CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2026; 32: e952326
DOI: 10.12659/MSM.952326

Received: 2025.12.03
Accepted: 2026.04.26
Available online: 2026.06.03
Published: 2026.XX.XX

Combined Whole-Body Cryotherapy and Exercise vs Exercise Alone for Lower Limb Strength and Mobility in Multiple Sclerosis

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEFG 1 **Malwina Pawik**
BDEG 1 **Łukasz Pawik**
CEF 1 **Wioletta Dziubek**
CD 1 **Małgorzata Stefańska**
ABEF 2 **Joanna Rymaszewska**

1 Faculty of Physiotherapy, Wrocław University of Health and Sport Sciences, Wrocław, Poland
2 Faculty of Medicine, Wrocław University of Science and Technology, Wrocław, Poland

Corresponding Author: Wioletta Dziubek, Faculty of Physiotherapy, Wrocław University of Health and Sport Sciences, Paderewskiego 35, 51-612 Wrocław, Poland, e-mail: wioletta.dziubek@awf.wroc.pl
Financial support: None declared
Conflict of interest: None declared

Background: Exercise therapy has been shown to be beneficial in reducing disability in patients with multiple sclerosis. This study aimed to evaluate the effectiveness of whole-body cryotherapy and exercise on muscle strength and mobility in 60 patients with multiple sclerosis.

Material/Methods: The study included a group of 60 patients diagnosed with multiple sclerosis. The CryoGym group (n=20) received whole-body cryotherapy and exercise; the Cryo group (n=20) received whole-body cryotherapy alone; and the Gym group (n=20) received exercise alone.
The patients' functional status was assessed using the Rivermead Mobility Index. Muscle strength and muscle function parameters were measured using a Biodex System 4 Pro multi-joint isokinetic dynamometer at angular velocities of 60°/s and 180°/s.

Results: Improvements of knee flexor and extensor strength at both angular velocities in the measured parameters were observed in the CryoGym group, which included patients who participated in whole-body cryotherapy and an exercise program. In the Cryo and Gym groups, increases in selected parameters were also observed, particularly at an angular velocity of 60°/s.

Conclusions: Appropriately selected physical exercise remains the foundation of rehabilitation for patients with multiple sclerosis, effectively improving lower limb muscle strength and endurance. The use of whole-body cryotherapy as an adjunctive intervention can complement standard forms of rehabilitation. Overall, the differences between groups were limited, and the observed changes should be interpreted with caution given the sample size and duration of the study.

Keywords: Cryotherapy • Exercise Therapy • Multiple Sclerosis • Muscle Strength • Neurology

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/952326

3515 10 1 48

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Introduction

Multiple sclerosis (MS) is a chronic disease in which the immune system contributes to damage of the central nervous system [1]. Regardless of disease subtype, MS can result in increasing disability. The disease is characterized by a chronic inflammatory and demyelinating process driven by complex neuroimmunological mechanisms and is the leading cause of neurological disability and the second cause of disability, after injuries, in young adults [2,3]. MS can progress through relapses, with subsequent stages of exacerbation and remission, and can follow a secondary progressive or primary progressive course. However, regardless of the form, disability tends to increase [4].

The pathogenesis of MS is neuroimmunological in nature, encompassing autoimmune processes and secondary neurodegenerative mechanisms. Within the immune system, autoreactive T cells and B cells play a key role. Through the production of proinflammatory cytokines and autoantibodies, they initiate and sustain central nervous system (CNS) inflammation, leading to demyelination and axonal damage. This process is associated with dysfunction of the blood-brain barrier, which facilitates the migration of immune cells into neural tissue and the activation of microglia, which secrete cytotoxic mediators and chemokines. Chronic neuroimmune inflammation contributes to acute flares and the gradual progression of neurodegeneration, independent of flare activity. Multilevel immunological studies, encompassing immune cell signaling and their interactions with resident CNS cells, are currently the subject of intensive analysis in the context of the development of precise immunomodulatory therapies for MS [5].

The primary goal of rehabilitation for patients with MS is to improve muscle strength and overall physical fitness, compensate for coordination disorders, maintain a full range of active joint movements, normalize muscle tone, maintain balance, prevent muscle atrophy, and counteract fatigue [6].

Clinical studies have shown that exercise therapy is a beneficial factor in reducing disability in patients with MS [7-11]. There is no universal rehabilitation model for people with MS. It is important to remember that MS is a condition that predisposes to the co-occurrence of degenerative spine disease, depressive syndromes, and fatigue syndrome. Therefore, rehabilitation is crucial at every stage of the disease, with the primary goal of an individualized approach and a focus on improving the patient's quality of life [12].

Cryotherapy is primarily used in treating musculoskeletal disorders, ankylosing spondylitis, rheumatoid arthritis, degenerative joint and spine diseases, injuries, and MS. Cryotherapy also has a place in the wellness of athletes [13]. The frequent use of cryogenic temperatures is associated with a number of important therapeutic clinical, hormonal, and biochemical effects. These include primarily analgesic and anti-edematous effects, skeletal muscle relaxation, and increased joint mobility. These clinical effects persist for at least 3 hours after leaving the cryochamber, creating excellent conditions for intensive rehabilitation, which can then be extended up to 3 times [13].

The systematic literature review by Alito et al [14] suggests that whole-body cryotherapy may have beneficial antioxidant effects as a short-term adjunctive therapy in MS. Results from the 2024 study suggest that whole-body cryotherapy may complement therapeutic options for patients with MS, as cryogenic cold stimulation has been shown to activate antioxidant processes and improve functional status, mood, anxiety, and fatigue. Whole-body cryotherapy may lead to reduced fatigue and improved functional status, which has a beneficial effect on mental and physical well-being. No significant changes were observed in antioxidant enzyme activity, nitric oxide levels, metalloproteinase levels, blood counts, rheology, or biochemistry, and no adverse effects were reported [14].

In the study by Ptaszek et al, the levels of oxidative and antioxidant stress markers were analyzed in women with MS who underwent 20 sessions of whole-body cryotherapy, with the study results showing no significant changes in antioxidant enzymes. However, an increase in total antioxidant capacity was evident, and many authors consider it as evidence that cryotherapy can modulate the oxidative-inflammatory environment, a component of neuroimmunological pathology in MS, and that the use of whole-body cryotherapy has a positive effect on the rheological properties of blood in healthy women [15]. Therefore, in this study, we aimed to evaluate the effectiveness of whole-body cryotherapy and exercise on muscle strength and mobility in 60 patients with MS.

The decision to create a study group solely dedicated to whole-body cryotherapy was dictated by the changing demographic profile of patients with MS, who are increasingly being diagnosed at a younger age. These individuals typically remain professionally and socially active, leaving limited time for regular participation in long-term exercise programs. Therefore, we sought a therapeutic intervention that could positively affect patients' health without requiring a significant time commitment. We considered whole-body cryotherapy, a short-term and easy-to-implement method, as a potential alternative or complement to traditional forms of rehabilitation. The purpose of selecting this group was to determine whether whole-body cryotherapy alone could provide measurable clinical benefits and thus serve as a pre-rehabilitation component, enabling patients in remission to maintain their best possible level of functioning.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 1. Characteristics of the study groups.

		CryoGym group		Cryo group		Gym group		ANOVA Kruskal Wallis
		Median	IQR	Median	IQR	Median	IQR	*P* value
Age [years]		50.00	13.50	43.00	15.00	57.00	17.00	0.0864
Height [m]		166.50	10.50	167.00	16.00	161.50	12.50	0.3340
Body weight [kg]		68.50	14.00	64.00	33.00	73.00	23.00	0.7264
BMI [kg/m^2]		23.19	5.00	23.51	6.97	25.90	5.54	0.1791
Years of illness		10.00	11.50	10.00	13.00	9.00	11.00	0.7908
		n	%	n	%	n	%	χ^2/Fisher *P*
Sex	Male	3	15	8	40	5	25	0.2433
	Female	17	85	12	60	15	75	
Marital status	Married	15	75	12	60	14	70	0.4718
	Widowed	0	0	0	0	2	10	
	Single	4	20	6	30	2	10	
	Divorced	1	5	2	10	2	10	
Professional work	yes	12	60	11	55	8	40	0.4199
	no	8	40	9	45	12	60	

Material and Methods

Study Design

Patients with MS were recruited from the Polish Multiple Sclerosis Society, Lower Silesian Branch, Wroclaw, Poland. The study protocol was approved by the Ethics Committee of the Wroclaw University of Health and Sport Sciences, Poland (12.07.2011). Written consent was obtained from all analyzed participants after an explanation of the purpose and course of the study, assurance of confidentiality of the collected data, and information about the voluntary nature of their participation and the possibility of withdrawing at any time during the study.

Participants

All participants were recruited for participation in the program by a neurologist and a physiotherapist. The inclusion criteria were as follows: consent to participate in the study; diagnosis of MS; a period of disease remission (minimum of 6 months since the last relapse); independent mobility (Expanded Disability Status Scale score 0-6); approval from the attending physician; and age 30 to 60 years.

The exclusion criteria were as follows: adherence to training units below 70%; use of other non-pharmacological (eg, rehabilitation) forms of support during the study; and lack of consent to participate in the study.

Characteristics of the Study Groups

The characteristics of the study group are presented in **Table 1**. Seventy participants who met the inclusion criteria were enrolled in the study and provided oral consent before starting the project. One participant did not provide written consent. Sixty-nine patients participated in the initial study and were randomly divided into 3 experimental groups of 23 participants each. Participants were randomized using a computer-generated sequence. Allocation was concealed in sealed opaque envelopes. Nine participants withdrew for various reasons during the first few days of the study.

Ultimately, 60 participants completed the study (Figure 1).

The results of 60 patients divided into 3 groups were analyzed. Patients in the CryoGym group (n=20) participated in whole-body cryotherapy and in strengthening exercises using Thera-Band equipment to strengthen their lower limb muscles. Patients in the Cryo group (n=20) participated in whole-body cryotherapy treatments. Patients in the Gym group (n=20) participated in lower limb exercise using Thera-Band equipment to strengthen their lower limb muscles.

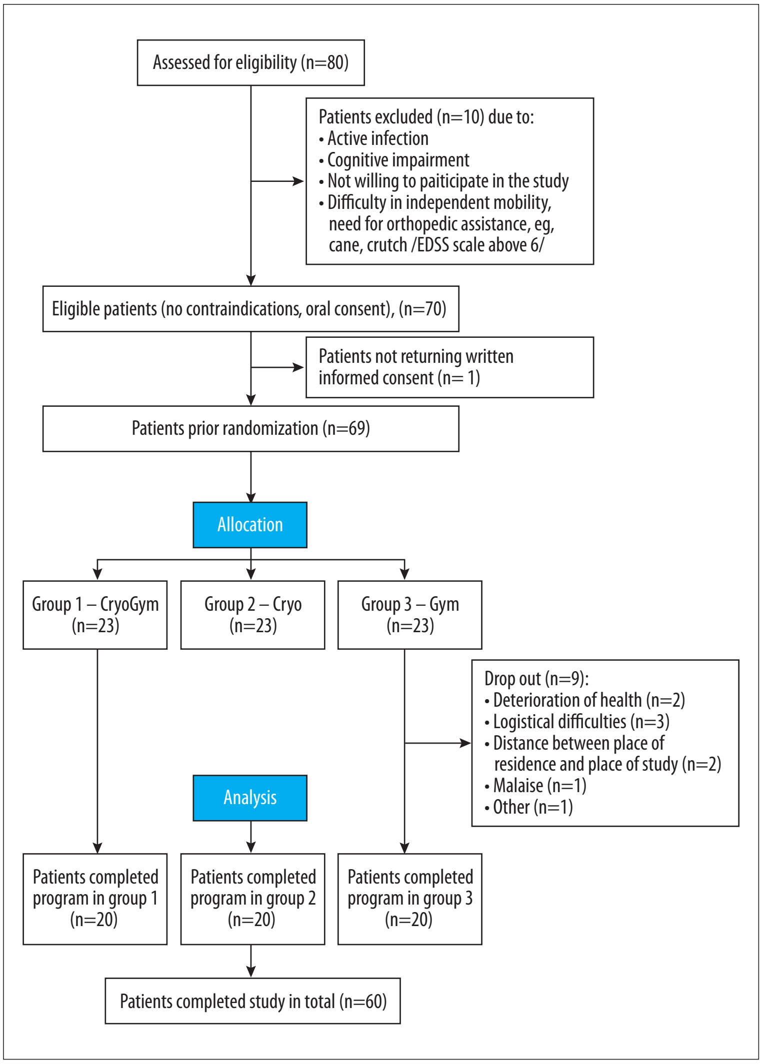

Figure 1. Patient recruitment process and dropout during the study.

Interventions

Whole-Body Cryotherapy

Patients were qualified for whole-body cryotherapy treatments by a physician. Blood pressure was measured before each treatment and recorded in the treatment card. Patients were required to wear appropriate attire in the chamber: women wore swimsuits, and men wore shorts. Hands were protected with gloves, shins with knee-high socks, feet with wooden clogs, and ears with a headband or hat. A surgical mask was worn. Patients were instructed not to rub creams or lotions into the skin before the treatment, so that the cold would spread evenly across the skin. Before entering the cryochamber, they were asked to remove their watches, jewelry, and glasses (contact lenses were safe) and to thoroughly dry their bodies, especially under the arms and in the creases of the knees. The patients were instructed in proper breathing and movement while in the chamber. Breathing consisted of first a short inhale through the nose, then a long exhale through the mouth; this is extremely important, as cooled air expands in the lungs and can cause shortness of breath. Instructions for movement were to walk slowly, avoiding touching the skin. Individuals undergoing cryotherapy entered the cryochamber vestibule (temperature -60°C) with a therapist dressed in special protective clothing to protect against the effects of cold. After approximately 30 seconds of adaptation to the cryogenic temperatures, they proceeded alone to the cryochamber itself, where the temperature ranged from -110 to -130°C, and the treatment lasted 3 minutes. Whole-body cryotherapy treatments were performed in a closed cryogenic chamber, using liquid nitrogen to cool the cryochamber. Sessions were performed Monday through Friday for 2 weeks at a fixed time (a total of 10 sessions). The full study cycle lasted 2 weeks for each patient.

Exercise Training Sessions

Exercises to strengthen the lower limb muscles lasted 60 minutes each session. Each session began with a warm-up, followed

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

by the main phase, with exercises using Thera-Bands to improve lower limb muscle strength, and the final phase, with the main goal of calming the body. Sessions consisted of a series of 6 to 10 exercises covering major muscle groups, performed in 1 to 3 sets of 8 to 15 repetitions, depending on the patient's ability. Resistance intensity was individually adjusted, starting with lower resistance bands (yellow/red) and progressively increasing to higher resistance bands (green/blue or higher) as strength and training tolerance improved. The band color and stretch length were selected based on the patient's ability to complete the planned number of repetitions with correct technique. Training intensity was assessed using a subjective 10-degree Borg scale. The training was conducted under the constant supervision of a doctor and physiotherapist. In the group performing exercises after exiting the cryochamber, all exercise sessions were carried out under the supervision of a physiotherapist. Patients in the Gym group were familiarized with the exercise program during an initial session with a physiotherapist, who provided methodical instruction on how to perform each exercise correctly and safely. They also received written and illustrated materials to take home, describing and demonstrating all prescribed exercises. Throughout the duration of the program, participants were informed that they could contact the physiotherapist at any time if they had questions or concerns regarding the exercises.

Measurement Tools

Assessments were conducted at 2 predefined time points: baseline (T1), prior to the initiation of treatment, and after intervention (T2), after 10 days of therapy and a 2-day washout period to avoid fatigue-related effects.

To monitor the implementation of the research intervention, participants maintained attendance logs, recording their participation in scheduled sessions according to their research group. In the groups participating in the physical exercise program, attendance and exercise intensity were recorded. For participants assigned to the whole-body cryotherapy group, attendance at cryotherapy sessions and blood pressure measurements, performed each time before entering the cryochamber, in accordance with applicable safety procedures, were recorded in the logs.

In the study, the primary outcome was the Rivermead Mobility Index, and secondary outcomes included peak torque, total work, and average power. The Rivermead Mobility Index assesses general motor skills and functional mobility, while the isokinetic measurement shows the biomechanical characteristics of the knee extensors and flexors. The Rivermead Mobility Index was administered by a qualified physiotherapist. Muscle strength tests were conducted in the Internal Medicine Functional Research Laboratory of the Faculty of Physiotherapy by a qualified laboratory technician.

Mobility Status Assessment

The patients' functional status was assessed using the Rivermead Mobility Index, a scale used to assess functional ability in general motor skills. The index is a motor-functional scale that primarily assesses mobility and locomotion (position changes, transfers, gait, stair climbing) [16]. The higher the score, the greater the patient's mobility.

Muscle Torque of the Lower Limb in Isokinetic Conditions

Lower limb strength was measured using the Biodex System 4 Pro multi-joint isokinetic dynamometer (Biodex Medical System, NY, USA). The functionality of the flexor and extensor muscles of the knee joint in both limbs was assessed in all patients.

Before the test, the patients had a warm-up consisting of 3 submaximal knee flexion repetitions at the 2 angular velocities of 60°/s and 180°/s. The isokinetic test was then performed. At an angular velocity of 60°/s, the patient performed 5 repetitions, and at an angular velocity of 180°/s, the patient performed 20 repetitions, consisting of alternating extension and flexion of the limb at the knee joint. During the test, patients were instructed to exert maximum muscle force in the shortest possible time for each movement. There was a 1-minute rest between attempts. Muscle parameters were measured: peak torque, total work, and average power at 60°/s and 180°/s angular velocities [17].

Statistical Analysis

Normal distribution of quantitative variables describing the study group was not demonstrated. Descriptive statistics were calculated. The median was used as a measure of central tendency, and the interquartile range (IQR=Q3-Q1) was used as a measure of dispersion. The significance of differences between assessments at T1 (baseline) and T2 (after intervention) was tested using the Wilcoxon signed-rank test. The difference between the results of the 2 assessments (T2-T1) was calculated to determine the level of change in the analyzed variables. Differences between groups were analyzed for the differences between T2 and T1. The significance of differences between groups was tested using Kruskal-Wallis ANOVA and, when necessary, the Dunn Bonferroni-Holm post hoc test. For nominal variables, the chi-square test or Fisher exact test was used. The effect size for the Wilcoxon signed-rank test was estimated using the r coefficient according to the formula $r=Z/\sqrt{n}$ [18]. The effect size for the Kruskal-Wallis ANOVA was estimated using the Eta squared (η^2) value transformed to Cohen's d [19]. Effect size was calculated post hoc. For Cohen's d, effect sizes were interpreted as follows: less than 0.1, no effect; 0.1 to 0.4, small effect; 0.5 to 0.7, intermediate effect; and greater than 0.8, large effect. For the correlation coefficient r, values of 0.1

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 2. Within-group comparison of Rivermead Mobility Index scores at baseline (T1) and after intervention (T2) using the Wilcoxon signed-rank test.

Group	Test 1		Test 2		T	Z	*P*	r
	Median	IQR	Median	IQR				
Gym	12.00	13.00	13.50	12.00	4.5	1.890	0.0587	0.42
Cryo	14.00	10.00	15.00	9.00	0.0	2.366	0.0180*	0.53
CryoGym	14.00	13.00	14.00	6.00	5.5	1.750	0.0800	0.39
Total	14.00	13.00	14.00	12.00	31.0	3.254	0.0011*	0.77

* p<0.05.

Table 3. Within-group comparison of changes in the measured parameters from baseline (T1) to after intervention (T2) at an angular velocity of 60°/s in the Gym group using the Wilcoxon signed-rank test.

Parameters	Muscle group	Body side	T1		T2		T	Z	*P*	r
			Median	IQR	Median	IQR				
Peak torque [Nm]	E	R	78.95	76.00	94.15	67.45	64.50	1.51	0.1305	0.34
		L	70.30	96.20	75.10	70.70	92.00	0.12	0.9039	0.03
	F	R	42.60	36.75	41.40	34.90	58.50	1.18	0.2397	0.28
		L	26.75	37.60	33.30	31.50	39.00	2.46	0.0137*	0.55
Total work [J]	E	R	129.60	115.25	134.45	113.75	50.00	2.05	0.0400*	0.46
		L	116.20	110.40	126.30	104.05	100.00	0.19	0.8519	0.04
	F	R	66.00	50.00	58.75	58.30	66.00	0.85	0.3958	0.20
		L	43.20	49.00	54.05	51.50	64.00	1.25	0.2122	0.29
Average power [W]	E	R	455.25	459.75	484.15	425.85	40.00	2.43	0.0152*	0.54
		L	405.25	536.15	405.15	348.95	87.00	0.67	0.5016	0.15
	F	R	176.95	248.60	182.75	244.15	19.00	1.85	0.0640	0.51
		L	144.65	265.95	154.95	225.30	23.00	1.57	0.1159	0.44

Abbreviations: E, extensors; F, flexors; R, right; L, left. * *P*<0.05.

to 0.3 were considered a small effect, 0.3 to 0.5 an intermediate effect, and greater than 0.5 a large effect [19]. The analysis was performed using Statistica 14.1.0.4 and PQStat 1.8.4., as well as online statistical calculators: https://www.psychometrica.de/effect_size.html#transform (accessed November 24, 2025). The level of significance was set at *P*<0.05.

Results

Sixty participants completed the study, and 9 participants withdrew. The main reasons for withdrawal were health deterioration (fever), as well as family and professional factors that prevented further participation in the planned study sessions. Additionally, some patients cited logistical difficulties related to travel to the study site, which posed a significant barrier to continuing their participation (**Figure 1**).

The following dependent variables were analyzed: functional capacity (Rivermead Mobility Index) and functional assessment of the knee flexor and extensor muscles at 60°/s and 180°/s velocities.

Mobility Assessment (Rivermead Mobility Index)

A statistically significant change was demonstrated in the mobility assessment (the difference between T1 and T2 measurement points) in the Cryo group (*P*=0.0180), while the results in the other 2 groups were not statistically significant: *P*=0.0587 for the Gym group and *P*=0.0800 for the CryoGym group (**Table 2**).

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 4. Within-group comparison of changes in the measured parameters from baseline (T1) to after intervention (T2) at an angular velocity of 60°/s in the Cryo group.

Parameters	Muscle group	Body side	T1		T2		T	Z	*P*	r
			Median	IQR	Median	IQR				
Peak torque [Nm]	E	R	94.10	16.00	101.95	28.20	35.00	2.20	0.0279*	0.34
		L	97.10	33.60	99.65	40.90	54.00	1.37	0.1701	0.03
	F	R	42.80	28.00	49.05	23.90	14.50	3.09	0.0020*	0.28
		L	41.85	11.00	48.70	13.00	23.00	2.72	0.0065*	0.55
Total work [J]	E	R	157.80	69.60	175.20	48.80	43.00	1.85	0.0642	0.46
		L	158.70	66.00	168.05	44.40	16.00	3.03	0.0025*	0.04
	F	R	68.60	64.20	83.80	70.20	29.00	2.02	0.0437*	0.20
		L	65.60	33.10	71.20	34.80	23.00	2.53	0.0113*	0.29
Average power [W]	E	R	533.60	140.9	576.2	169.20	19.00	2.72	0.0065*	0.54
		L	514.35	233.2	599.2	296.30	36.00	2.16	0.0311*	0.15
	F	R	221.50	236.2	266.85	202.70	13.00	2.48	0.0132*	0.51
		L	204.95	140.9	257.65	134.00	4.00	3.04	0.0023*	0.44

Abbreviations: E, extensors; F, flexors; R, right; L, left. * *P*<0.05.

Table 5. Within-group comparison of changes in the measured parameters from baseline (T1) to after intervention (T2) at an angular velocity of 60°/s in the CryoGym group using the Wilcoxon signed-rank test.

Parameters	Muscle group	Body side	T1		T2		T	Z	*P*	r
			Median	IQR	Median	IQR				
Peak torque [Nm]	E	R	71.85	31.30	76.50	31.20	26.00	2.59	0.0096*	0.58
		L	56.45	39.60	66.35	48.30	23.00	2.72	0.0065*	0.61
	F	R	34.40	15.20	46.55	16.70	30.00	2.42	0.0156*	0.54
		L	30.95	20.60	39.00	28.90	25.00	2.63	0.0084*	0.59
Total work [J]	E	R	321.3	186.70	400.30	95.90	17.00	2.98	0.0029*	0.67
		L	273.55	194.10	366.85	233.20	15.00	3.07	0.0021*	0.69
	F	R	163.70	117.10	221.25	122.80	33.00	2.29	0.0222*	0.51
		L	118.65	136.60	170.50	165.10	9.00	3.20	0.0014*	0.71
Average power [W]	E	R	36.45	20.20	43.85	19.20	12.50	3.03	0.0024*	0.68
		L	32.60	21.30	40.85	22.50	11.00	3.10	0.0019*	0.69
	F	R	20.15	8.20	30.00	13.60	17.00	2.64	0.0084*	0.59
		L	16.50	14.10	21.45	14.80	2.00	3.04	0.0024*	0.68

Abbreviations: E, extensors; F, flexors; R, right; L, left. * *P*<0.05.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 6. Within-group comparison of changes in the measured parameters from baseline (T1) to after intervention (T2) at an angular velocity of 180°/s in the Cryo group using the Wilcoxon signed-rank test.

Parameters	Muscle group	Body side	T1 Median	T1 IQR	T2 Median	T2 IQR	T	Z	*P*	r
Peak torque [Nm]	E	R	50.10	40.45	61.65	48.25	52.00	1.98	0.0479*	0.44
		L	49.45	38.45	50.30	38.90	37.00	2.11	0.0347*	0.50
	F	R	20.00	21.35	30.00	20.80	2.00	3.74	0.0002*	0.86
		L	19.55	22.30	22.90	20.70	20.00	3.17	0.0015*	0.71
Total work [J]	E	R	80.50	66.15	90.55	72.25	35.00	2.61	0.0090*	0.58
		L	79.10	46.65	87.90	50.90	80.00	0.93	0.3507	0.21
	F	R	32.40	33.15	47.20	30.85	31.00	2.58	0.0100*	0.59
		L	31.70	32.70	39.45	33.35	71.00	0.97	0.3341	0.22
Average power [W]	E	R	567.95	595.15	604.6	542.00	6.00	3.70	0.0002*	0.83
		L	484.90	557.85	488.05	517.25	31.00	2.76	0.0057*	0.62
	F	R	145.30	340.95	227.15	352.05	13.00	1.78	0.0754	0.54
		L	143.80	305.10	161.15	321.05	9.50	2.70	0.0069*	0.72

Abbreviations: E, extensors; F, flexors; R, right; L, left. * *P*<0.05.

Table 7. Within-group comparison of changes in the measured parameters from baseline (T1) to after intervention (T2) at an angular velocity of 180°/s in the CryoGym group.

Parameters	Muscle group	Body side	T1 Median	T1 IQR	T2 Median	T2 IQR	T	Z	*P*	r
Peak torque [Nm]	E	R	54.90	12.20	59.65	15.70	18.00	2.77	0.0056*	0.67
		L	55.75	10.90	59.80	22.60	38.00	1.82	0.0684	0.44
	F	R	27.45	17.00	33.65	15.00	43.00	1.59	0.1128	0.38
		L	28.80	10.40	30.75	12.70	44.00	1.54	0.1239	0.37
Total work [J]	E	R	87.20	48.40	100.15	35.70	22.00	2.38	0.0174*	0.59
		L	90.60	36.50	95.75	29.00	34.00	1.76	0.0787	0.44
	F	R	43.30	31.60	50.10	32.30	20.00	2.27	0.0231*	0.59
		L	48.10	21.40	47.05	26.70	27.00	2.12	0.0340*	0.53
Average power [W]	E	R	1074.65	506.9	1186.1	373.8	8.00	3.24	0.0012*	0.79
		L	1027.50	416.00	1202.2	420.8	35.00	1.96	0.0495*	0.48
	F	R	386.05	534.90	531.00	598.00	14.00	2.20	0.0277*	0.61
		L	348.70	358.20	379.45	525.20	8.00	2.22	0.0262*	0.67

Abbreviations: E, extensors; F, flexors; R, right; L, left. * *P*<0.05.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 8. Within-group comparison of changes in the measured parameters from baseline (T1) to after intervention (T2) at an angular velocity of 180°/s in the Gym group using the Wilcoxon signed-rank test.

Parameters	Muscle group	Body side	T1		T2		T	Z	*P*	r
			Median	IQR	Median	IQR				
Peak torque [Nm]	E	R	41.40	32.60	42.65	20.80	29.00	2.25	0.0245*	0.55
		L	33.90	30.10	42.15	28.20	18.00	2.39	0.0171*	0.62
	F	R	26.80	11.80	32.85	15.70	20.00	2.48	0.0131*	0.62
		L	22.35	17.90	24.40	26.60	8.00	2.95	0.0031*	0.76
Total work [J]	E	R	57.30	28.60	64.20	24.20	18.00	2.94	0.0033*	0.69
		L	47.05	31.00	60.00	48.80	18.00	2.59	0.0097*	0.65
	F	R	36.00	15.30	44.10	18.20	19.00	2.72	0.0065*	0.66
		L	31.05	25.60	35.55	35.00	13.00	2.84	0.0045*	0.71
Average power [W]	E	R	661.15	517.20	804.05	615.90	15.00	2.74	0.0061*	0.69
		L	443.9	405.60	752.85	771.30	12.50	2.31	0.0211*	0.64
	F	R	348.1	298.00	545.15	420.60	3.00	2.97	0.0030*	0.82
		L	254.4	429.90	327.10	742.00	2.00	2.76	0.0058*	0.83

Abbreviations: E, extensors; F, flexors; R, right; L, left. * $P<0.05$.

Lower Limb Torque Testing

In the within-group analysis of lower limb strength at both angular velocities, all 3 groups demonstrated statistically significant improvements from T1 to T2. At 60°/s, the CryoGym group showed the greatest increases in the measured parameters. The Cryo group also improved in most parameters, with the exception of flexor peak torque. The Gym group demonstrated the least improvement among the 3 groups across the measured outcomes (**Tables 3-5**).

Within-group analysis of knee muscle endurance at an angular velocity of 180°/s showed statistically significant improvements from T1 to T2 in all measured parameters for the Gym group. The Cryo group also demonstrated significant increases in all assessed parameters. The CryoGym group showed significant improvements in most parameters, with the exception of total work for the flexors and extensors of the left limb (**Tables 6-8**).

To determine differences in the effectiveness of the applied therapy, the change between T2 and T1 was calculated for each variable in each study group, and the significance of group differences was tested. In most analyses, at both angular velocities, no significant differences were found in the magnitude of change. The exception was total work, which differed significantly between groups (**Tables 9, 10**). In case of statistically significant differences, post hoc analysis was used, which showed significant differences only between the CryoGym and Gym groups. The differences observed in the CryoGym group were significantly lower than those in the Gym group (Dunn Bonferroni-Holm test, $P<0.05$).

Discussion

The results of this study should be regarded as preliminary data indicating the need for further studies on larger patient groups. MS generates higher social costs than do other neurological diseases due to its long duration, higher incidence in younger age groups, and early loss of work capacity [20]. Many authors note that patients with MS exhibit lower physical activity levels and a more sedentary lifestyle compared with the general population. High levels of physical activity is associated with delayed progression of motor disability and improved quality of life [21]. Studies have shown that physical exercise, including resistance and aerobic training, positively affects balance, endurance, fatigue, and quality of life in patients with MS [22].

Whole-body cryostimulation (whole-body cryotherapy) is currently one of the more popular rehabilitation methods for

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 9. Between-group comparison of the change in measured parameters from baseline (T1) to after intervention (T2) at an angular velocity of 60°/s.

			CryoGym group		Cryo group		Gym group		ANOVA Kruskal Wallis		Cohen's d
			Median	IQR	Median	IQR	Median	IQR	H	*P*	
Peak torque [Nm]	E	R	9.20	17.45	4.45	13.60	7.80	13.80	0.06	0.9692	0.38
		L	-0.40	28.10	3.30	13.80	10.10	14.00	3.15	0.2068	0.29
	F	R	2.10	7.30	5.95	8.10	7.40	19.00	5.36	0.0686	0.50
		L	2.50	4.80	6.00	8.70	6.20	11.30	2.91	0.2333	0.26
Total work [J]	E	R	18.65	74.40	27.85	78.80	44.35	57.10	0.62	0.7319	0.32
		L	16.95	143.55	46.85	59.40	97.80	118.60	7.12	0.0284*	0.63
	F	R	5.35	45.20	34.75	71.40	39.15	67.50	3.63	0.1627	0.34
		L	6.80	63.50	43.20	71.90	43.30	79.20	5.74	0.0566	0.53
Average power [W]	E	R	6.40	10.45	6.20	15.50	4.85	8.50	0.53	0.7685	0.33
		L	4.30	15.50	6.50	8.20	11.50	10.90	5.54	0.0627	0.52
	F	R	1.55	3.00	2.60	8.90	6.80	10.70	3.45	0.1782	0.32
		L	0.80	3.50	5.20	3.10	5.70	8.40	6.93	0.0313*	0.62

Abbreviations: E, extensors; F, flexors; R, right; L, left. * *P*<0.05.

Table 10. Between-group comparison of the change in measured parameters from baseline (T1) to after intervention (T2) at an angular velocity of 180°/s.

			CryoGym group		Cryo group		Gym group		ANOVA Kruskal Wallis		Cohen's d
			Median	IQR	Median	IQR	Median	IQR	H	*P*	
Peak torque [Nm]	E	R	2.80	10.70	3.80	13.30	3.60	7.90	0.57	0.7506	0.32
		L	2.80	10.40	4.10	9.40	6.70	13.95	0.89	0.6409	0.28
	F	R	3.80	4.50	2.60	12.40	5.20	9.00	0.67	0.7149	0.31
		L	3.00	4.00	1.70	5.90	5.45	7.85	2.46	0.2926	0.18
Total work [J]	E	R	57.50	84.75	77.45	291.65	177.55	229.90	2.99	0.2247	0.27
		L	27.40	127.35	61.30	248.55	257.70	258.10	9.59	0.0083*	0.78
	F	R	32.20	68.80	58.30	264.90	174.10	359.10	2.63	0.2682	0.21
		L	0.70	38.20	78.65	147.50	84.60	319.70	6.20	0.0451*	0.56
Average power [W]	E	R	12.65	11.65	7.80	16.70	11.50	20.40	0.58	0.7494	0.32
		L	6.75	9.05	10.20	24.40	22.10	14.60	5.31	0.0702	0.50
	F	R	6.60	7.50	6.80	17.40	18.95	17.30	3.13	0.2091	0.28
		L	4.45	4.10	5.00	13.10	14.40	22.10	3.30	0.1918	0.31

Abbreviations: E, extensors; F, flexors; R, right; L, left. * *P*<0.05.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

patients with MS. Exposure to low temperatures triggers numerous hormonal, neuromuscular, and circulatory responses and enhances the effectiveness of kinesiotherapy conducted immediately after cryotherapy sessions [23-26]. Whole-body cryotherapy demonstrates beneficial effects on pain, sleep quality, physical function, and overall quality of life [14,27]. Studies have shown that whole-body cryotherapy alone and combined with kinesiotherapy reduces spasticity, improves body stability, and enhances psychophysical functions [26-30]. In our study, we specifically investigated how whole-body cryotherapy and exercise together influence patient functioning. In one study, patients undergoing twice-daily whole-body cryotherapy combined with rehabilitation tolerated the treatment well, experiencing reduced spasticity and improved physical fitness and mobility [24]. The combination of cryotherapy and physical training proved more effective in controlling calf muscle spasticity than did physical training alone [29,30].

Resistance exercises, including those using Thera-Bands, are well received by patients, increasing muscle strength and endurance, improving gait, and reducing fatigue [22,30-38]. Research indicates that resistance training combined with functional training positively affects physical fitness, muscle endurance, psychological well-being, and fatigue [38]. Deficits in strength and endurance of the knee flexor muscles are particularly pronounced, adversely affecting gait quality and the ability to walk longer distances. Motor symptoms of MS, such as muscle weakness, fatigue, and coordination disturbances, lead to reduced mobility, decreased physical activity, and impaired quality of life [39].

Properly selected therapy and exercise regimens can significantly improve the functioning of patients with MS. Studies have demonstrated a correlation between lower limb muscle strength and gait quality, supporting the use of resistance and functional training in rehabilitation [36,40,41]. In our study, the greatest improvements in knee joint muscle strength and endurance were observed in the Gym and Cryo groups, with the Gym group achieving the best results. The variable levels of endurance and well-being in patients with MS complicated the clear evaluation of therapy effects, highlighting the need for further studies with larger samples [42,43]. The aim of our study was to generate a measure of program effectiveness, assessing whether exercise influenced patient condition and whether patients could maintain their fitness independently through home-based exercises.

Limited physical activity in MS leads to progressive disability and reduced quality of life [39,44]. Studies show that patients can tolerate exercise well, with exercise improving physical fitness and mitigating disease effects, making training an integral part of therapy [10,31,37,45-47]. A 2025 systematic review indicates that targeted functional training improves mobility, balance, muscle strength, and endurance, reduces fatigue, and enhances overall patient functioning [48].

Limitations

The main limitation of this study is the small size of the group that participated in the training and the absence of a non-intervention control group, which limits our ability to distinguish treatment effects from natural disease fluctuations or placebo effects. Furthermore, the intervention lasted 10 days, without an extended follow-up period, so the durability of the effects cannot be determined. Finally, pharmacological treatment, disease subtype, and disease-modifying therapies were not fully controlled for and may have influenced the response to rehabilitation.

Conclusions

The basis of rehabilitation of patients with MS relies on appropriately selected physical exercises that help improve functional fitness, particularly in terms of muscle strength and endurance of the lower limbs. The use of whole-body cryotherapy as an adjunctive intervention can complement standard forms of rehabilitation, enabling short-term therapeutic exposure that does not require significant time commitment from the patient. This information is valuable for therapists working with patients with MS, suggesting that the intervention is feasible in clinical practice and may provide preliminary evidence to support further studies with larger sample sizes and longer follow-up periods.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Acknowledgements

The authors would like to thank the patients for their help in this study.

Institution Where Work Was Done

Faculty of Physiotherapy, Wrocław University of Health and Sport Sciences, Wrocław, Poland.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

References:

1. Siffrin V. Pathways to progressive disability in multiple sclerosis: The role of glial cells in chronic CNS inflammation. Glia. 2025;73(10):1928-50
2. Kornberg MD, Calabresi PA. Multiple sclerosis and other acquired demyelinating diseases of the central nervous system. Cold Spring Harb Perspect Biol. 2025;17(3):a041374
3. Schäffner E, Bosch-Queralt M, Edgar JM, et al. Myelin insulation as a risk factor for axonal degeneration in autoimmune demyelinating disease. Nat Neurosci. 2023;26(7):1218-28
4. Kwolek K. Rehabilitation in multiple sclerosis. University of Rzeszów Publishing House, Rzeszów; 2015
5. Eva L, Pleș H, Covache-Busuioc RA, et al. A comprehensive review on neuroimmunology: Insights from multiple sclerosis to future therapeutic developments. Biomedicines. 2023;11(9):2489
6. Hauser SL, Cree BAC. Treatment of multiple sclerosis: A review. Am J Med. 2020;133(12):1380-90.e2
7. Amatya B, Khan F, Galea M. Rehabilitation for people with multiple sclerosis: An overview of Cochrane Reviews. Cochrane Database Syst Rev. 2019;1(1):CD012732
8. Grasso MG, Troisi E, Rizzi F, et al. Prognostic factors in multidisciplinary rehabilitation treatment in multiple sclerosis: An outcome study. Mult Scler. 2005;11(6):719-24
9. Khan F, Pallant JF, Brand C, Kilpatrick TJ. Effectiveness of rehabilitation intervention in persons with multiple sclerosis: A randomised controlled trial. J Neurol Neurosurg Psychiatry. 2008;79(11):1230-35
10. Mostert S, Kesselring J. Effects of a short-term exercise training program on aerobic fitness, fatigue, health perception and activity level of subjects with multiple sclerosis. Mult Scler. 2002;8(2):161-68
11. Thompson AJ. The effectiveness of neurological rehabilitation in multiple sclerosis. J Rehabil Res Dev. 2000;37(4):455-61
12. Momsen AH, Ørtenblad L, Maribo T. Effective rehabilitation interventions and participation among people with multiple sclerosis: An overview of reviews. Ann Phys Rehabil Med. 2022;65(1):101529
13. Zagrobelny Z. Local and systemic cryotherapy. In: Rymaszewska J, Tulczyński A, Zagrobelny Z, et al, editors. The impact of whole-body cryotherapy on human mental state. Wrocław: Urban & Partner; 2003;177-85
14. Alito A, Fontana JM, Franzini Tibaldeo E, et al. Whole-body cryostimulation in multiple sclerosis: A scoping review. J Clin Med. 2024;13(7):2003
15. Ptaszek B, Podsiadło S, Adamiak J, et al. Effect of whole-body cryotherapy on oxidant-antioxidant imbalance in women with multiple sclerosis. J Clin Med. 2023;12(18):5958
16. Vaney C, Blaurock H, Gattlen B, et al. Assessing mobility in multiple sclerosis using the Rivermead Mobility Index and gait speed. Clinical Rehabilitation. 1996;10(3):216-26
17. Rogowski Ł, Kowalska J, Bulińska K, et al. Assessment of physical performance and muscle function in hemodialysis patients participating in an exercise regimen: A cluster-randomized, single-center study. Adv Clin Exp Med. 2025;34(12):2105-18
18. Tomczak M, Tomczak E. The need to report effect size estimates revisited. An overview of some recommended measures of effect size. Trends in Sport Sciences. 2014;1(21):19-25
19. Lenhard W, Lenhard A. Computation of effect sizes. Psychometrica. 2022. Available from: https://www.psychometrica.de/effect_size.html
20. Carney P, O'Boyle D, Larkin A, et al. Societal costs of multiple sclerosis in Ireland. J Med Econ. 2018;21(5):425-37
21. Obara J, Maciąg D, Dugiel G, et al. Assessment of the quality of life of patients with multiple sclerosis. Acta Sci Acad Ostorv 2012;1:71-92
22. Du L, Xi H, Zhang S, et al. Effects of exercise in people with multiple sclerosis: A systematic review and meta-analysis. Front Public Health. 2024;12:1387658
23. Zagrobelny Z. [Therapeutic use of cold]. Acta Bio-Opt Inform Med. 1996;2:83-86 [in Polish]
24. Gregorowicz H, Dalidowski R. [Cryotherapy in the treatment of multiple sclerosis.] Acta Bio-Opt Inform Med. 1998;4:143 [in Polish]
25. Mraz M, Skrzek A, Gruszka E, et al. [The effect of physiotherapy using whole-body cryotherapy on the stability and balance of the standing position in patients with multiple sclerosis.] Fizjoterapia 2001;9(1):26-30 [in Polish]
26. Skrzek A, Mraz M, Gruszka E. [Cryotherapy in the treatment and rehabilitation of patients with multiple sclerosis – preliminary results.] Acta Bio-Opt Inform Med 1998;4(2):69-72 [in Polish]
27. Zielińska-Nowak E, Lipert A, Kikowski Ł, Miller E. Impact of whole-body cryotherapy on pain, sleep quality, functional status, and quality of life in multiple sclerosis: a comparative study with follow-up. J Pers Med. 2025;15(2):46
28. Staszkiewicz R, Rusek S, Lubkowska A, Szyguła Z. Effect of whole-body cryotherapy on body balance in patients with multiple sclerosis. Acta Bioeng Biomech. 2025;27(1):169-79
29. Abdelhakiem NM, Mahmoud TH, Saleh HM, et al. Effect of cryotherapy in controlling spasticity of calf muscles in patients with multiple sclerosis. NeuroRehabilitation 2024;54(4):653-61
30. Mraz M, Skrzek A, Proszewska A, et al. The influence of comprehensive rehabilitation including whole-body cryotherapy on the state of muscle tone in patients with multiple sclerosis. In: Zagrobelny Z, editor. Local and systemic cryotherapy. Wrocław: Urban & Partner; 2003;105-11
31. Torres-Costoso A, Martínez-Vizcaíno V, Reina-Gutiérrez S, et al. Effect of exercise on fatigue in multiple sclerosis: A network meta-analysis comparing different types of exercise. Arch Phys Med Rehabil. 2022;103(5):970-87
32. Sutherland G, Andersen MB. Exercise and multiple sclerosis: Physiological, psychological, and quality of life issues. J Sports Med Phys Fitness. 2001;41(4):421-32
33. Açık M, Şenışık S, Taşkıran D, et al. Exercise improves physical capacity, cognition, quality of life and promotes neurotrophic factors in patients with multiple sclerosis. Noro Psikiyatr Ars. 2023;60(4):335-43
34. Pilutti LA, Lelli DA, Paulseth JE, et al. Effects of 12 weeks of supported treadmill training on functional ability and quality of life in progressive multiple sclerosis: A pilot study. Arch Phys Med Rehabil. 2011;92(1):31-36
35. Dalgas U, Stenager E, Jakobsen J, et al. Resistance training improves muscle strength and functional capacity in multiple sclerosis. Neurology. 2009;73(18):1478-84
36. Kargarfard M, Etemadifar M, Baker P, et al. Effect of aquatic exercise training on fatigue and health-related quality of life in patients with multiple sclerosis. Arch Phys Med Rehabil. 2012;93(10):1701-8
37. White LJ, McCoy SC, Castellano V, et al. Resistance training improves strength and functional capacity in persons with multiple sclerosis. Mult Scler. 2004;10(6):668-74
38. Dodd KJ, Taylor NF, Denisenko S, Prasad D. A qualitative analysis of a progressive resistance exercise programme for people with multiple sclerosis. Disabil Rehabil. 2006;28(18):1127-34
39. Motl RW, McAuley E. Association between change in physical activity and short-term disability progression in multiple sclerosis. J Rehabil Med. 2011;43(4):305-10
40. Snook EM, Motl RW. Effect of exercise training on walking mobility in multiple sclerosis: A meta-analysis. Neurorehabil Neural Repair. 2009;23(2):108-16
41. Broekmans T, Gijbels D, Eijnde BO, et al. The relationship between upper leg muscle strength and walking capacity in persons with multiple sclerosis. Mult Scler. 2013;19(1):112-19
42. Ponichtera-Mulcare JA, Matthews T, Barret PJ, et al. Change in aerobic fitness of patients with multiple sclerosis during a 6-month training program. Sports Med Train Rehabil. 1997;7:265-72
43. Armstrong LE, Winant DM, Swasey PR, et al: Using isokinetic dynamometry to test ambulatory patients with multiple sclerosis. Phys Ther. 1983;63(8):1274-79
44. Vanner EA, Block P, Christodoulou CC, et al. Pilot study exploring quality of life and barriers to leisure-time physical activity in persons with moderate to severe multiple sclerosis. Disabil Health J. 2008;1(1):58-65
45. Tallner A, Waschbisch A, Wenny I, et al. Multiple sclerosis relapses are not associated with exercise. Mult Scler. 2012;18(2):232-35
46. Padgett PK, Kasser SL. Exercise for managing the symptoms of multiple sclerosis. Phys Ther. 2013;93(6):22-24
47. Petajan JH, Gappmaier E, White AT, et al. Impact of aerobic training on fitness and quality of life in multiple sclerosis. Ann Neurol. 1996;39(4):432-41
48. Adammek F, Gralla W, Kupjetz M, et al. Functional exercise training in persons with multiple sclerosis: A systematic review. J Neurol. 2025;272(9):590

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]