All study patients had relapsing-remitting MS.

The baseline levels of MSFC score, 9HPT, T25FW, and PASAT were compared with their corresponding levels in the four, six, and eight weeks following the first exercise session. The results obtained from the one-way ANOVA of the MSFC score and the component Z-scores are summarized in Table II. The Bonferroni post-hoc test of the MSFC score revealed a significant difference between all measurement times in the intervention group (all $p<0.05$). 9HPT showed a significant increment in comparison with the baseline levels (all $p<0.05$). A significant increment in T25FW and PASAT was also documented (all $p<0.05$). While these differences in the control group were not significant (Table III), an improvement was found in the MSFC score and the component Z-scores in the intervention groups from the fourth week onwards (Table II).

Discussion

In this study, we aimed at investigating the effect of the MFSST program on MSFC scores in women with MS. We found that functional impairment, measured by MSFC, improved significantly in MS patients after the MFSST program for 2 months. No differences were found in the control group. The change in the MSFC components in comparison with baseline was observed above all in the 9-HPT and T25FW tests. This phenomenon, which was to be expected and foreseen because the focus of the intervention was on motor function. Our findings was in agreement with the literature [14]. The stabilizer function of the skeletal muscles is a key factor for the coordinated performance of any voluntary movement which significantly affects the patterns of muscle coordination [15]. Muscle weakness and spasticity in MS patients often cause loss of mobility and upper extremities function, changes in posture, and abnormal stress on many structures necessary for movement [16]. Also, there is a significant relationship between lower extremity muscle weakness (both flexor muscle and knee extensor) and gait disorders in MS patients [17]. Studies have shown that the weakness of major muscles in the lower limbs was associated with short stride length, reduced speed, and instability while walking [17, 18]. Since mechanisms of muscle dysfunction in MS are probably of both muscular and neural origin [19], and the MFSST is a special kind of neuromuscular exercise because promotes coordination of the neuromuscular system due to focusing on strengthening trunk and limb muscles and stimulating the proprioceptors [20]. A possible explanation of the upper and lower extremity's function improvement could be the using the MFSST protocol. In this regard, researchers have been shown that neuromuscular exercises can correct abnormal biomechanics, improve muscle strength, and improve neuromuscular control of the lower extremities [21]. For example, Huang et al. (2021) have shown reliable results in improving the lower limb strength in patients with anterior cruciate ligament reconstruction. This improvement has been seen due to suspension training [21]. They also showed that compared with conventional exercise protocol, suspension protocol could more quickly improve muscle strength and shorten the rehabilitation period [21].

The patients with MS often have impaired trunk control which is directly influencing extremities function disability, as described by others [22] [23] [24] [25]. It has been reported that physical rehabilitation programs that comprehensively focus on the prerequisites of optimal balance control and the aspects of core stability can affect extremity function [22]. The key of suspension training is control of movement. ST as a training plane provides an unstable training environment, in which the participants were required to perceive the body position in three-dimensional space to maintain position stability [21]. The instability of the ST is higher, and the participants' core muscles need to bear more load during the exercises [21]. It can be inferred that the application of MFSST to MS patients can not only effectively improve neuromuscular control but also activate the strong contraction of the trunk muscles and promote the strength of the upper and lower limb muscles. Previous studies have demonstrated the substantial effect of ST on core muscle strength [6]. On the other hand, MFSST is one of the most efficient physical rehabilitation programs for the improvement of balance disorders through sensorimotor exercises. In particular, sensorimotor exercise on an unstable support surface leads to muscles tone restoration and redistribution, improvement of the harmony of neuromuscular reflexes reactions, and increasing the sensory feedback. As a result, balance is restored by increasing of the motor system response, co-contraction levels, and joint stability [26]. In fact, the MFSST promotes proprioceptive function and develops overall coordination of sensorimotor systems, that all together have a positive impact on postural stability and balance. We can say that since the MFSST is more effective to achieve ultimate muscles activation than conventional treatments, so can significantly affect extremities function.

On the other hand, significant associations between physical activity criteria (i.e., skeletal muscle contraction that leads to increased energy expenditure) and cognitive processing speed in patients with MS have been reported previously [27] [28]. The cognitive function can be affected by physical performance, such as muscle strength, walking capacity, and exercise capacity in this population [28]. In other words, improvement in physical performance factors can improve cognitive function. Importantly, the findings of recent neuroimaging studies demonstrated that some areas responsible for cognitive functions in the thalamus and hypothalamus have a consistent and strong association with physical performance in patients with MS [28]. Based on this evidence-based on both clinical and neuroimaging findings, it can be said the improvement of the PASAT score in the present study was followed by improvement in physical performance, muscle strength, and especially the improvement of lower limb muscle strength. As a result of improving T25FW, 9HPT, and PASAT factors, the MSFC scores were directly improved.

Conclusions

The present study demonstrated that the multiple sclerosis functional composite (MSFC) score is prone to practice effects which means that the progression of Multiple Sclerosis (MS) disability can be compensated for by physical exercise. Overall, these results indicate that multi-function swing suspension training (MFSST) can be used as an effective treatment method in patients suffering from MS due to its positive effects on physical parameters, such as muscles strength, functional impairments, cognitive problems, and balance. In the literature, few studies have investigated the effects of exercise on the MSFC. To date, most interventional studies that have used the MSFC score as an outcome measure have been clinical drug trials. Although our experience was in keeping with studies evaluating the effects of clinical drug treatment in MS patients. However, since phase III clinical trials usually last 2 years or more, the relatively short study duration of existing exercise rehabilitation studies represents a major limitation. Consequently, longer (years) exercise studies are needed to evaluate the effect of other types of exercise interventions on the MSFC score in MS patients with different disabilities.

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TABLES

Table I.— *Baseline characteristics of the study participants (N = 47).*

Table II. *Pairwise Comparisons in the MSFC score and the component Z-scores at 8 weeks*

Table III. *Paired Samples T-test Results*

Table I.

Characteristic	N	Minimum	Maximum	Mean	Std. Deviation
Age	47	30.00	46.0	36.89	4.93
Height	47	159.00	176.00	166.36	4.68
Weight	47	59.20	76.50	66.24	5.49
EDSS	47	2.00	6.50	4.12	1.22

Table II.

	(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference [b] Lower Bound	Upper Bound
MSFC	Pre-test	Fourth week	-0.20	0.06	0.02*	-0.38	-0.02
		Sixth week	-.036	0.07	0.00*	-0.58	-0.15
		Eighth week	-0.54	0.09	0.00*	-0.80	-0.29
T25FW	Pre-test	Fourth week	0.93	0.09	0.00*	0.68	1.19
		Sixth week	1.49	0.09	0.00*	1.22	1.77
		Eighth week	1.96	0.11	0.00*	1.64	2.30
9HPT	Pre-test	Fourth week	2.32	0.20	0.00*	1.76	2.89
		Sixth week	3.52	0.26	0.00*	2.78	4.26
		Eighth week	4.86	0.31	0.00*	3.98	5.75
PASAT	Pre-test	Fourth week	-3.11	0.58	0.00*	-4.75	-1.48
		Sixth week	-5.73	0.75	0.00*	-7.84	-3.63
		Eighth week	-10.02	0.96	0.00*	-12.74	-7.32

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

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b. Adjustment for multiple comparisons: Bonferroni.

Table III.

Variable	Time	Group	Mean	Std. Deviation	Sig	T
MSFC	Pre- test	Experimental	0.30	0.67	0.56	0.58
		Control	-0.80	0.17		
	Fourth week	Experimental	-0.14	0.55	0.00*	0.17
		Control	0.37	0.36		
	Sixth week	Experimental	-0.20	0.47	0.00*	- 7.04
		Control	0.53	0.23		
	Eighth week	Experimental	-0.19	0.38	0.00*	- 5.15
		Control	0.50	0.48		
T25FW	Pre- test	Experimental	5.95	0.93	0.92	0.09
		Control	5.92	0.14		
	Fourth week	Experimental	5.01	0.81	0.00*	- 3.40
		Control	5.88	0.72		
	Sixth week	Experimental	4.45	0.74	0.00*	- 6.95
		Control	5.93	0.28		
	Eighth week	Experimental	3.98	0.57	0.00*	- 7.81
		Control	0.92	0.92		
9HPT	Pre- test	Experimental	22.02	2.40	0.83	- 0.20
		Control	22.16	1.00		
	Fourth week	Experimental	19.69	1.97	0.00*	- 4.38
		Control	22.22	0.99		
	Sixth week	Experimental	18.50	0.31	0.00*	- 5.82
		Control	21.68	0.32		
	Eighth week	Experimental	17.15	1.64	0.00*	- 7.97
		Control	21.55	1.81		
PASAT	Pre- test	Experimental	31.73	10.00	0.26	1.14
		Control	28.38	5.42		
	Fourth week	Experimental	34.85	10.16	0.04*	2.06
		Control	28.69	5.32		
	Sixth week	Experimental	37.47	10.63	0.00*	2.76

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		Control	28.69	6.66		
	Eighth week	Experimental	41.76	10.51	0.00*	4.75
		Control	26.76	6.79		

TITLES OF FIGURES

Figure 1.— *flow-diagram of the study protocol*